"Erosion Potential Method" An Important Support For Integrated Water Resource Management.

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Abstract

"Erosion Potential Method (E.P.M.)" is a complex methodology designed for usage in the field of Integrated Water Resources Management. Its cover tasks from erosion mapping, sediment production and transport recalculating and as an important support for Water Master Plans and Integrated water Resource Management.

Up to date development of this method contributed to high degree of reliability of sediment production evaluation and sediment transport evaluation and reservoir sedimentation. Also very important field is planning optimal quantity of anti-erosion works and measures where E.P.M. is important input

Anti-erosion and torrent control works quantified trough E.P.M., carried out during the past fifty years, produced significant direct and indirect effects (decreased sediment production, reduced sediment transport in many rivers in Serbia, considerable enhancement of the state of ecosystem in eroded regions etc). Rough estimation reveals that the annual sediment discharge in the Velika Morava catchments was reduced to a half as compared with the previous period. The paper presents obtained result during half-century permanents development and usage. Last floods improved its value.

Keywords: Erosion, Mapping, GIS Integrated water Resource Management

Introduction

Soil erosion is a natural phenomenon which occurs throughout the continental portion of the globe. The intensity of erosion is directly dependent on natural factors, but also on those which are under direct human influence. The natural factors include land erodibility, landscape characteristics which favor erosion processes, and aggressive climatic features such as temperature fluctuations, rainfall and wind.

The factors under the direct or indirect human influence arise from the all-encompassing human activity relating to the use of an area of land. A mistaken notion which is well rooted in the human conscience is that of the "natural environment". Such an environment began to emerge the moment man burned and felled the first forest. Since then, extensive areas have changed significantly worldwide. Former forests, savannas and steppes are now deserts. In other places man forcefully changed the types of trees and replaced forests with pastures or arable land. Numerous civilizations perished in the past millennia, either as a result of conflicts or conquerors' avarice in striving to plunder as many riches as possible from the conquered land. And riches are always available in forests, livestock, farming and mineral resources. Arrogant land use to exhaustion has always and everywhere resulted in land erosion and the degradation of nature and the environment. Figure 1 shows a detail from North Africa, the ancient Punic Empire which Rome conquered after defeating Hannibal. Roman history indicates that they harvested about 10 tons of cereal per hectare from those territories, with two annual harvests during the first few decades. After only three centuries, the annual yield dropped to less than 700 kg/ha.

The traditional struggle against erosion included the erection of terraces for crop farming and construction of levees, and rock paving as defenses against torrent flooding. Systems constructed to prevent erosion exist since ancient times. For example terraces with vineyards and for farming of other crops exist from ancient age.

Figure 1. Detail of a region in North Africa devastated by erosion.

Erosion Classification and Mapping

Application antierosion works and torrent training works need lot of money. These works are expensive. Also it is very important to know proper quantity works for application. Only one way to do it is classification of the erosion process and mapping which support these.

The investigation of erosion processes started with the development of science and with gaining knowledge on erosion processes. The first definitions and maps précised the qualitative categories of erosion.

Erosion processes are mapped, like all aerial phenomena, and this is nothing new. However, more than a hundred years of development of this specialized field witnessed the emergence of several mapping methods. Photographs or drawings were used when aerial imagery was not available (i.e. using balloons or airplanes). This remained the practice to the present day, but now only for illustration purposes. The development of aerial photogrammetry allowed the use of this technology, as well as the most recent development of remote sensing via satellite. The methods of erosion mapping developed to date can be classified into descriptive and analytical.

Descriptive methods are based on a visual assessment of the extent and intensity of erosion processes, and in most cases they cover the occurrence of gullies and their depth. Such methods are not suitable for any mathematical analyses and should be recognized solely as qualitative assessment tools. A characteristic of the methods is that they are vulnerable to human error during the mapping process. Furthermore, it is difficult to train specialists in a manner that would reduce the possibility of human error to an acceptable level. At the same time, this does not mean that such methods do not employ the most up-to-date techniques of remote sensing, since they are in fact the shortest routes to information about the status of a territory.

On the other hand, analytical methods of erosion mapping have their own target groups, such as agricultural, water resource management, banking and similar users.

Consequently, the methods feature a distinctly defined research procedure from the preparation, analysis, special data processing and assessment of remote sensing imagery to the generation of erosion maps. Each of the methods is subject to its own limitations governed by the intended use.

It may be strange that there are methods intended for banking purposes, but it is seldom that investors are reluctant to invest extensively in detailed analytical or descriptive erosion mapping before any basic mapping of the "erosion risk". Namely, investment in the development of design documents for the construction of a dam and river reservoir, or for arable land improvement, may mean money wasted if it is ultimately established that erosion processes in the area preclude any cost-effective or economical projects. Erosion risk mapping allows the investor to abandon an unrealistic project on time, and incur only minimal cost. This set of methods makes use of satellite imagery in a very small scale, which is proportionally inexpensive but provides sufficient data for an erosion risk assessment.

The degradation of the environment by erosion processes was recognized as a major problem during the first half of the 20th century, and the degradation continues in most parts of the world. USA Soil Conservation Service develop the first well known analytical erosion mapping method is SLE (later USLE). At this time erosion was State enemy No.1.

However, the problem has lost is precedence to the new evil of environmental pollution. It is for this reason that developed countries focus their activities on the pollution problem, allocate significant funds and also achieved extraordinary results, while erosion processes are now only one of the problems which will resume its central position once the pressing pollution problems have been resolved.
The territory of the former Yugoslavia was not endangered by pollution, but by erosion development processes and frequent torrent floods. As such, it was the latter pressing problems that were the primary focus of attention.
Over more than a hundred years of activity, numerous methods were developed that are still in use. Namely, all past and present water-related laws of the Republic of Serbia contain provisions that prescribe mandatory erosion and torrent flood control, monitoring, as well as institutional organization of control of these two inter-related phenomena. As in other countries, the competence and responsibilities with regard to the said efforts are shared by specialized state enterprises, agencies, and local bodies of self-governance.
Regulation of torrents was not sufficient, since the intensification of erosion processes increased the rate and frequency of torrent floods occurring after each heavy rainfall. Bare surfaces are generally ideal for unhindered runoff and concentration of destructive torrent floods waves.
In order to protect the important traffic corridor (10) in Serbia, activities on fully organized erosion control began in 1952 in the region of the Grdelica Gorge and the Valley of Vranje, by complex works on riverbeds involving extensive biological and engineering activities in torrent catchments. Administrative measures of erosion control were then implemented for the first time. Extensive works were performed in order to regulate torrents that until then regularly crossed railway and roadway traffic. Eroded surfaces were protected by biological and engineering works. A program of erosion control by appropriate land husbandry was implemented. The territory of the Grdelica Gorge and the Valley of Vranje isn't large, but quantity of lead out works was significant. Success wasn't follow quantity applied works. Obviously differences follow specific erosion characteristic. Fig.2. show basics information about covered territory with done works from 1952. To 1956.

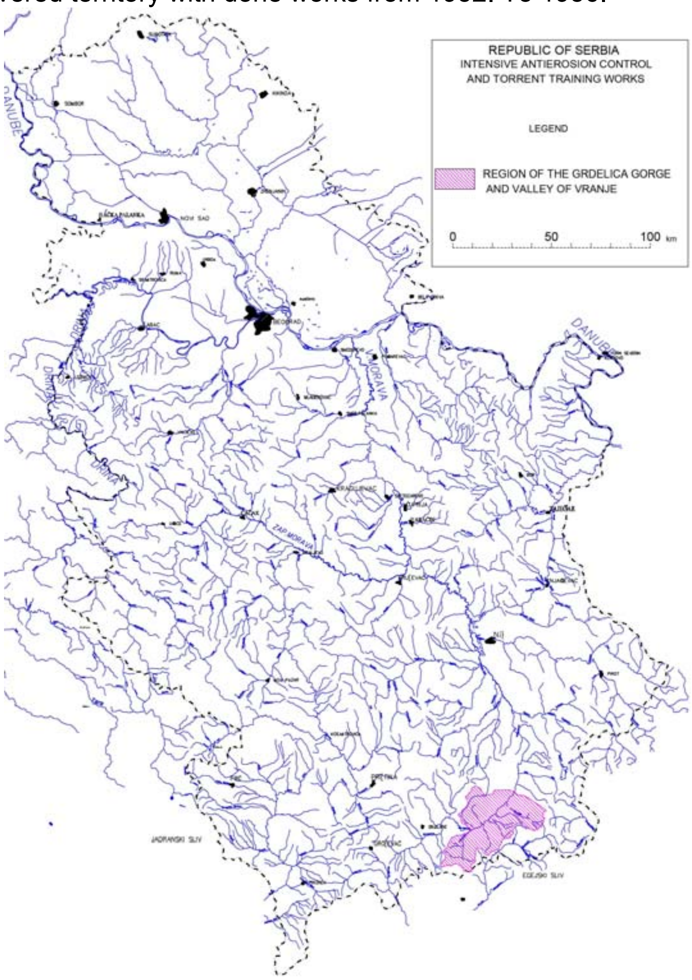

Figure 2. Grdelica Gorge region where biological and technical antierosion works was implemented

Densities of applied works are impressive. Technical works has density more than 500 m³/km². Biological works has density 50-100 ha/km². Several torrents are covered 100%.
SLE and USLE method covers erosion mapping and classification are limited to agricultural lands with slopes less than 15 %. Territory of former Yugoslavia and Serbia has small part territoritory with slopes les than 15%. Obviously steep slopes and erodibility layer needs new erosion investigation and mapping method.

Systematic investigations of the intensity of erosion were begun in former Yugoslavia sixty years ago ("Jaroslav Černi" Institute for the Development of Water Resources, 1947.), and they enabled the development of The Method for the Quantitative Classification of Erosion (MQCE), 1954. During the investigation work it was notified that erosion intensity could be used for computing the amount of sediment that reaches the downstream part of a river so that the investigations were extended to include the observations of the transport of the sediments to the control profiles. During last fifty years of permanent developing process results as a complex methodology for investigation erosion process, mapping, sediment calculating and torrent classification. Name of this method is "Erosion Potential Method". Since 1968. EPM is a standard method for erosion and torrent training engineering in water management.

Erosion Potential Method

The development of the method was achieved by a combination of information provided by the processing of remote sensing data (aerial imagery), surveillance of experimental watersheds and special erosion plots, and laboratory tests. The experimental watersheds including erosion plots were situated on several locations in the former Yugoslavia, and the laboratory was at the Jaroslav Cerni Institute for the Development of Water Resources from Belgrade.

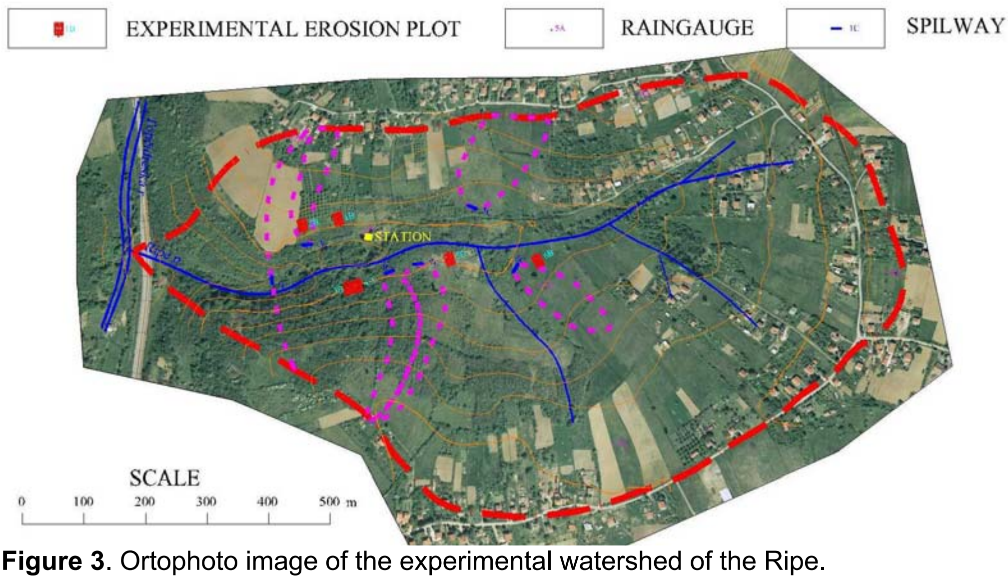

Figure 3. Ortophoto image of the experimental watershed of the Ripe.

Figure 3 shows a 2003 ortophoto image of the oldest experimental watershed in the former Yugoslavia, including details of the location and the landscape. This is the Ripe Brook, the right tributary of the Topcider River, with a catchments area of 59 ha. The seemingly tame catchment's area is concealing below its vegetation cover a highly erodible base (black forest soil on serpentine) and numerous gullies that were regulated by a system of environmental engineering works after World War II. Regardless of the small catchment's area and practically unaltered appearance and use of the land, the brook cut off the railroad line from Belgrade to Nis several times. This very fact led to the creation of an experimental watershed and the development of an erosion mapping method consistent with the conditions prevailing in a hilly and mountainous country where most of the terrain features slopes greater than 15%. Experimental watershed of the Ripe operated from 1952. To 1986. and from 2002. Up today.

EPM (Erosion Potential Method) is complete tool for all erosion and torrent engineering problems which are important for watershed management. This methodology contains:

- Quantitative classification of erosion (1954.)
- Quantitative sediment regime (1955.)
- Torrent classification (1956.)
- Antierosion and torrent training works optimization calculation (1958).

The first EPM was upgraded several times.

- Erosion Potential method I Phase (1966.)
- Erosion Potential method II Phase (1968.)
- Erosion Potential Method III Phase (1986.)
- Erosion risk zoning (1998.)

EPM Quantitative classification of erosion

Erosion is a phenomenon occurring on the whole surface; the most rational presentation of the surface spreading of erosion is the mapping of the erosion.
The EPM erosion mapping procedure requires investigations and computations to determine and present on a map the surfaces with the same quantitative erosion class. The basic EPM value of the quantitative erosion intensity is the Erosion Coefficient (Z).
Since erosion is a natural phenomenon is necessary to carry out a field investigation works such as are: estimation, determination and verification of the coefficients and relief characteristics needed for further computations. The coefficient of observed erosion is estimated. Other coefficients are determined in the previous office processing but should be verified in the field, although they could be determined directly on the spot for small areas. The coefficient of erosion (Z) is calculated from the following equation:

$Z = Y \times X \times a \times (\varphi + \sqrt{I})$ Where:

Y = coefficient of soil resistance to erosion
X = Land use coefficient
a = conservation coefficient
φ = coefficient of the observed erosion process
I = is mean slope of the surface
Classification of erosion is possible, in the cartographic sense, only in the form of qualitative categories. The quantitative value of the erosion coefficient (Z) has been used to separate erosion intensity to classes or categories.

MPE Erosion categorization			Table 1
Erosion category	Qualitative name of erosion category	Range of values of coefficient (Z)	Mean value of coefficient (Z)
I	Excessive erosion - deep erosion process (gullies, rills rockslides and similar)	Z > 1.0	Z=1.25
II	Heavy erosion - milder forms of excessive erosion	0.71< Z <1.0	Z=0.85
III	Medium erosion	0.41<Z<0.7	Z=0.55
IV	Slight erosion	0.20<Z<0.4	Z=0.30
V	Very slight erosion	Z< 0.19	Z=0.10

The mean value of the EPM erosion coefficient (Z) for the catchment’s area is the basics value for all EPM calculations.

EPM Quantitative sediment regime

The erosion intensity and erosion sediment transport measuring problems are conditioned by the distribution of erosion (the whole surface of the Earth) and by the agent producing them (rain and wind). It is impossible to carry out measurements over the whole surface so that it is performed at the special stations.
The terms "erosion intensity" and "erosion sediment transport" are not related by chance. Namely, the "eroded material" is the part of the land which has been moved, and only that quantity of material could be measured. When considering sediment movement measurements, it is enough to say that

only suspended sediment transport (by water) measurements are today carried out with the appropriate accuracy while the bed load movement measurements are not reliable.

The reliable measuring of bed load is possible only by the geodetic survey of the sediment deposits in lakes and reservoirs. However, the occurrence of eolian sediment which is deposited together the water sediment, is also possible.

The eolian sediment movement measurements are still in the phase of the mode of observation and measurement investigations since the eolian sediment, differently from the water one, moves within the wide areas. The data on the erosion intensity and sediment transport are not abstract data but have a great practical importance. The erosion intensity data indicate the rate of soil degradation and the decrease of the soil productivity and are used for planning in agriculture and forestry. Data on sediment transport give the dimension of the yearly sediment entry at the profile of the existing lake or the designed reservoir.

The sediment transport and entry measurements require a measuring period, not shorter than ten years, being a very long period for probably useless measurements at the profile which will be abandoned due to erosion sedimentation. Since the small reservoirs are usually constructed on streams which are often extremely torrential, without any current measuring, not to talk about the sediment movement observations, the problem of the previous erosion sedimentation estimation gains the primary importance. This is also valid for the developing countries where large reservoirs are built on streams with very scarce observations or without them at all.

EPM quantitative classification makes it possible to make precalculate amount of erosion-produced sediments. The eroded material is generally transported for years and not gradually broken-down to smaller particles. Along the entire flow from the source to the inlet point, it can be seen that there is a gradual change in the grain size distribution curve toward finer grain-sizes. The variation in the grain size distribution may be smaller or greater depending on the mechanical strength of the sediments, on the length of the transportation route and differences in the elevation of the route.

The sediment inlet or sediment transport calculated using this method are two identical values. The term "sediment inlet" is used for storage reservoirs if the sediments end their route there, while the term "sediment transport" is used for calculating the sediment at a given profile. Both terms refer to the average annual volume sediment that reaches or flows through observed profile. The EPM calculated sediment volume includes both the stream-borne and suspended volumes.

EPM quantitative sediment regime calculations are applied during design water reservoirs as a proscribed standard procedure. Figure 4 show relation between catchment's area and siltation rate Gsp (m³/km² year). All data represent sediment deposits module. Red points are measured values and green points are EPM precalulated values. It is visible that lot of points has good agreement between precalculated and measured data, but exists several points which has visible diversity. In the fact those data are made in the first days of EPM practice and low experience and sufficient EPM erosion mapping training.

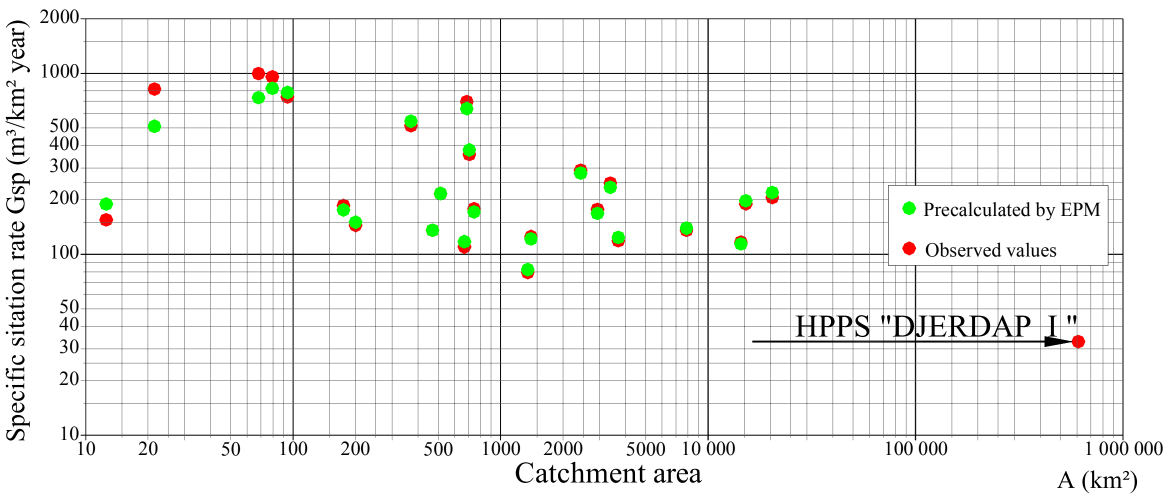

Figure 4. Relation between Catchments area and siltation rate for reservoirs in Serbia

Today it is very easy trough GIS processing to compute all imputed values except value of the coefficient of the observed erosion process (**φ**). This value directly depends on personal experience.

A well-trained specialist may overestimate or underestimate by no more than 10%, and this does not significantly affect the end result. However, a greater error in the assessment of an observed erosion process (**φ**) leads to an erosion classification error by one to two categories, and this directly affects the accuracy of subsequent mathematical analyses where the erosion coefficient *Z* is an input parameter. This includes the quantification of the eroded material which depends on climatic factors (temperature, precipitation and wind). Namely, the method was designed to provide the appropriate category that has been investigated by an authority, and to permit other specialists with minimal training to compute the sediment production rate (Wsp) in m³/km² according to the formula

$$W_{sp} = K \times \pi \times \sqrt{Z^3}$$

Where *K* is the numerical value for climatic characteristics obtained by the EPM method. This function is exponential and an erosion classification error introduces an exponential error into the analyses, as can clearly be seen in the figure 5 showing the sediment production rate multiplier (*Wsp/K)* as a function of the erosion coefficient *Z* and the potential magnitude of error due to an inadequately determined coefficient of the observed erosion process ***φ***.

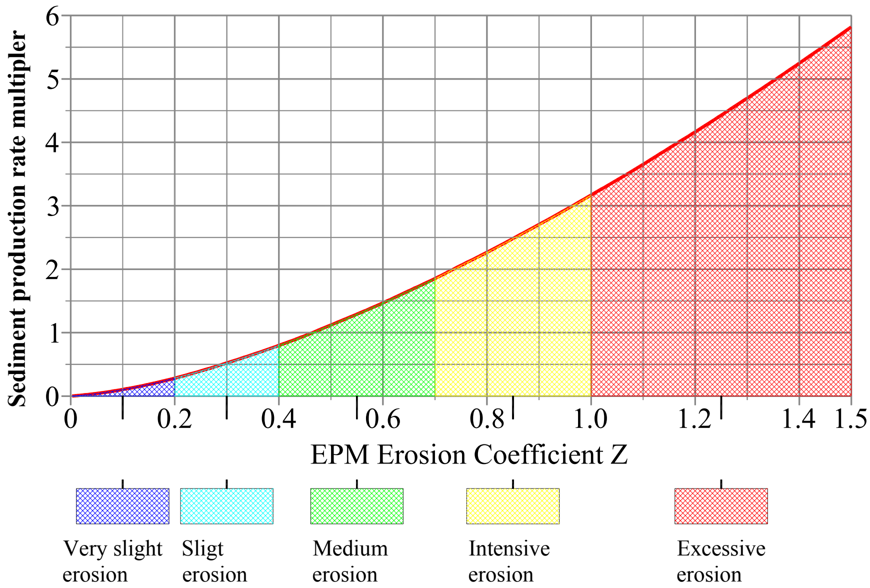

Figure 5. Sediment production rate multiplier as a function of the erosion coefficient Z

One erosion class error means that future reservoir will be filed in very short time or calculated values can stop reservoir designing.

EPM Torrent classification

Special EPM feature is torrent classification. It is well known that exist torrents with great differences of catchment's area. Great torrent rivers with catchment's area greater than 100km² and gullies with catchment's area les than 1 ha.

EPM torrent classification has procedure for calculating torrent hydrographic class coefficient (Hk). Depending on the numeric value EPM separate torrents in six torrent classes.

Torrent classification		Table 2
Torrent class	Description	Torrent hydrographic class coefficient (Hk)
A	Torrent Rivers	Hk>20
B	Small torrent Rivers	10<Hk<20
C	Torrent streams	1.0<Hk<10
D	Small temporary torrent streams	0.1<Hk<1.0
E	Landslide small torrents	0.05<Hk<0.1
F	Gullies	Hk<0.05

EPM torrent class (A-F) and erosion coefficient (Z) are basic values for antierosion and torrent training works optimization.

EPM Antierosion and torrent training works optimization calculation

Long duration of intensive complex antierosion and torrent training works help us to find optimal quantity of the works. Long term investigation was successful. Best fit correlations found between EPM torrent classes and erosion coefficient (Z). Figure 6 show relation who help us to define optimal quantity of biological and biotechnical works depending on erosion intensity (Z) and torrent class. Figure 7 show similar relation for technical works.

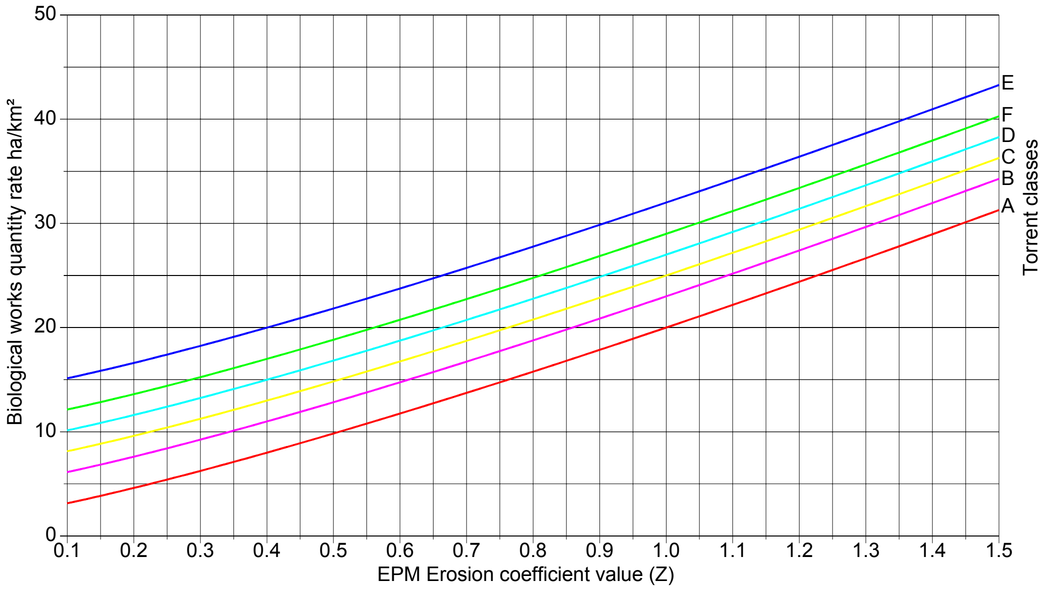

Figure 6. Relations between erosion coefficient and biological works quantity rate by torrent classes

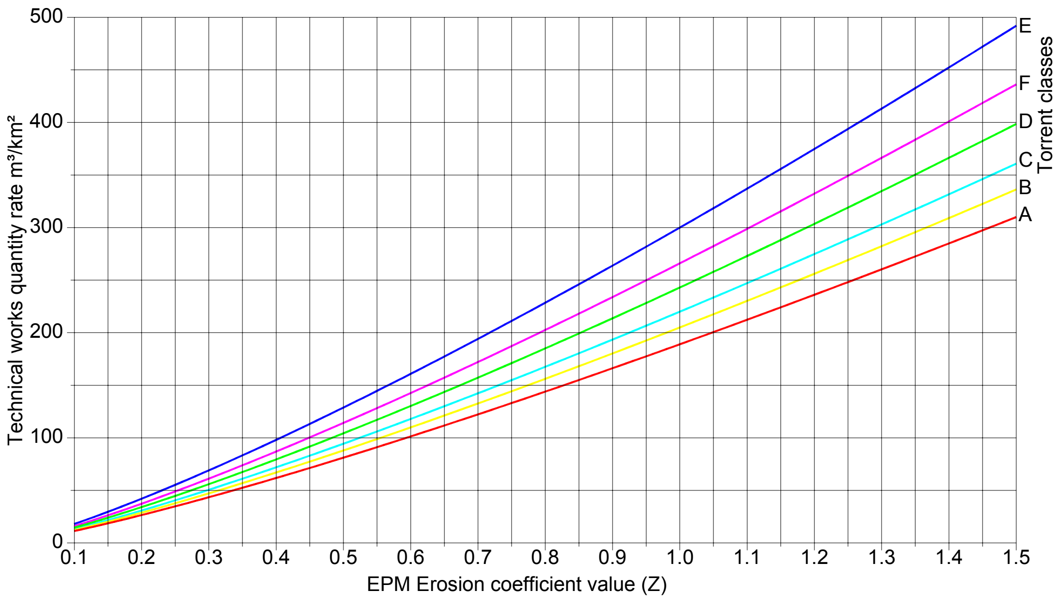

Figure 7. Relations between erosion coefficient and technical works quantity rate by torrent classes

Those optimizations relations make fundamental changes during antoerosion and torrent training works. Optimized quantity of applied works directly mean greater territory covered and protected.

Figure 8 show lead out antierosion works in Serbia between 1907. 2000. Year. A graph show that massive works starts at 1955. Period between 1945. To 1955. was focused only to region of Grdelica Gorge (Fig.2.).

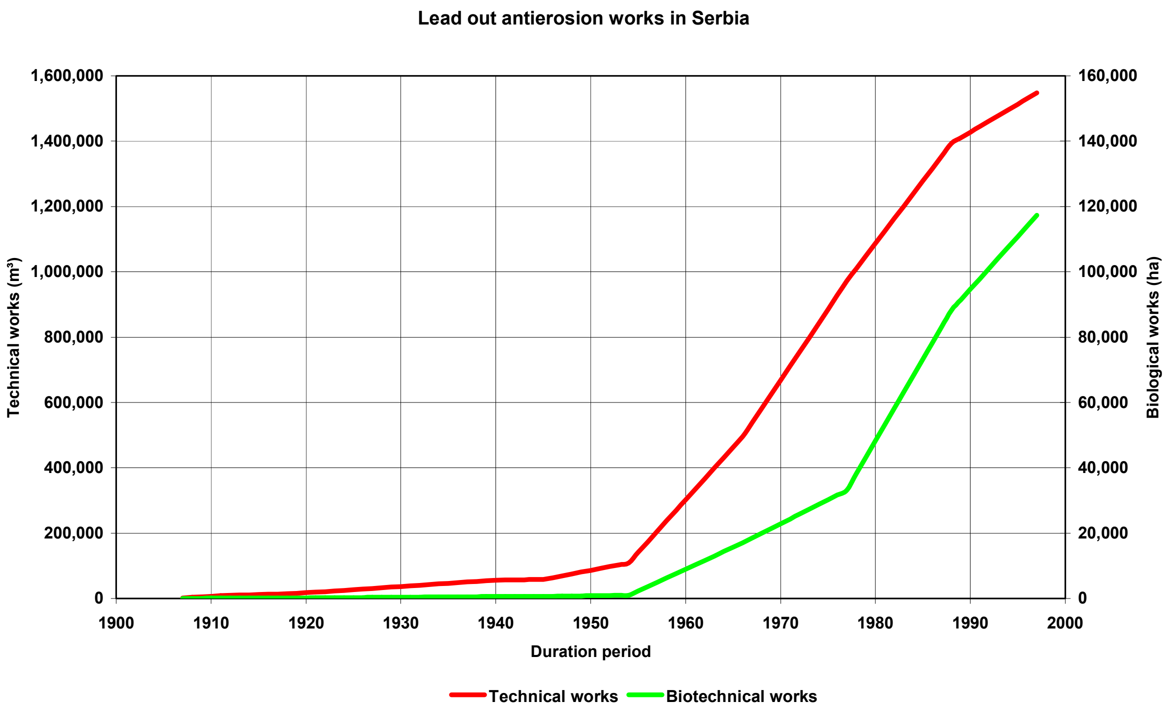

Figure 8. Lead out antierosion works in Serbia between 1907. 2000. Year

Figure 9 show two characteristically examples of typical lead out biological and technical works. A forestation is combined with contoured orchards. Special attention is focused to forest fruit species. Technical works are implemented as an important part of integrated antierosion protection system.

Figure 9. Contoured orchards and torrent check dams are lead out

Figure 10 show territory of Serbia and coverage of antierosion works. In the comparison with Figure 2 it is clear that EPM support helps to save money and to cover larger territory in the shorter time. Now day's Serbian territory are covered with complex antierosion works. Benefits can be abstracted into:

- no more destructive torrent floods and damage costs
- This territory has significant income from raspberry, strawberry, apples, pears and many other products from mountains region.

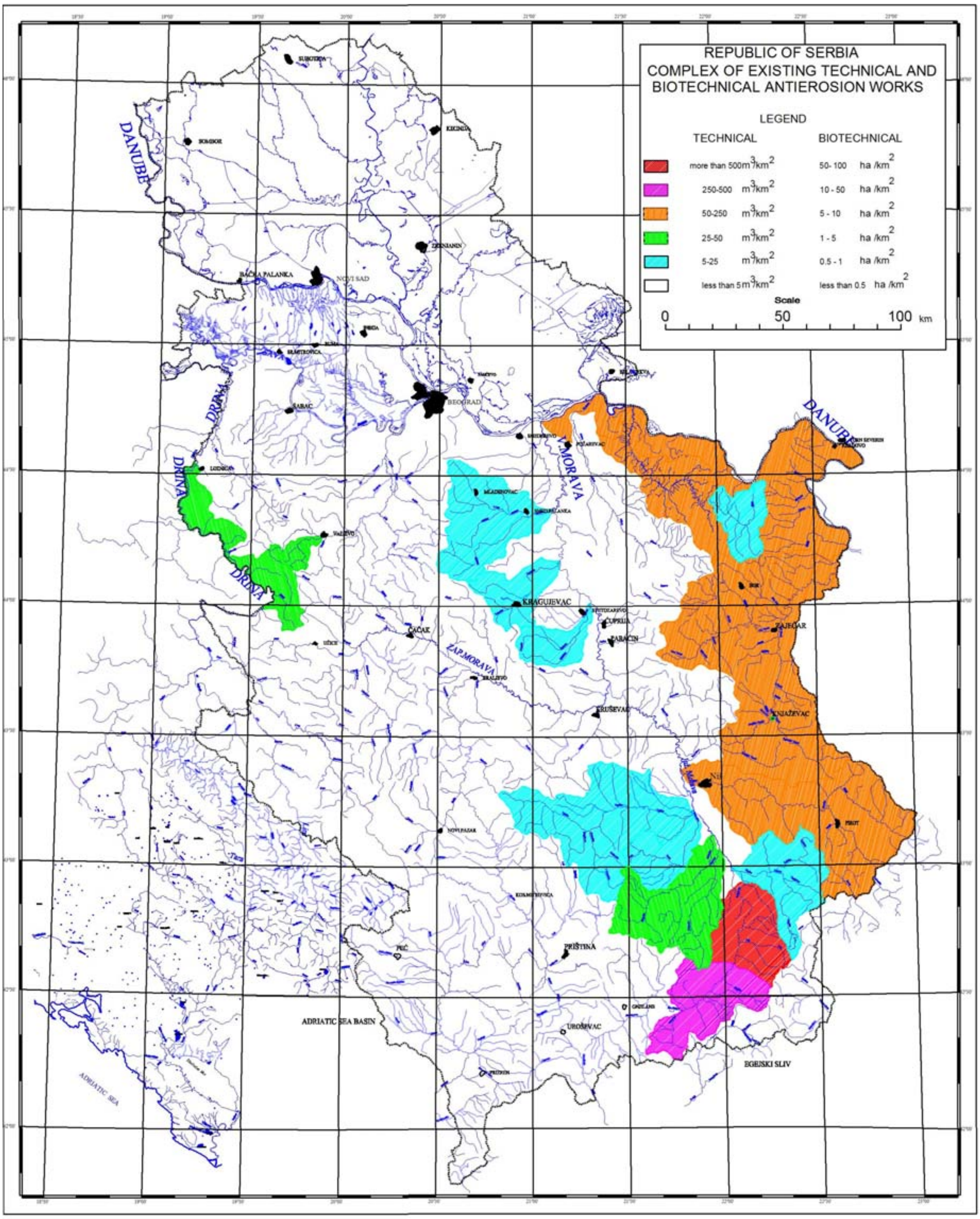

Figure 10. Coverage of lead out complex antierosion works

EPM Erosion risk zoning

New EPM task is erosion risk zoning. Namely, Public companies and specialized firms have been entrusted with the task of reversing erosion processes in totally devastated areas, as well as of training torrents in order to upgrade them from non-regulated and non-defended to regulated and defended rivers.

Measures of erosion control by appropriate land husbandry are implemented by local bodies of self-governance (municipalities) on their territories. Such measures are introduced for land surfaces that have been identified as *erosion zones*.

Municipalities are required to made identification of erosion zones and proclamation them. Results were different. These plans need an expert foundation. In order to synthesize and standardize program quality, in 1998 the Ministry prescribed methodology to be applied in the preparation of the said program. The methodology is an upgrade EPM.

Terms “Erosion zone” and “Eroded class” are usually identified. However, Eroded zones of erosion are surfaces attacked by different classes and categories of erosion that are classified in accordance with appropriate methods of erosion survey, while erodibile zones are surfaces without developed erosion, but might become sources of erosion if some factor significant for the development of the erosion changed.

The purpose of the administrative clause, through timely proclamation of erosion areas, is to provide legal basis for the implementation of other measures prescribed by the law on forests, the law on waters, the law on agricultural lands and the law on environment in order to restrain further soil degradation caused by inadequate land use. Based on aforesaid, next definition of the erosion area should be accepted:

“Erosion zone“ is a soil surface overtaken by apparent processes of erosion. It is also a surface without apparent erosion, but it might occur due to change in land use”.

A set of administrative measures, carried on by the land users on compulsory bases represents successful ant erosion measures. These measures usually require a relatively low cost a part of which is allocated to the state agency in charge (planning, implementation and erosion control). The administrative measures should be legally defined and implemented over a long time-period.

Practice has proved that the best results in preventing and abatement of erosion can be achieved by combining the technical works in the beds of torrential streams, biomechanical works in the channels and the catchments areas, biological works in the catchments areas and application of administrative measures.

Figure 11. show orchards nearby Belgrade. Slopes aren’t too steep. EPM erosion coefficient (Z=0.34). Erosion class IV- Slight erosion. But soil is erodible. Half century ago erosion class was medium. After applied antierosion measures erosion intensity was minimized.

Figure 11. Erosion zone identified inside low EPM erosion classes

Obviously, erosion is present on all surfaces, but erosion zones are only there where different way of land use can change erosion category to lower one. This way is low cost and can be applied on significant areas were people normal use land for their wide activates. In the case of heavily eroded lands there is needed very expensive technical and biological works.

To identify erosion zone at the first it must be calculated expected change after different land use or conservation method. Equation has shape:

$$Z_n = \frac{Z \times (X_n \times a_n)}{(X \times a)}$$ Where:

Z= Coefficient of Erosion before antierosion measures
X = Land use coefficient before antierosion measures
a = conservation coefficient before antierosion measures
Z_n= Coefficient of Erosion after antierosion measures
X_n = Land use coefficient after antierosion measures
a_n = conservation coefficient after antierosion measures
Values for this calculation are shown in table 3.

Land Use and Conservation coefficient values Table 3.

No.	Surface Conditions	Coefficient		
		X	a	Xa
A	Surfaces which were not treated by conservation works			
1	Barren untilled soil	1.00	1.00	1.000
2	Plowed field with plowing upwards and downwards	0.90	1.00	0.900
3	Orchards and vineyards without low vegetation	0.70	1.00	0.700
4	Degraded woods and under bush with eroded soil	0.60	1.00	0.600
5	Mountain pastures	0.60	1.00	0.600
6	Meadows and similar perennial crops	0.40	1.00	0.400
7	Good woods on slopes	0.20	1.00	0.200
8	Good woods on flat land	0.05	1.00	0.050
B	Surfaces after conservation works (biological, technical and administrative)			
1	Contour farming	0.90	0.70	0.630
2	Contour farming with mulching	0.90	0.60	0.540
3	Contour - strip cultivation with crop rotation	0.90	0.50	0.450
4	Contour orchards and vineyards	0.70	0.45	0.315
5	Terracing of plowed fields, terraces, graded terraces	0.90	0.40	0.360
6	Grassing, meadow amelioration	0.60	0.50	0.300
7	Contour trenches of medium density	0.60	0.40	0.240
8	Forestation (holes and strips)	1.00	0.20	0.200
9	Forestation and grading	1.00	0.10	0.100
C	Catchments area after technical works on torrent control			
1	Retarding waterways and micro – reservoirs	0.90	0.30	0.270
2	Riverbed regulation (torrent dams, channels etc.)	1.00	0.70	0.700

Proclamation of erosion zones of a municipal territory

Erosion zones are proclaimed on the basis of provisions of the Law on water resources of the Republic of Serbia and an Erosion status report in which erosion zones of a municipal territory have been identified by applying the prescribed methodology.
The following administrative measures of erosion control are implemented:
Ban on slope farming that requires loosening of soil (Corn and similar crops)
Ban on plowing of slopes;
Ban on deforestation of slopes;
Ban on grazing in degraded fields;
Mandatory contour plowing;
Mandatory conversion of crop fields into grass fields;
Mandatory reclamation of degraded grazing fields;
Mandatory forestation of bare land;
Mandatory conversion of annual to perennial farming in degraded areas;
Mandatory erosion-preventive land husbandry;
Mandatory erosion-preventive forest husbandry.

The results were extraordinary. The difference between past and present conditions prevailing on the surface of the catchments is obvious. Figure 12. Show comparative photographs same detail from east Serbia at the time of commencement of the works and thirty years later. The previously bare land is now productive and convenient for forests, fruit, mushroom, and herb growing.

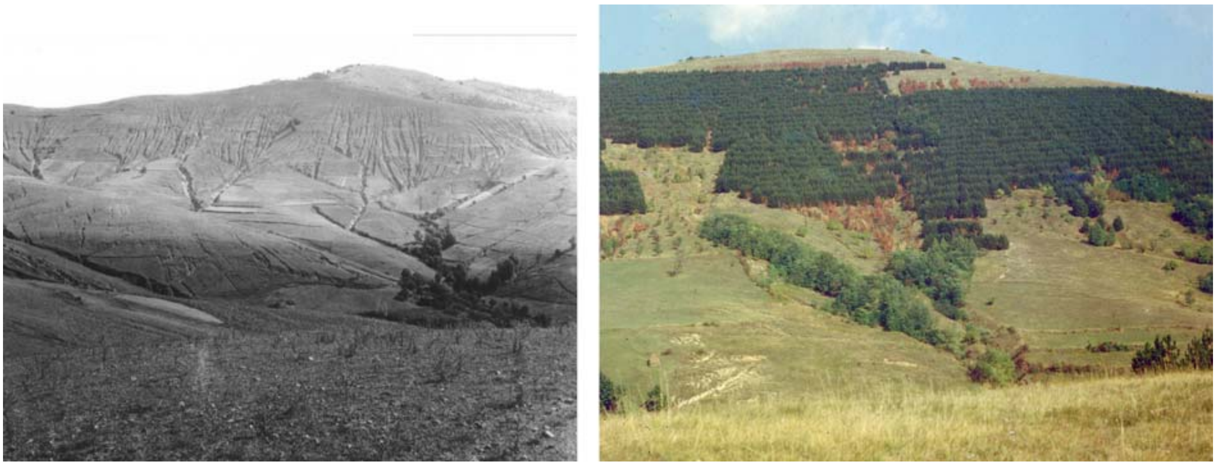

Figure 12. Same territory at the beginning applying antierosion measures and thirty years later

Identified erosion areas are technical basis for the proclamation of erosion areas on the territory of municipality. So proclaimed erosion areas become by law document, which enables act of prompting to users in order to carry out husbandry in antierosion way. For every individual erosion area is made a detailed project which ascertain possible range of measures wherefrom user chooses the optimal one.

Only in the extreme cases might some measure, which drastically changes conditions of the land utilization, be prompted. Such are cases with heavily eroded arable lands that, for a longer period, must be excluded from agricultural, orchard or forest production and protected with perennial sylvan vegetation. Professional services must ordinarily check the state of the terrain and issue timely directions for application of appointed measures.
Heavily eroded land exists in Serbia. Improper forest exploitations on erodible substrate all-around world produce bad-lnds. This eroded spots need massive works. When applied works success this is the point to keep new erosion state trought antierosion management. This area always is erosion zone. Figure 13 show one small heavily eroded catchments protected with complex combination of technical, biotechnical, and biological works. Lead out works is expensive, but that is only one way to prevent reservoir siltation.

Figure 13. Check dam and combination of countered and normal protective forestation

Conclusion

The erosion and torrent investigation engineering using (Erosion Potential Method) is improved thought half century experience and upgrading. No one reservoir, designed with EPM support, is not filed with sediment deposits.

Average cost of dam and reservoir with optimized antierosion protection is nearby 100 millions dollars. It is clear that any erosion and sediment siltation calculating errors are not abstract terms, but the errors which are best presented by the loss of millions of dollars. The under estimated values will cause the reservoir life decrease, i.e. much expensive works for reservoir protection against erosion are needed. The mentioned example includes, as the consequence, the cost increase and automatically causes the benefit decrease. As the structures in question are very expensive, the losses are enormous.

The fight against erosion and torrent flooding needs to be taken seriously since it is a war in the true sense of the word. Although some damage is hidden and other clearly visible, the magnitude is far greater than that of destruction in combat.

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