Internationales Symposion
INTERPRAEVENT 2004 – RIVA / TRIENT

" EROSION POTENTIAL METHOD" AND EROSION RISK ZONING IN MOUNTAINOUS REGIONS

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ABSTRACT

There are several methods to define the risks which may occur on the agricultural soil in the valleys. "Erosion Potential Method" is designed for usage in the mountainous regions and on the big catchment areas. Up to date development of this method contributed to high degree of reliability of sediment production evaluation and sediment transport evaluation. The paper presents the definition of the erosion risk on the mountainous soil and other terrain using the "Erosion Potential Method". During development this method has been improved and its achieved results are impressive.

Key words: Erosion, Mapping, GIS

INTRODUCTION

The topsoil layer is exposed to aggressive weathering processes. Degree of erosion depends on unchangeable land characteristics within the drainage (geomorphologic, pedologic and similar features) as well as on the climatic conditions (temperature, rainfall, wind). However, erosion is greatly affected by human's activities (vegetative, cover, land use pattern and land use practices).

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The climate prevailing in Serbia and Montenegro prevents exclusive forms of eolian (wind) erosion, and it is always combined with water erosion. For this reason diverse forms and patterns of erosion are present in Serbia and Montenegro, some of which have become wonders of nature.

Fig.1 Erosion diversity and erosion wonders of nature in Serbia and Montenegro

The only factor under human control that initiates erosion processes is the method of land utilization. Excessive exploitation of forests results in bare terrain. Improper plowing of slopes is a significant factor of erosion intensification, especially if the plowed base is prone to erosion.

Fig 2. Human impact on increasing erosion processes

Erosion development is to a great extent the result of the kind of civilization and degree of its development. Nomadic civilizations left devastation in their wake, searching for new grazing fields generally acquired by war. Non-migratory rural civilizations are not prone to ready change of habitat, since agriculture is the focal point of survival and not conducive to relocation for at least several years or decades. The territory of the Balkan Peninsula is characterized by the long-term settlement and non-migratory (agrarian) cultures that resisted numerous nomadic incursions.

HISTORICAL BACKGROUND OF EROSION AND TORRENT CONTROL IN SERBIA AND MONTENEGRO

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.

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, 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 results were extraordinary. The difference between past and present conditions prevailing on the surface of the catchments is obvious. Photographs show the same detail adjacent to the Belgrade-Skopje railroad line at the time of commencement of the works and thirty years later. The previously bare land is now productive and convenient for fruit, mushroom, and herb growing.

Fig.3. Same territory at the beginning applying antierosion measures and thirty years later

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*.

Bodies of self-governance were given a special role in this regard. Municipalities are required to prepare two programs:

- Torrent flood defense Action Plan of rivers and streams external to the regular control system;
- Proclamation of erosion zones.

The said programs form the basis of planning and evaluation with regard to erosion and torrent flood control.

Each of these two plans need an expert foundation. In order to synthesize and standardize program quality, in 1998 the Ministry prescribed methodologies to be applied in the preparation of each of the said programs. The methodologies were developed by the Institute for the Development of Water Resources “Jaroslav Černi”.

APPLIED METHOD FOR EROSION INVESTIGATION AND MAPPING

Two methods for erosion process investigation and mapping are commonly used in Former Yugoslavia. The first method is the Universal Soil Loss Equation – USLE developed by America's Soil Conservation Service – SCS. It serves to determine the erosion intensity on agricultural land. Although it provides reliable data on losses of soil and nutrients, this method is limited to agricultural lands with slopes less than 15 %.

The second method is the "Erosion Potential Method" (EPM). It was developed in the Institute for Development of Water Resources "Jaroslav Cerni". This method has been used to determine the erosion intensity and to calculate the erosion sediment yield and transport needed for water resources planning and management and hasn't slope limitation. The method proved reliable for assessment of sedimentation that affects reservoirs, river channels, important structures and urban areas. It is now a standard method for erosion mapping in water management.

The investigation procedures starts at 1947.year and after several steps (1952.; 1956.; 1962.year) computations methodology was defined in 1968.year. EPM (Erosion Potential method) has been widely used in Yugoslavia since that time, being constantly improved.

The basic value by which we define, using the EPM to define the erosion intensity is the Erosion Coefficient (Z).[Gavrilović S].

Since 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 mapping procedure requires investigations and computations to determine and present on a map the surfaces with the same class Erosion Coefficient (Z). The coefficient of erosion (Z) is calculated from the following equation: [Gavrilovic S, Gavrilovic Z]

$Z = Y \times X \times a \times (\varphi + \sqrt{I})$ 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 done in five categories. Ranges of the Erosion Coefficient (Z) are shown in table 1.

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	Moderate 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

There is an opinion that mapped category of the erosion process is identical with sediment production. Since the climate factor is changeable one, every area has its own characteristic values of the sediment production related by another EPM equation:

$W_{sp} = T \times H \times \pi \times \sqrt{Z^3}$ where

Wsp - is the average annual specific production of sediments per km^2 in m^3 /year

T - is the temperature coefficient calculated from

$T0\sqrt{\frac{t}{10}+0.1}$ where t is the mean annual air temperature in Celsius degrees (C°)

H - is the mean annual amount of precipitation in mm (millimeter/year)

Z - is the coefficient of erosion calculated using the mentioned methodology (average value for whole catchments or area).

The sediment production vary within the wide range of values, which is shown in Figure 4 and Figure 5. Those figures show dependence of modules of erosion production for the most excessive and very slight erosion processes. Even just a cursory glance at the graphs in Figures 4 and 5 points out that production of erosion sediment cannot be the same in the cases of excessive and very slight erosion; in fact, qualitative aspect of the erosion is not identical with the quantitative values of the EPM (Z) coefficient.

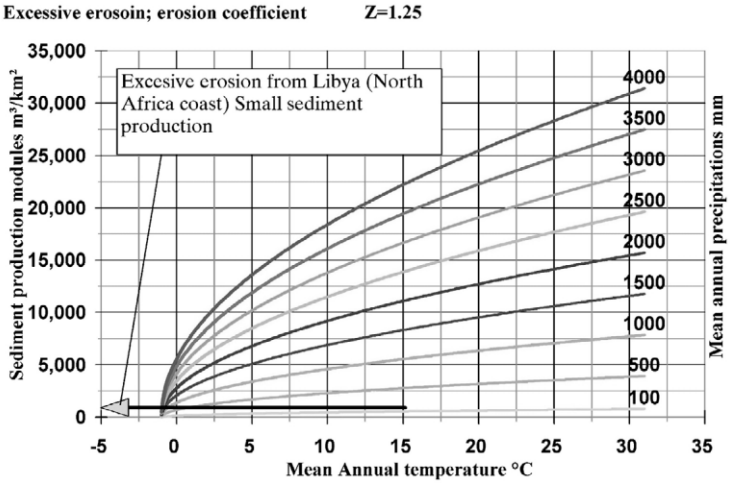

Fig. 4. Modules of erosion production in function of the temperature and rainfall for excessive erosion

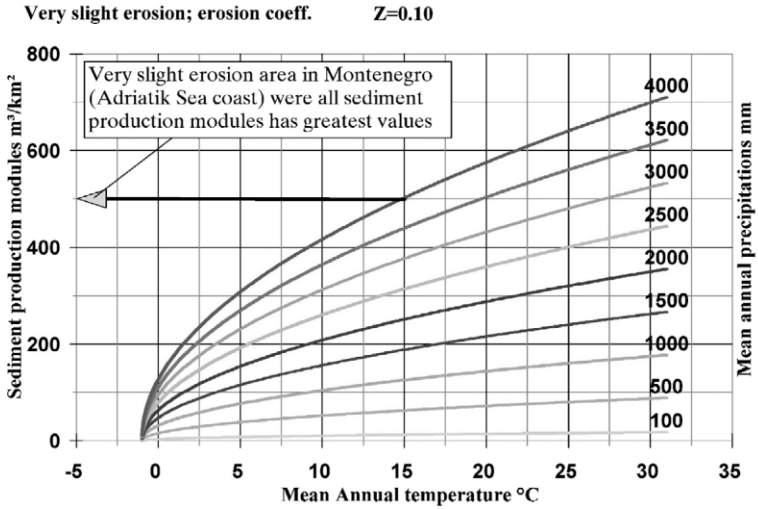

Figure 5. Modules of erosion production in function of the temperature and rainfall for very slight erosion

Fig 6. Area of excessive erosion in North Africa (Libya) and area of slight erosion in Montenegro

Figures 6 show two areas that are apparently stricken by the same category of erosion process. However, the area in left picture, from North Africa, is attacked by excessive erosion, while the area in right picture, from Montenegro, is attacked by very slight erosion although both of them have almost the same specific production of sediment. The area in Libya is exposed to extreme temperatures with very low depth of rainfall, while the area in Montenegro is exposed to extremely high depths of rainfalls where some daily sums of precipitation are higher than two-year sum of precipitation in the significant part of North Africa. [Stefanovic M., Gavrilovic Z.]

DEFINITION OF EROSION ZONES

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 Redouble 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", [Gavrilovic Z].

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.

Obviously, erosion is present on all surface, 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.

Land Use and Conservation coefficient values Table 2.

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

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 these calculation are shown in table 2. [Gavrilovic S , Gavrilovic Z ., Stefanovic M., Gavrilovic Z].

AN EXAMPLE OF APPLIED EPM FOR EROSION MAPPING AND ZONING

There we presented two examples from different regions of Serbia. First is located in the valley of West Morava (Zapadna Morava). Town Cacak is one of the great industies center in the Republic of Serbia. Expansion industries zone and the town is present. Several torrents come from the mountain Jelica (elevation is higher than 1000m) and directly atack industries zone and railway and roads communications. On this territory ant erosion measures and torrent regulation works are not present. In the fact, protection works hasn't sufficient financial support to follow development of industries and the town. Figure 7 show detail from erosion map and erosion zones prepared for proclamation.

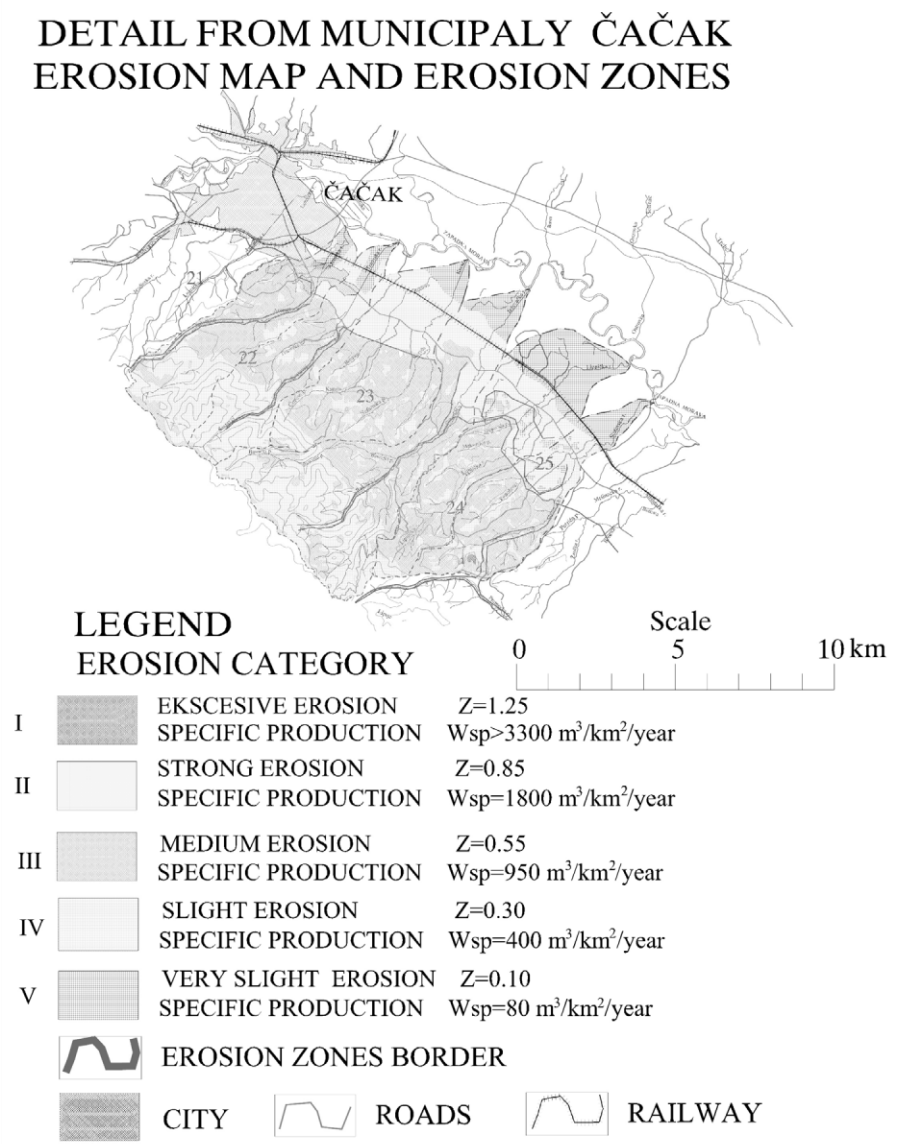

Fig. 7 Detail from erosion map and erosion zones prepared for proclamation.

Erosion and erosion areas also occur in the plains. It is not an exception but the rule. Eroded and erosion areas are not isolated occurrences but relate to each other as well as to problems of torrential floods. Such is an example of municipality Pozarevac, which comprises approximately 75% plains in the valleys of the Great Morava, the Danube and the Mlava. The rest is rolling terrain with a maximal dieseling of 150m. There are erosion areas on this territory. They are identified and notably marked which is shown in Figure 5. Regardless of

the fact that torrential flows are of proportionally small tracts and lengths, torrential floods are common occurrences. The one from July of 1999 had disastrous effect. Reconstruction of those flood waves has shown that all of them originated from the areas, marked as “erosion areas”, [Gavrilovic Z, Stefanovic M., Gavrilovic Z].

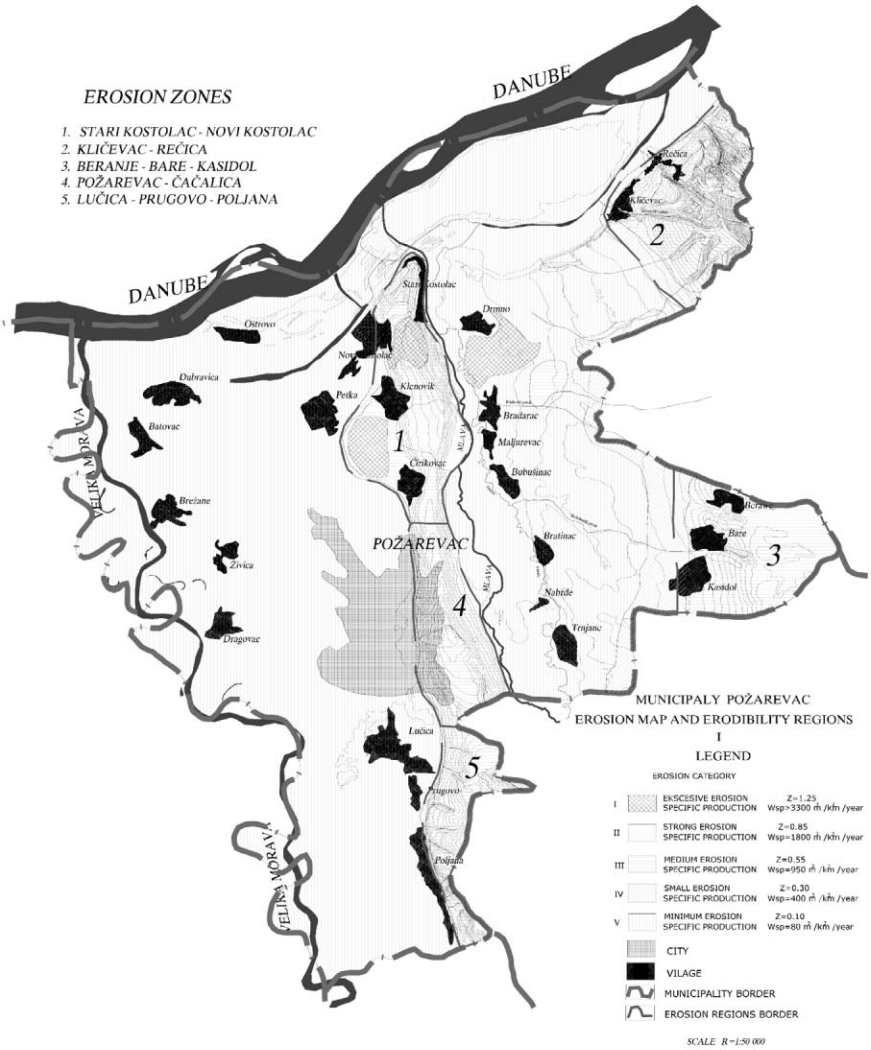

Fig. 5. Map of erosion and erosion areas of municipality Pozarevac

PROCLAMATATION 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.

CONCLUSION

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.
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 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.

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