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The Application of the Erosion Potential Method to alpine areas. Methodological improvements and test case

Luca Milanesi, Marco Pilotti & Alberto Clerici

Università degli Studi di Brescia, Dipartimento di Ingegneria Civile, Architettura, Territorio, Ambiente e di Matematica – Via Branze, 43 – 25123, Brescia

e-mail: luca.milanesi@unibs.it

1. Introduction

The assessment of soil erosion intensity is of primary importance for land use planning, soil conservation, pollution control and water resources management. For these reasons many researches were prompted in order to develop instruments for the estimate of the sediment budget. The hydraulic approach deals with the problem on the basis of the transport capacity of the river in each cross section, disregarding the availability of sediments at the basin scale. On the contrary, conceptualized models evaluate the intensity of erosion processes at the basin or the parcel scale with different time horizons.

The Erosion Potential Method (Gavrilovic 1988), in the following also indicated as "EPM", is an empirical semi distributed model to estimate the mean annual volume of soil erosion and sediment yield at the basin scale. It combines in a simple structure all the most statistically significant parameters controlling soil particles detachment and transport. Although calibrated for the Dinaric Alps, several applications to the Italian and Swiss Alps can be find in the literature.

2. The Erosion Potential Method

The specific mean annual soil erosion W_{sp} ($m^3/km^2/y$) depends on the mean cumulative annual rainfall H (mm), on the erosion coefficient Z (-) and on the parameter T (-), that is a function of the mean annual temperature t (°C):

$$W_{sp} = T \cdot H \cdot \pi \cdot \sqrt{Z^3} \qquad (1)$$

$$T = \sqrt{\frac{t}{10} + 0.1} \qquad (2)$$

$$Z = X_a \cdot Y \cdot (\varphi + \sqrt{i}) \qquad (3)$$

The erosion coefficient Z is a combination of the soil protection coefficient X_a (-), of the parameter Y (-) describing erodibility, of the active erosion processes coefficient ϕ (-) and of the mean slope of the basin i (m/m). The parameters in Eq. (3) are computed by means of tables proposed by Gavrilovic (1988) and revised by several authors (e.g., Zemljic 1971;Milanesi et al. 2013). The sediment yield volume G (m^3/y) depends on the drained area of the basin F (km^2) and on the retention coefficient R (-), which is the percent of eroded sediments that reaches the exit section, that according to Zemljic (1971), can be written as:

$$R = \frac{\sqrt{O \cdot \hat{H}}}{L + 10} \frac{\sum_i L_i}{F} \qquad (4)$$

$$G = W_{sp} \cdot F \cdot R \qquad (5)$$

where $\hat{H}$ (km a.s.l.) is the mean altitude of the basin, and L_i (km) is the length of the reaches of i-th order.

3. Methodological improvements

EPM was originally derived for the Dinaric Alps through experimental analyses and field data at the parcel scale. The modifications suggested wish to improve the applicability of EPM in areas with different climatic features from the Dinaric Alps. Moreover a novel calculation approach is suggested in order to couple the application at the basin scale, while keeping the local details of the processes.

Application of the model to the period from May to October:

- in fall and winter periods most of the areas experience completely frozen soil with low discharge in the streams so that soil detachment and transport is negligible;
- the radical of Eq. 2 is positive also for regions with mean annual temperature below 0°C.

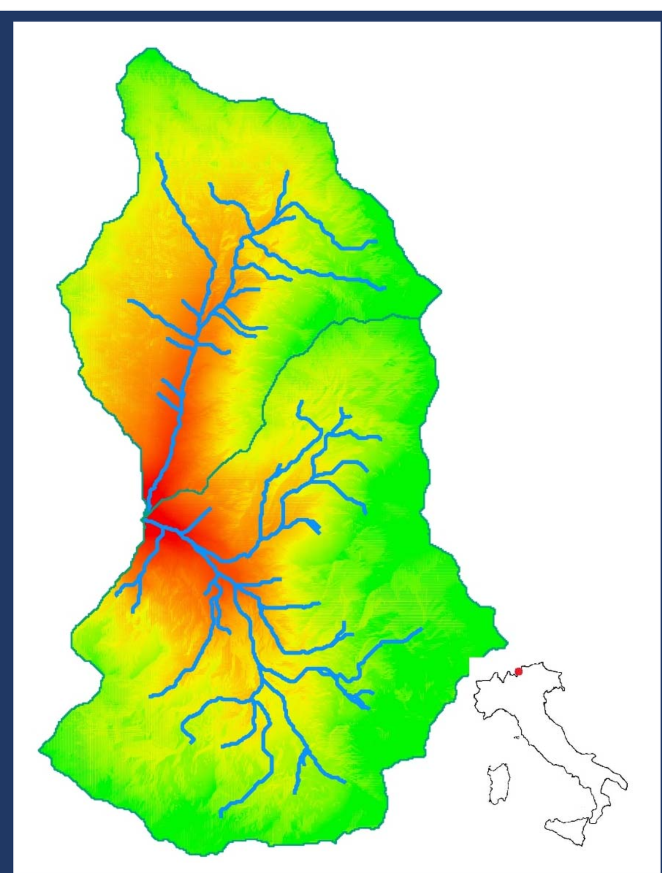
Application of EPM in a distributed form through a properly developed algorithm in GIS environment:

- extraction of topologic and geomorphological information from a DTM;
- local application of the model equations moving from link to link within the space filling drainage network and following the same direction of the runoff on the surface.

4. Test case in alpine area

Two small catchments in Alta Valtellina (Northern Italy) were studied in order to assess the performances of EPM in Alpine areas. Most of the water of these basins, drained respectively by the Cedec and Frodolfo torrents, are stored in a small barrage at the confluence (2167 m a.s.l.) and then diverted for hydropower purposes. While the coarser sediment fraction is mostly stopped at the barrage by trap basins, the fine fraction flows towards the diversion structures. The assessment of the local temperature in each cell was based on a -0.004 °C/m gradient, while the precipitation value was assumed constant on the basin.

	Parameter	Frodolfo Basin	Cedec Basin
Morphological parameters	Area (m^2)	29.1	17.8
	Mean slope (m/m)	0.49	0.48
	Mean altitude (m a.s.l.)	3019	2909
	Maximum altitude	3800	3800
Hydrological parameters at the outlet (2167 m a.s.l.)	Mean annual temperature (°C)	1.7	1.7
	Mean annual rainfall (mm)	944	944
	May to October mean temperature (°C)	7.5	7.5
	May to October rainfall (mm)	656	656
Corine Land Cover	Bare rocks (3.3.2) (%)	33.2	46.3
	Glaciers and perpetual snow (3.3.5) (%)	57.5	28.7
	Natural grasslands (3.2.1) (%)	0.1	1.3
	Sparsely vegetated areas (3.3.3) (%)	9.2	23.4
Geology	Hard rock masses (%)	4.5	4.3
	Weak rock masses (%)	27.7	22.0
	Coarse soils (%)	0.63	0.8
	Poorly sorted soils (%)	2.3	5.8
	Fine and medium soils (%)	19.7	50.6
	Glaciers (%)	44.8	16.2
Active erosion processes	Rockfalls (%)	1.9	4.5
	Avalanches (%)	3.7	4.4
	Rill erosion (%)	2.5	15.5



5. Results and conclusions

Granulometric analyses of sampled soils allowed to estimate a content of fine particles (d< 0.15 mm) of 45%.

Accordingly, a volume of fine sediment eroded soil of 15400 m^3/y can be estimated for these basins, to be compared to a volume of suspended sediment of 18000 m^3/y measured at the barrage.

The difference between lumped and distributed approach is about 2.5% and in some cases it might grow up to 10%

References

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