MODPERL - A NEW ROMANIAN MODEL FOR GULLY EROSION PREDICTION

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Abstract: Among different types of land degradation which affects the Romanian agricultural lands on slopes, soil erosion and in particular gullies have a relatively big proportion, both by their area of manifestation and by the major damages caused to different economical sectors, especially to agriculture.
In Romania, S. Mircea has studied for many years time the evolution of several gullies located on agricultural lands, from one of the most affected area in the country, both by surface and gully erosion and landslides as well, the Carpathian Curvature area. As a result, a new deterministic model for the gully erosion prediction in length has been developed. In comparison with the other prediction models mentioned above, which do not always take into account all the factors of risk, this model takes into account the contribution of almost all the factors which contribute to the gullies development, such as: maximum flow at the gully head cut (q), soil characteristics (C, U), geometric characteristics of gully (h_v, i_{fv}) and the presence of erosion control works in the gully's watershed (C_s), especially on the headcut's watershed.
This new model, having almost the general structure like the very well known USLE equation (Universal Soil Loss Equation, Wischmeier & Smith, 1978), has been called in Romanian language as MODPERL (MODel of Evolution Prediction in Length of Ravines), and has the following equation: R_{ar} *(m/year)* $= [a + (b \cdot q_{10\%} + c \cdot h_v + d \cdot i_{fv})]\ C \cdot U \cdot C_s$
Keywords: gully erosion, prediction model, catchment, independent variables.

EIN NEUES RUMAENISCHES MODELL UEBER DIE PREDICKTION DER ENTWICKLUNG DER EROSIONSGRABEN

Zusammenfassung: In Rumaenien S. Mircea hat ein neues Modell ueber die Predicktion der Entwicklung der Erosionsgraben bearbeitet. Der Modell wird MODPERL genannt, und ist aenlich USLE (Die Universelle Ekuation der Erosion).
Die Struktur der Modell, nimt im Rechnung fast alle Faktoren die bei der Erosion teilnehmen, und hat die Form: R_{ar} *(m/year)* $= [a + (b \cdot q_{10\%} + c \cdot h_v + d \cdot i_{fv})]\ C \cdot U \cdot C_s$
Schlusselworte: Erosionsgraben, Modell ueber die Predicktion, Unabhaenige Varabel.

1. Introduction

Gully erosion phenomena affect an important part of the Romanian territory. The most significant gullies in the country are the torrents and ephemeral and permanent gullies that are present in several locations, inducing important damages to the agricultural lands, human settlements and socio-economic units. Generally speaking, soil erosion annually generates about 36 million tons of alluvia, with annual losses of lands estimated at about 2300 ha (Motoc, 1999).

As it is known, the gullies evolvement on the three main directions, in length, breadth and depth, having an immediate impact on the lands and on environment as entire both on short and long term. These effects could be quantified through specific stage and risk indicators, contributing in this way to the general assessment of the river basin vulnerability for gully erosion.

Gullies length's evolution is becoming therefore more and more important. To better predict of the rate of gully headcut movement, there have been developed in time several specific determinist models, out of which can be mentioned the followings: Thompson (1964), Seginer (1966), Soil Conservation Service (1977), Sueddon (1985), Temple (1992),

Ichim & Radoane (1994, 1998). Most of the models have been in general presented as regressions (simple and multiple correlations), using the following independent variables:
- the catchments area at the gully head-cut;
- terraced area, out of the total catchments area at the gully's head-cut;
- annual rainfall measured at the gully head-cut catchments;
- soil features (content of clay) at the gully head-cut;
- gully's length at a certain moment;
- distance and relief energy between the gully's head-cut and the highest altitude in the river basin;
- valley's slope upstream of gullies' head-cut.

It has been determined that the gully evolution's rate in length varies very much from a region to another, as well as within the same area. According to the researches developed in the world so far, it has been resulted that the gully evolution rate covers a very wide range of values. For example, in Tajikistan, in conditions of irrigated crops, the value is of about 674.7 m/year while in natural conditions (soil covered with natural vegetation) the measured value is of about 1.4 – 82.5 m/year in the same region. In Israel, the average rate of gully headcut movement is about 8.5 m/year (Seginer, 1966), and in India it reaches values between 0.6 – 1.0 m/year (Haigh, 1984). In Romania, the annual rate of gully headcut movement varies as follows:
- Colinele Tutovei region, 0.5 – 2.0 m/year (Motoc et al., 1979);
- Buzau, in the Curvature Carpathians region, 1.4 – 5.4 m/year (Mihaiu, 1980), and respectively 1.75 – 6.70 m/year (Mircea, 1999);
- Barlad Plateau region, 12.5 m/year (Ionita, 1998), etc.

In 1993, the Romanian researchers of the "Stejarul" Laboratory in Piatra Neamt, have developed a statistical model corresponding to the Moldovenesc Plateau Region. The model is a multiple regression type, meant to evaluate the rate of gully headcut movement. The study has been run on 38 ephemeral and permanent gullies, having in general the catchments smaller than 10 ha.

2. Localization of the researches and short characterization of the gullies studied

The study was carried out in one of the most affected area by surface and gully erosion and landslides in Romania, Buzau County, being located in the South-Eastern part of the country. This is the main part of the Subcarpanthians Curvature region where the soil losses reach about 30-45 tons/ha/year, coming mainly from surface and gully erosion. The agricultural lands located on the slopes cover about 35% from the total surface of the County. The gullies represent about 1000 km, which actually cover a surface of about 1000 hectares. In fact it can be said that in this region all the valleys are affected in different degrees by gully erosion, mainly located on the valley's thalwegs. More specifically, the study was carried out on 11 gullies located in the most representative subcatchment of the region from gully erosion point of view, the Slanic River Basin. This subcathment is a tributary of the Buzau River and the gullies taken into study have been located in the medium and lower sectors of the Slanic River catchment. Some of the main morphological characteristics of the studied gullies are presented in the table no 1 below.

From the climatic point of view the area taken into study is characterized by an average multi-annual amount of rainfalls during the vegetation period (April – September) of about 350-400 mm and the maximum 15-minutes rainfall intensity (I_{15}) of about 1.2-1.5 mm/min.

Regarding the pedology, there are different types of soil in the area, but mainly there are cernozioms and pseudorendzines.

As regard to the land use and vegetation from the gullies catchments, there are mainly agricultural lands, covered by crops, grasslands, vineyards and orchards. The forests are present especially along the gullies riverbanks, contributing to their stabilization.

*Table 1. M*orphological characteristics of the studied gullies in Slanic basin (in 1989 year)

No crt.	Gully	*Total gully watershed (ha)*	*Gully's headcut watershed (ha)*	*Gully length (m)*	*Average slope of thalwegs (%)*
0	1	2	3	4	5
1	Draghici	377.50	4.50	2748	9.1
2	Oarzei	90.00	20.25	1372	8.3
3	Irimesti	86.25	2.56	1702	4.6
4	Caldaresti	198.73	9.37	2950	8.0
5	Vladului	98.73	23.45	1375	9.8
6	Plutesului	120.50	23.25	1552	8.6
7	Galbeaza	101.70	7.54	1674	11.7
8	Balaurului	288.12	14.06	3786	5.4
9	Mereului	86.25	35.00	1423	8.7
10	Tatarului	51.25	15.75	900	11.4
11	Funduri	92.85	28.85	892	10.5

3. Development of gully erosion prediction model

The study has covered a period of more than 25 years of data recordings, taken in two different stages of gullies' development, in the 1962 and1989 years.

A large amount of topographical and photogrammetric materials were studied for this period of time as well as several topographical measurement were carried out in 1997 on some gullies.

In collaboration with M. Motoc (1999), the following aspects have been considered for the development of the model's structure:

- there were chosen the independent variables, determined from direct measurement performed in the field; for several situations, information available within the existing literature has been used;
- the specific access flow and valley slope were considered as important factors for defining the stream energy. The $q_{10\%}$ flow has been considered the origin flow (initiating the gullies), because the gullies evolution is generated by flows significantly higher than in the ones involved in the river cases;
- the depth at the gully headcut has been considered as an important factor influencing the evolution of the erosion movement;
- valley's slope upstream of the gully head-cut that influences the water velocity and the length of the waterfall;
- the influence of the C, U, C_s factors has been established based on the available data within the literature.

As a result of the study it has been determined the head-cut gullies' annual rate of movement on the basis of a deterministic model. Comparing to the other known models, this prediction model, that was called MODPERL, considers among the other factors, the hydrological factor as well that is represented by the specific access flow at the gully head-cut. The obtained deterministic model takes into account the factors generating the gully length evolution at the head-cut has the following equation:

$$R_{ar} = [a + (b \cdot q_{10\%} + c \cdot h_v + d \cdot i_{fv})]\ C \cdot U \cdot C_s \quad (1)$$

where R_{ar} is the annual rate of the gully head-cut movement (m/year), q is the specific access flow at the gully head-cut, h_v is the gully's depth at the head-cut, i_{fv} is the valley slope upstream of the gully's head-cut, C is a coefficient of correction function of soil erosion vulnerability (0-1), U is a coefficient of correction function of soil moisture at the gully's head-cut movement section (<1), C_s is a coefficient of correction function of existing land reclamation works on the gully's head-cut catchments (0-1).

The dependent variable R_{ar} has established as corresponding to the period between 1962 and 1989 using mainly the topographical maps and direct observations and measurements in the field.

To determine the independent variables q, h_v and i_{fv}, the multiple correlation method has been used, while the C, U and C_s factors have been established using the indexation methodology.

After calibrating and testing the model, it has been established that the specific flow at the gully's headcut has a major influence on the rate of gully headcut movement, while the variables h_v and i_{fv} have a smaller impact, as follows:

$$R_{ar} = [1.08 + (7.02 \cdot q'_{10\%}/q''_{10\%} + 0.15 \cdot h_v + 0.06 \cdot i_{fv})]\ C \cdot U \cdot C_s \qquad (2)$$

In this model the variable $q'_{10\%}/q''_{10\%}$ represents the ratio between the specific access flow at the gully head-cut, corresponding to the following moments:

- $q'_{10\%}$ corresponds to a gully head-cut position estimated at a certain moment in the past, depending of the available records, in this case for 1962 year;
- $q''_{10\%}$ corresponds to the gully head-cut position existing at the analyzing moment, in this case for 1989.

A centralization of the dependent and independent variables for setting up of the prediction model is presented in the table 2 below.

Table 2. Centralization of the data needed for setting up of prediction model

No crt.	Gully	R_{ar} measured (m/year)	q'62 /q'89	h_v (m)	i_{fv} (%)	C	U	C_s	CUC_s	R_{ar} predicted (m/year)
0	1	2	3	4	5	6	7	8	9	10
1	Draghici	2,65	1,11	2,35	12,3	0,7	0,7	0,4	0,196	1.98
2	Oarzei	4,35	2,24	1,50	9,5	0,6	0,7	0,6	0,252	4.50
3	Irimesti	6,70	3,37	1,00	10,6	0,6	0,7	0,6	0,252	6.52
4	Caldaresti	2,45	1,31	2,45	21,6	0,7	0,6	0,5	0,210	2.53
5	Vladului	2,15	1,15	2,90	15,3	0,7	0,7	0,5	0,245	2.59
6	Plutesului	2,75	1,10	3,10	14,7	0,7	0,7	0,5	0,245	2.51
7	Galbeaza	6,15	7,63	0,90	20,1	0,35	0,7	0,5	0,122	6.92
8	Balaurului	5,75	2,79	1,30	15,8	0,3	0,7	0,6	0,126	2.78
9	Mereului	2,25	1,33	1,70	12,5	0,7	0,7	0,6	0,294	3.39
10	Tatarului	2,15	1,57	3,30	10,3	0,6	0,6	0,4	0,144	1.92
11	Funduri	1,75	1,34	1,20	14,7	0,5	0,7	0,5	0,175	2.04

4. Conclusions

The results obtained using this deterministic prediction model have been statistically validated by comparing the annual rate of gully headcut movement both measured on the maps and direct in the field and predicted as well. The measured and predicted values of the annual rate of gullies' headcut movement are very similar, the correlation coefficient obtained for this model is a very high one, having the value of $r = 0.976$.

5. References

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