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Predicting of Soil Loss in the Tisovec Catchment, Slovakia

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Soil erosion is a major form of land degradation and has been recognized as a severe environmental problem since late 18th century. In Europe soil erosion affects large areas and it is estimated that about 17 % of the total land area is affected. Sediments, originated by erosion, cause silting of water basins and they also affect water quality in reservoirs because they play an important role by being the ultimate sink of pollutants.
Nowadays, it should be rather a preference to predict the erosion and its control. There are a lot of mathematical models for predicting of reservoir sedimentation. The most widely accepted and utilized empirical model for prediction of water erosion hazards throughout the world is Universal soil loss equation (USLE), developed by Wischmeier and Smith, which computes the average annual soil loss as the product of six major factors whose most likely values at a particular location can be expressed numerically.
This paper is focused on the soil loss calculation using the USLE in the Tisovec catchment situated in the east of Slovakia, with emphasis on the suggestion of the crop/vegetation and management factor (the C factor) calculation, which is related to the land-use and represents the ratio of soil loss from a given vegetal cover. The determination of the average annual C factor is divided into five periods for each of the main periods of the cropping cycle. In accordance with the suggested calculation the total average annual soil loss from the arable land and also soil loss from the whole watershed of the Tisovec river is determined.

1. Introduction

Land degradation and soil erosion as one form of soil degradation are important global issues because of their adverse impact on agronomic productivity (Kettl et al., 2010), the environment, and their effect on food security and the quality of life. During the last 40 years, nearly one-third of the world's arable land has been lost by erosion and continues to be lost at a rate of more than 10 million hectares per year. Each year, 75 billion metric tons of soil are removed from the land by wind and water erosion, with most coming from agricultural land (Pimentel et al., 1995). In Europe, 12 % of the soil is threatened by water erosion and about 4 % by wind erosion. In Slovakia soil erosion belongs to most frequent soil degradation processes and is mainly due to water (39.7 %) and to a lesser extent to wind (5.5 %).
For soil erosion risk assessment there are a large variety of models in the literature (Engel et al., 2004). One of the most widely applied empirical models for assessing erosion is the Universal Soil Loss Equation (USLE), developed by Wischmeier and Smith (1978), that was created for use in selected cropping and management systems. In this equation, six major factors are used to calculate the soil

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loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages. The most important parameter in USLE equation is the cover management factor (C factor) that represents effects of vegetation canopy and ground covers. The C factor reflects the effect of cropping and management practices on the soil erosion rate. The method described by Wischmeier and Smith allows for the determination of C factor values for the crop rotations and management practices found in the USA. For other countries, the detailed information for computing the C factor in this way is scarce (Gabriels, 2003).
This paper summarizes the soil loss calculation in Tisovec catchment situated in the east of Slovakia, with emphasis on the suggestion of the C factor computation.

2. Material and methods

This case study was realized in the Tisovec river catchment, located in the east of Slovakia, in Bardejov district. The area of this watershed is about 6.0 km^2 with annual average discharge 0.045 m^3/s. In followed watershed, the Klusov-Hervartov reservoir is located at an altitude of 343 meters above sea level. Average depth of this reservoir is 3.5 m, surface area 2.2 ha and its total capacity is about 72,000 m^3. It was built for fishing, irrigations, recreation and for retention of high water.
The average annual rainfall in the study area is about 670 mm, with maximum in summer months. The mean annual temperature is about 8 °C with a maximum of 20 °C in the month of July and a minimum of -3 °C in January. Majority of land has slope more than 8 %. In general, soil types of the watershed are planosols, cambisols and albic luvisols. From the soil texture point of view, medium heavy soils (sandy loam) occur in this area. And according to the content of skeleton in the soil, slightly stony soils lead. The land use of the catchment was found to be mixed type. The upstream part and middle part of the Tisovec catchment is an area mainly covered with forest (39.2 %) and pastures (21.7 %), while the lower part is an arable land (21.4 %) used for cereals (spring barley, winter wheat), corn silage and winter oilseed rape growing. The rest of the land area is used for other purposes.
Soil loss from the arable land in the Tisovec river catchment was computed based on the particular crop rotations in the followed catchment during 10 years (1998-2007) using the USLE equation recommended by Slovak legislation (Ministry of Environment of the Slovak Republic, 2004). It computes the average annual soil loss for a given plot as the product of six major factors (Wischmeier and Smith, 1978):

$$G = R \times K \times L \times S \times C \times P \quad (1)$$

$G_{r,i}$ – represents the potential long term average annual soil loss in tons per hectare,
R – the rainfall and runoff factor by geographic location in MJ cm/ha hr,
K – the soil erodibility factor in t ha hr/ha MJ mm,
L,S – the length slope gradient factor,
C – the crop/vegetation and management factor,
P – the support practice factor.

3. Results and discussion

The factors for soil loss calculation in the Tisovec catchment were determined subsequently. The average annual R factor, representing the erosivity of the climate at a particular location, was determined for investigated area according to statistical values obtained from historical weather records derived by Fališek (1990) for Bardejov station. It represents R = 22.43 MJ cm/ha hr. The determination of the K factor was based on the soil textures which exist in the Tisovec river catchment by using the code of the relevant evaluated soil-ecological unit for each plot individually (Linkeš et al., 1996). The LS factor used in the USLE considers the effect of topography on erosion and it is an essential parameter to quantify the erosion generated due to the influence on surface runoff speed. It was determined separately based on the map at a scale of 1:10,000 for each outflow profile (Figure 1).

The C and P factors are related to the land-use and are reduction factors to soil erosion vulnerability. These factors express the ratio of soil loss from a given vegetal cover, support practice**,** type of soil and slope and they also represent the conditions that can be easily changed to reduce erosion. Therefore, it is very important to have good knowledge concerning land use in the basin to generate reliable C factor values. The C factor resulting from this calculation is a generalized C factor value for a specific crop that doesn't account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country. Because erosion varies according to the height of plant cover from the ground, also the C factor changes as the plants grow and the state of the soil surface alters.

Figure 1: Outflow profiles in the Tisovec catchment

For lack of information about land use within followed watershed, the C factor was accurately calculated for two units (plots 1004/1 and 2001/1) of arable land situated in the neighbourhood of the reservoir in the Tisovec catchment. The reason of this hypothesis is the fact, that the Tisovec catchment falls from the farmed land point of view to Klusov agricultural cooperative, where all plots have similar soil characteristic, especially topographically characteristics and cover crops and management.

In our study, the average annual C factor for crop rotation in followed watershed ($C_{VP,watershed}$), used in USLE equation, was determined as a weighted mean of C_{P1} and C_{P2} values, given for two plots (P1 – 1004/1 and P2 – 2001/1) of arable land located in the vicinity of reservoir. The crop rotations for two followed plots are given in Table 1.

For more accurate calculation, the average annual $C_{r,i}$ factor in *i*-year for followed plots were computed as a sum of corrected partial values by Wischmeier and Smith divided into five periods for each of the main periods of the cropping cycle (rough fallow, seedling, establishment, growing and maturing crop, residue or stubble field) according to equation (Antal, 2005):

$$C_{r,i} = \sum_{i=1}^{5} C_i . \Delta R_i \qquad (2)$$

$C_{r,i}$ – the average annual C factor in *i*-year for followed plot,

C_i – tabular value of C factor by Wischmeier and Smith pertaining to crop in *i*-cropping period,

ΔR_i - redistribution of R factor in corresponding *i*-cropping period.

The partial C values for each land use of two followed plots in the vicinity of reservoir divided into five cropping periods and also the average annual C factor in *i*-year for followed plots calculated using the equation (2) can be found in Tables 2 and 3. Numbers 0 (zero) given in this tables mean that it isn't assumed soil loss in these particular cropping periods in calculation.

Table 1: Crop rotations for plots 1004/1 and 2001/1 during 10 years

Year	Crop	
	Plot 1004/1	Plot 2001/1
1998	winter oilseed rape	corn silage
1999	triticale	spring barley
2000	corn silage	triticale
2001	winter wheat	winter oilseed rape
2002	winter oilseed rape	triticale
2003	winter wheat	pea
2004	potatoes	winter wheat
2005	winter wheat	spring barley
2006	spring barley	winter rye
2007	winter oilseed rape	winter oilseed rape

The average annual C factor for crop rotation in followed watershed ($C_{VP,watershed}$), used in USLE equation and determined as a weighted mean of C_{P1} and C_{P2} values presents 0.277 (see Table 4). In work (Junakova and Balintova, 2011a) also partial soil loss in individual cropping periods for mentioned plots is given. The P factor was considered 1.0. The values of all factors used in USLE (1) are shown in Table 4 except R and P factors, which values are the same in the whole catchment (R = 22,43 MJ cm/ha hr; P = 1). This table also shows the results of the total average annual soil loss from the arable land in the Tisovec watershed. The total soil loss from the arable land in the Tisovec catchment is approximately 2027 tons per year. Soil loss from the whole of the followed catchment is given in Table 5 and represents 1559 m^3/year.

The method of the crop/vegetation and management factor determination has been verified based on the calculation of sediment yield in the Klusov-Hervartov reservoir in (Junakova and Balintova, 2011b). Based on the specification of the USLE calculation using the detailed C factor computing it is possible to calculate not only soil loss from the agricultural areas but also sediment yield from the watershed to the Klusov-Hervartov reservoir.

Information on sediment yields is generally important in maintenance of stream channels and particularly water reservoirs due to its sedimentation and subsequently desilting possibly dredging of sediments and its utilization (Junakova and Balintova, 2011c).

Table 2: The C factor in individual cropping periods by Wischmeier and Smith for plot 1004/1

Crop/year	Ci x ΔRi					$C_{r,i}$
	Cropping period					
	1.	2.	3.	4.	5.	
Winter oilseed rape 1998	0.137	0.069	0.005	0.044	0.028	**0.284**
Triticale 1999	0.198	0.013	0.003	0.057	0.028	**0.299**
Corn silage 2000	0.125	0.128	0.196	0.200	0.000	**0.649**
Winter wheat 2001	0.000	0.001	0.002	0.064	0.003	**0.070**
Winter oilseed rape 2002	0.072	0.049	0.004	0.046	0.028	**0.199**
Winter wheat 2003	0.192	0.007	0.002	0.054	0.028	**0.282**
Potatoes 2004	0.141	0.053	0.161	0.202	0.000	**0.557**
Winter wheat 2005	0.001	0.005	0.003	0.052	0.028	**0.089**
Spring barley 2006	0.153	0.035	0.088	0.031	0.008	**0.314**
Winter oilseed rape 2007	0.137	0.082	0.006	0.042	0.029	**0.295**
Average (C_{P1})						**0.304**

Table 3: The C factor in individual cropping periods by Wischmeier and Smith for plot 2001/1

Crop/year	Ci x ∆Ri Cropping period 1.	2.	3.	4.	5.	$C_{r,i}$
Corn silage 1998	0.010	0.065	0.188	0.229	0.001	**0.492**
Spring barley 1999	0.002	0.004	0.033	0.052	0.005	**0.095**
Triticale 2000	0.104	0.071	0.004	0.054	0.003	**0.236**
Winter oilseed rape 2001	0.052	0.147	0.009	0.046	0.028	**0.283**
Triticale 2002	0.183	0.015	0.003	0.053	0.028	**0.282**
Pea 2003	0.146	0.030	0.079	0.033	0.028	**0.316**
Winter wheat 2004	0.155	0.011	0.002	0.078	0.002	**0.248**
Spring barley 2005	0.009	0.015	0.049	0.043	0.028	**0.142**
Winter rye 2006	0.134	0.012	0.003	0.051	0.033	**0.233**
Winter oilseed rape 2007	0.130	0.014	0.004	0.041	0.029	**0.218**
Average (C_{P2})						**0.254**

Table 4: Soil loss from the arable land in the Tisovec catchment

Profile	Plot	Profile area	Length	Slope	K factor	LS factor	$C_{VP, watersh.}$ factor	G	G
		[ha]	[m]	[%]	[t ha hr/ ha MJ mm]	[-]	[-]	[t/ha/year]	[t/year]
1	1004/1	15.63	388	8.80	0.30	4.059	0.277	7.57	118.29
2	2001/1	18.46	980	10.49	0.30	8.375	0.277	15.61	288.21
3	3003/1	3.53	180	10.17	0.40	3.424	0.277	8.51	30.04
4	3005/1	3.06	200	8.87	0.35	2.947	0.277	6.41	19.62
5	2003/1	16.84	708	10.97	0.35	7.617	0.277	16.57	279.01
6	3101/1	35.36	786	10.37	0.39	7.367	0.277	17.86	631.39
7	2203/2	35.58	900	13.54	0.25	11.944	0.277	18.56	660.23
Total		**128.46**							**2026.79**

Table 5: Soil loss in the Tisovec catchment

Land use	Area F	G	G*
	[km^2]	[t/year]	[m^3/year]
Arable land	1.285	2026.79	
Permanent grass	1.301	0	
Forests	2.352	0	
Build up areas	0.458	0	
Water areas	0.270	0	
Other areas	0.335	0	
Total/average	**6.000**	**2026.79**	**1559**

Note: *An average sediment bulk density is considered 1.3 t/m^3.

4. Conclusion

This contribution summarizes the results of the study focused on the soil loss determination in the Tisovec catchment situated in the east of Slovakia, where soil loss is computed using the Universal Soil Loss Equation developed by Wischmeier and Smith.

Because the crop/vegetation and management factor (C factor) resulting from this calculation is a generalized C factor value for a specific crop that doesn't account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country and erosion varies according to the height of plant cover from the ground, we have suggested to specify the USLE calculation with the correcting of the average annual C factor in our study. The average annual C factor is divided into five periods for each of the main periods of the cropping cycle (rough fallow, seedling, establishment, growing and maturing crop, residue or stubble field). In accordance with this suggested calculation we have determined the total average annual soil loss from the arable land and also soil loss from the whole watershed of the Tisovec river. The average annual soil loss represents approximately 2026 tons.

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