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Assessment and Maping Soil Erosion Risk in the Watershed of Sedelska River

Eli Pavlova-Traykova*

Forest Research Institute – Bulgarian Academy of Sciences,
132 "St. Kliment Ohridski" Blvd.1756 Sofia, BULGARIA
*Corresponding author: pavlova.eli77@gmail.com

Abstract. The geographical features of Bulgaria such as steep slopes, rugged terrain, and unregulated forest activities, and easily susceptible to erosion soils are considered as main reasons for the erosion processes we observe. One of the most affected region from soil erosion in the country is the Struma River watershed. Sedelska River is one of its torrential tributaries, part of its middle reaches. On the territory of Sedelska River erosion control activities have been conducted in the past, but there are still signs of erosion in the watershed. The study aims to assess potential and actual soil erosion risk in forest territories and to determine the spatial distribution of them. The total assessment in the Sedelska River is "low to moderate" potential soil erosion risk and "very low to low" actual soil erosion risk. Part of the territories, mainly around the first grade tributaries are with "moderate to strong" risk of erosion, which showed the prerequisite for bank erosion in the watershed and the need for sustainable management practices.

Key words: soil erosion, risk assessment, Sedelska River.

Introduction

Natural hazards become more severe with each passing year. This situation brings a negative impact on all terrestrial ecosystems, where among the most affected are forests. According to many authors they are recognized as highly sensitive and vulnerable to changes in environmental conditions (Grabherr et al., 2000; Michelsen et al., 2011; Kozyr 2014; Takur et al., 2021). As in the definition of vulnerability meant that a variety of elements, including sensitivity and lack of capacity to cope and adapt (IPCC, 2014). Although in themselves they are vulnerable, the forest plays a key role in soil protection (Meléndez-Pastor et al., 2017).

Soils are a limited natural resources and considered the biggest threat to them is soil erosion. This environmental problem occures in all parts of the terrestrial world. It is a constant process, which can be very intensive if there is a combination of adverse factors. Another important thing about soil erosion is that we commonly are aware of the consequences only when it could be too late or too expensive to solve it (Spalevich et al., 2020). For that reason methods for assessing soil erosion risk are applied. In general, these erosion methods are mathematical descriptions of the relationships between the amount of eroded soil and erosion factors. The most famous model used is the Universal Soil Loss Equation (USLE) developed by Wishmeier & Smith (1978) and those derived from it. Nowadays models used the potential of Geographic Information Systems (GIS), which give us an opportunity to establish territories at risk and gives accurate information which could be easily used by decision-makers to mitigate negative consequences by applying appropriate silviculture and agriculture practices and if it is needed to conduct erosion control activities.

For Bulgaria, one of the most affected by soil erosion territories is the watershed of Struma River. In the watershed many factors influence, but the most significant are steep slopes (Martensson et al., 2001) and easily prone to erosion soils. In the past most of the forest territories in the watershed are cut down by locals to make places for pasture. This activity greatly worsened the condition of the forest and reduce its potential.

In some tributaries of the Struma River, in the upper part of its watershed a methodology for potential and actual soil erosion risk in forest territories is applied (Pavlova-Traykova & Marinov, 2018; Pavlova-Traykova, 2019) and the received results are comparable with the results received by applying other models for soil erosion risk assessment. In the middle part of Struma, where our object of investigation – Sedelska River is situated, this methodology is also chosen to be applied. Through its application we will also track the change in risk levels since the application of similar methodology 20 years ago (Marinov et al., 2002).

The purpose of the investigation is to assess potential and actual soil erosion risk in the forest territories in the Sedelska River watershed and to establish and mapped the territories according to the degrees of risk.

Material and Methods

The object of investigation is Sedelska River catchment area (Fig. 1), which is the right tributary of Struma River and its catchment area cover 50.2 km^2 of the eastern slopes of Maleshevska Mountain (Marinov, 2014). Despite erosion control activities like afforestation and limitation of pasture and unregulated activities in the forest, the current ecological situation in the watershed showed that about 30% of forest territories are under bad ecological conditions (Marinov, 2014). Most of these territories are in the belt up to 600 m. For the period 2071-2099, it is expected more than 50% of these territories to become under bad ecological conditions (Marinov, 2014).

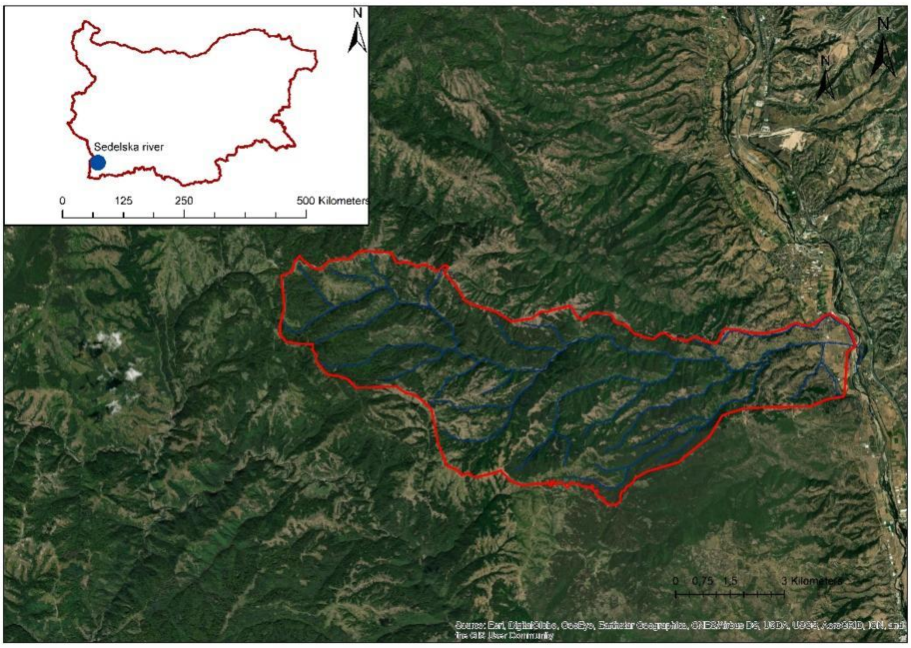

Fig. 1. Location of Sedelska River watershed.

In the present investigation, an assessment of potential and actual soil erosion risk was made only for forest territories, applying part of the "Methodology for preparing the national long term programme for protecting from erosion and flooding in the forest lands" (Marinov et al., 2009). An adapted version of methodology of MERA project is used (Stoev et al., 1997). The steps for assessment of potential and actual soil erosion risk have been precented in details in some other investigations (Pavlova-Traykova et al., 2017; Pavlova-Traykova & Marinov, 2018; Pavlova-Traykova, 2019). Some of the factors are directly taken from the Forest management plan of Strumyani. The subsection is the basic unit of area.

Precipitation influence on soil erosion development is assessed with rainfall erosivity index (R factor). All forest territory with altitude of 1000 m a.s.l. have annual index of erosion 1 (600 MJmm/hah), from 1000 to 1200 m a.s.l. – index 2 (601 – 1000 MJmm/hah), and over 1200 m a.s.l. are with rainfall index 3 (1001 – 2000 MJmm/hah) (Rousseva et al., 2010).

Soil index (*Is*) is obtained by multiplying the class according to the degree of erosion and class according to the type of erosion from forest management plans and are divided into three soil indexes– 1 (with value 1), 2 (with value 2 or 3) and 3 (with value 4 and 6). In case there are no data in forest management plans about bare area, about areas not suitable for forest barrens and areas without information for degree and type of erosion, soil index (*Is*) of 2 is accepted, and for gullies, landslides and sliding - the soil index is 3.

Topography factor is classified in four indexes: 1 – to 10^o, 2 - 11- 20^o, 3 - 21 – 30^o and 4 – above 30^o.

Potential soil erosion risk is determine by multiplication of *R* factor, slope index and soil index. Potential soil erosion index is 1 when the value is less then 4, 2- when the values are from 4 to 9 and 3- when the values are above 9.

For influence of vegetation cover a data from forest management plans is used. Vegetation index 1 have crops and forest with density above 0.6, these with density 0.3-0.6- index 2, and open stands, not suitable for forest area, barrens, gullies, landslides and landslips - index 3.

Actual soil erosion risk is determined by multiplication of potential soil erosion risk index and vegetation cover index in six grade scale - from very low (index 1) to strong (index 6). Assessment for the forest territories in the watershed is determined according to the value from sum of "moderate", "moderate to strong" and "strong" actual soil erosion risk grade.

Result and Disscusion

The significant part of the area of Sedelska River watershed are forest territories. From 50.2km^2, 41.8km^2, are forests. The characteristics of the watershed are presented in table 1. The length of main River current is 18 km. The territories on sunny and shady exposure are almost with the same area and the flat territories are only 0.64 km^2.

Table 2 are presented the main factors for soil erosion risk. It is obvious from the results, that the factor that influenced potential erosion most is the slope index. Most of the forest territories are on steep slopes with degrees 21-30°. This is a prerequisite for easy transportation of eroded particles from slopes to River bed as a result of this water quality will be reduced (Montanarella et al., 2016; Lal, 2017) and infrastructure disruptions may occur. Slope index is considered as main for the entire watershed of Struma, part of which is Sedelska and separately some of its tributaries (Martensson et al., 2001; Pavlova-Traykova et al., 2017; Pavlova-Traykova, 2019; Pavlova-Traykova & Marinov, 2021).

Table 1. Characteristics of Sedelska River watershed.

	Main charcteristics	**Unit**	**Results**
Sedelska River watershed	Area	km^2	50.2
	Length	km	18
	Average altitude	m	774
	Average slope	o	20
	Slope	km^2	
	< 10 °		0.9
	11–20 °		10.3
	21-30 °		32.94
	>30 °		6.06
	Slope exposure	km^2	
	Sunny (S, SE, SW, W)		23.27
	Shady (N, NW, NE, E)		26.29
	Flat		0.64

Table 2. Area distribution of main soil erosion risk factors.

R factor	**Area, кm²**	**Soil index (Is)**	**Area, кm²**	**Slope index**	**Area, кm²**
1	38.52	1	30.39	1	1.34
2	4.29	2	6.34	2	8.3
3		3	6.08	3	29.96
				4	3.21
Total area	42.81		42.81		42.81

The potential risk of erosion is presented in Table 3. The predominant degree for potential soil erosion is "low", but there is a presence of almost 40% of territories with a "moderate" degree. This distribution allows making a final assessment of "low to moderate" potential risk in forest territories. For the total area of the watershed risk in 2002, it is established that 64% of the territory is with "strong" potential soil erosion risk (Marinov et al., 2002). These results are mainly because non-forest territories are included and also in 2002 forest territories are considered for almost 64% and now these territories are about 86%. Normally in the eroded objects, the non-forest territories are with worse soil characteristics which led to this assessment. The great advantage of forest vegetation is expressed in the fact that, at the same time as limiting erosion, it supplies a large amount of organic matter, which supports soil formation processes on these eroded terrains (Pavlova-Traykova et al., 2018).

From the spatial distribution of forest area, it is well presented that the territories with "strong" risk are mainly around the tributaries from first grade in the part of the watershed near Drakata village. This distribution is an indicator of the presence of strong bank erosion, which actually is established on field. A significant part of the watershed is with "moderate" erosion. If not well thought out proper management, in situation of climate change these territories could pass into next level of risk.

For assessment of actual soil erosion risk, the influence of vegetation is considered. The table 4 are presented the distribution by vegetation index. Most of the forest are with full protection from soil erosion - index 1, but 32% are with moderate protection, and some part of the forest is with poor protection.

In 2002, the assessment for actual soil erosion risk is "moderate to low" (Marinov et al., 2002), now after calculation (Table 5), the total assessment of actual soil erosion risk is assessed as "low to very low". This is probably the positive influence of forest vegetation, which was found to have increased its area. In the current assessment, there is the presence of territories in all degrees of risk, but their area in the higher degrees is not significant. However, it is necessary to pay attention to the territories in the 4th, 5th, and 6th degrees to avoid the risk of worsening their condition and reaching irreversible processes.

The spatial distribution of actual soil erosion risk is presented in Fig. 3. Some of the territories with actual risk concur with these with potential risk. It seems that the forest area above the Drakata village is not only with the potential of "strong" erosion, but actual erosion is also to the highest degree.

Table 3. Potential soil erosion risk at forest territories.

Potential soil erosion risk		Distribution of forest territories	
Index	Degree	Area, км^2	Area,%
1	Low	24.97	58.3
2	Moderate	16.37	38.2
3	Strong	1.47	3.4
Total		42.81	100

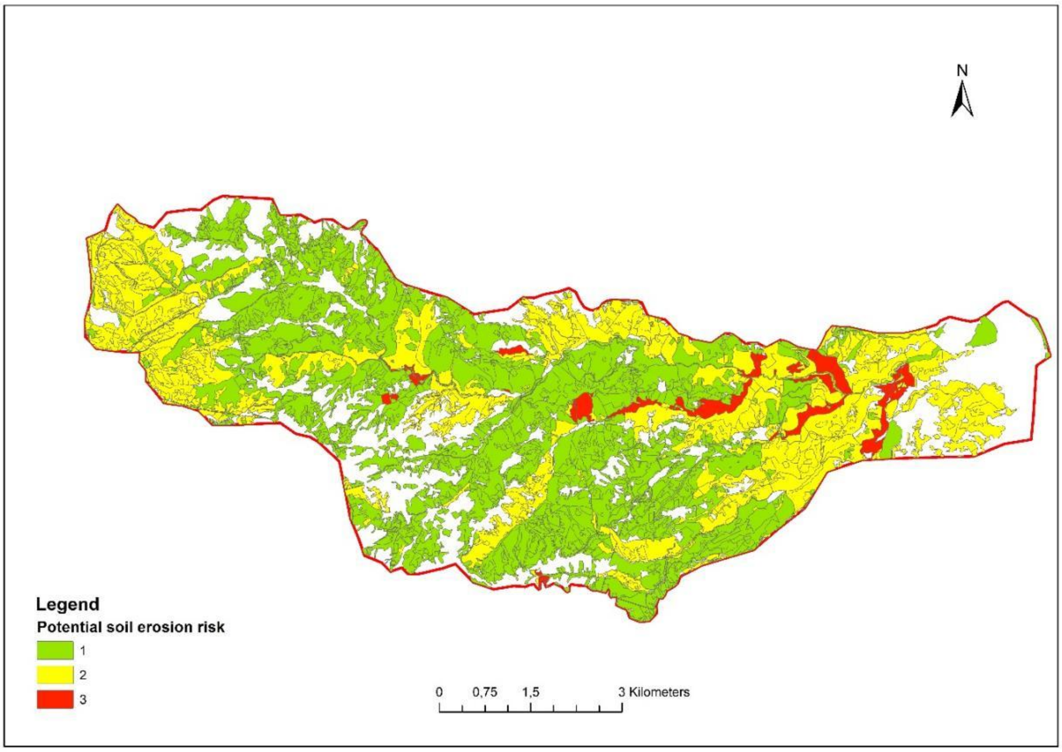

Fig. 2. Potential soil erosion risk at forest territories.

Table 4. Vegetation index.

Vegetation index	Area, кm^2	Area,%
1	22.87	53.42
2	13.71	32.03
3	6.23	14.55
Total	42.81	100

Table 5. Actual soil erosion risk on forest territories.

Actual soil erosion risk		Distribution of forest territories	
Index	Degree	Area, кm^2	Area,%
1	Very low	13.93	32.5
2	Low	16.34	38.2
3	Low to moderate	3.65	8.5
4	Moderate	4.95	11.6
5	Moderate to strong	3.84	9.0
6	Strong	0.11	0.2
Total		42.81	

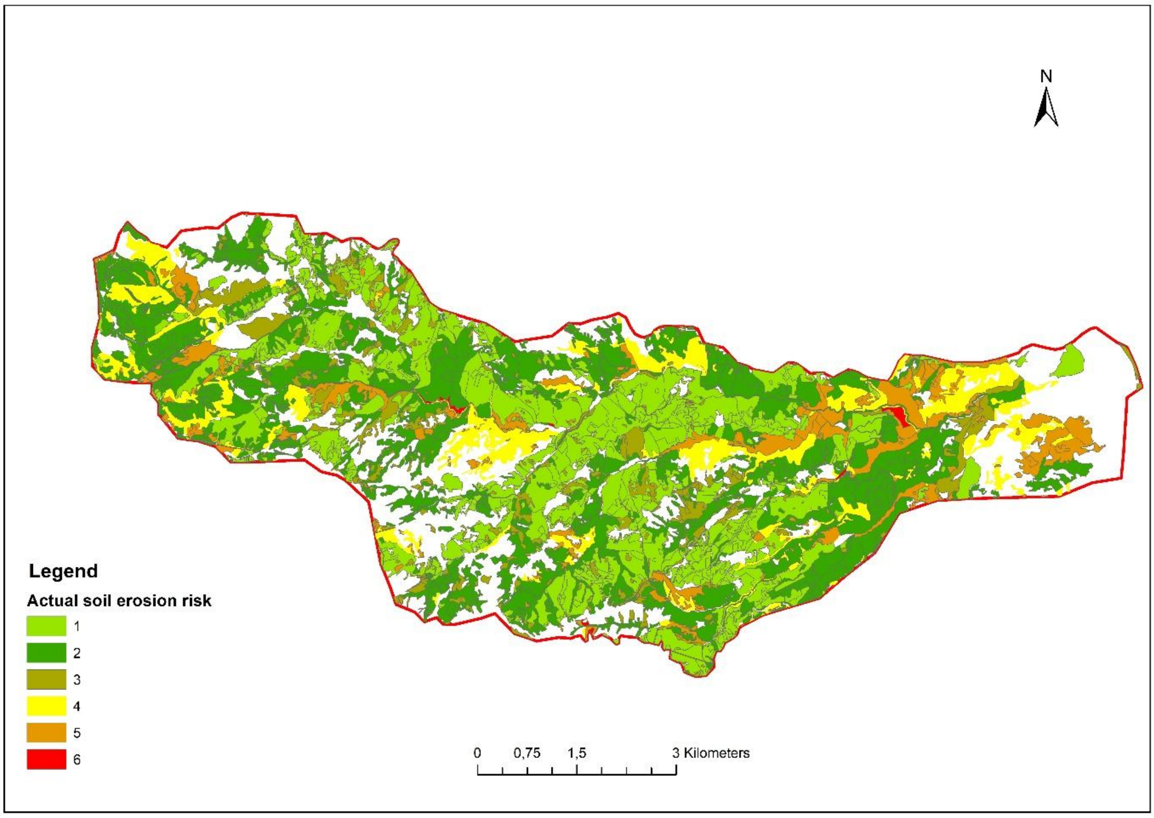

Fig. 3. Actual soil erosion risk at forest territories.

Conclusion

The main factor for erosion processes in the Sedelska River watershed is the topographical factor (steep terrain). The presence of territories assessed with "strong" risk indicates the need for additional erosion control activities. Attention should be paid to the coastal erosion and coastal stabilization activities should be undertaken.

In the case of improper management of the forest territories with risk of actual and potential erosion, they can easily pass into a stronger degree of risk.

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