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RESEARCH ARTICLE

Using the EPM method for the estimation of soil erosion in forest territories in the upper part of Dzherman River

Eli Pavlova-Traykova

Forest Research Institute, Bulgarian Academy of Sciences, 132, "St. Kliment Ohridski" Blvd.1756 Sofia, Bulgaria

Corresponding author: Eli Pavlova-Traykova (pavlova.eli77@gmail.com)

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Abstract

One of the most vulnerable to soil erosion parts in Bulgaria is the Struma river watershed. In the past, a lot of erosion control activities have been carried out in this catchment, but the topographic condition and easily prone to soil erosion soils are still redounding to erosion processes.

As a global problem with severe effects on the environment, soil erosion is on the agenda of scientific community. Because of difficult recognition on time, various methods for erosion risk and sediment loss assessment were applied. For mountainous watersheds one of the most appropriate approach is Erosion Potential Model (EPM).

The study aims to evaluate soil erosion and investigate its spatial distribution by applying EPM, also known as Gavrilovic method. The object of investigation is the upper part of the Dzherman river, which is tributary of Struma river. The method was implemented only for forest territories to determine the most vulnerable part of the forest. The results showed that for the forest territories the average value of the coefficient Z is 0.19, which defines erosion as "low" and the average soil loss only for forest areas is 15.28 m3/km2/year. Nevertheless there are territories with more than 100 m3/km2/year.

Keywords

soil erosion, EPM, forest territories, Struma river

Introduction

Soils play an essential role in the balance and preservation of terrestrial ecosystems, however, they are increasingly threatened by many factors (Hara et al., 2022) and are vulnerable to climate change and anthropogenic impact. In just two centuries we have managed to pollute soils with organic and inorganic substances (Malinova et al., 2022), to decrease the topsoil layer due to intensive farming and influence their destruction by allowing unregulated activities in forests and arable lands.

One of the most serious threats to soil is erosion. Soil erosion is a pervasive phenomenon that occurs in all parts of the terrestrial world (Pavlova-Traykova, 2019) and it is a major cause of land degradation. Erosion is a serious environmental concern in the era of worldwide change, natural hazards, and climate problems and it can be considered one of the most serious global issues (Lal, 2017). Global soil erosion rates are estimated to be around 10.2 t ha^{-1} yr^{-1} (Yang et al., 2003), while soil renewal rates are estimated to be considerably slower at less than 0.6 t ha^{-1} yr^{-1} (Branigan et al., 2022). Most of the European soils are affected too. It is considered that 6.6% of the total agricultural area in the EU suffered from severe erosion in 2016 (Panagos et al., 2020). It is estimated that the cost of annual crop productivity loss is 1.25 billion Euro (Panagos et al., 2018). And while some European countries are reducing soil loss rates, in others like Bulgaria it is increased (Panagos et al., 2020). Nowadays soil loss prediction is essential for better management and sustainable silviculture and agriculture practices. For that reason, a lot of models have been used. One of these methods is the Erosion Potential Method, which has acceptable accuracy and has a simple structure. It requires little input data and is also associated with Geographic Information Systems (GIS), which allows the visualization of the most susceptible to erosion areas.

The purpose of the investigation is to determine soil erosion and to investigate its spatial distribution in the forest territories of the upper part of the Dzherman river by applying the EPM method.

Materials and methods

Study area

The upper part of the Dzherman river (fig. 1) includes an area of 111.3 $km^{2,}$ 37.45km^2 of which are forest territories. This part of the river is characterized by steep slopes and active erosion processes. The average altitude is 1297.9 m. The length of the main current is 27.10 km. The density of the hydrographic system isIn this part of the watershed, a lot of erosion control activities have been conducted. For stabilization of steep slopes, the large-scale afforestation are made, mainly with white pine, (Pinus sylvestris L.), black pine (Pinus nigra Arn.), and acacia (Robinia pseudoacacia L.). To strengthen the river bed in this part of the watershed eight hydro-technical facilities have been constructed (Sokolovska et al., 2021). All these erosion control activities led to better soil conditions, stabilization of the territories, and a decrease in the risk of soil erosion and torrential floods. But there are still sights of active degradation processes which, along with climate changes, and with more and more frequent intensive precipitation, this part of Dzherman must be under monitoring.

The Erosion Potential Model (EPM)

One of the methods for estimation of soil erosion, appropriate for our territories is the EPM method, also known as the Gavrilovic method (Gavrilovic, 1988). It is developed for estimating erosion for application in torrential watersheds in southern and south eastern Yugoslavia (present-day Serbia), but it is also widespread and applicable in many other countries (Bazzoffi, 1985; Milanesi et. al., 2014; Efthimiou and Lynoudi, 2016; Pavlova-Traykova, 2021). It this empirical model three descriptive parameters are used, the other variables are quantitative and describe catchments. Gavrilovich determines erosion in 5 degrees (table.1), but for Bulgaria “low” and “very low” (IV and V) degrees of erosion are combined and it is customary to use – “low” erosion. (Marinov, Gruev, 2002; Pavlova-Traykova, 2021).

The annual volume of soil erosion by the Gavrilovich method is determined by the following equation:

$Wyear=T.H.\pi.\sqrt{Z3}$

In which W is the annual volume of soil erosion ($m^3/km^2/year$) H is the annual rainfall (mm), Z is erosion intensity, *T* is the coefficient of temperature which is calculated as shown in the following equation:

$$T=\sqrt{\left(\frac{t'}{10}\right)+0,1}$$

Where *t* is the mean annual temperature (°C). The data used to calculate the temperature coefficient of the area and the amount of precipitation are from the Dupnitsa climate station and are for a 39-year period. Climate data are taken from the project Mitigating Vulnerability of Water Resources under Climate Change (2012-2014).

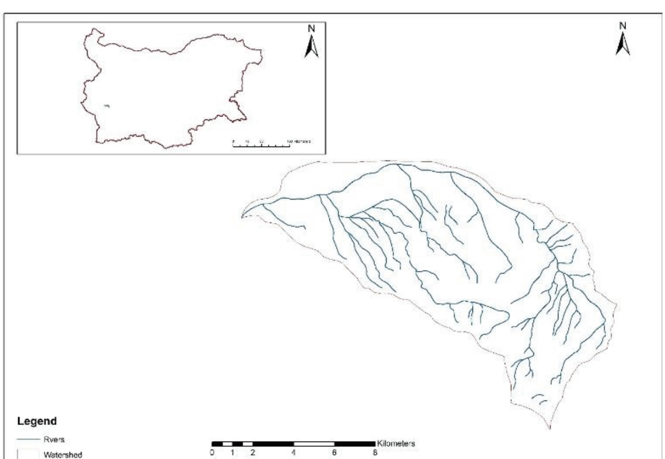

Figure 1. Upper part of Dzherman river

The erosion coefficient (Z) depends on four factors and is calculated as follows:

$Z=Y.Xa.(\varphi+\sqrt{Isr})$

Y is the soil erodibility coefficient, Xa is the soil protection coefficient, φ is the erosion coefficient, Isr is the average slope of the territories (%). These coefficients are determined by the tables which are presented in Pavlova-Traykova, 2021. This method considered the retention coefficient, which is assessed with the following equation.

$$Ru = \frac{\sqrt{O*D}}{0.2*(L+10)}$$

Where, O is the perimeter of the watershed (km), D is the average elevation of the watershed (km) and L is the length of the watershed (km).

The annual amount of transferred (transported) sediment (Gyear) was calculated as:

$Gyear = Wyear \cdot Ru$

In this research, each factor is described by the form of a digital map by using Geographic Information Systems. The digital layers are overlaid in order to estimate soil loss in the forest territories.

Results and disscusion

For forest territories, the average value of the coefficient Z is estimated as 0.19, which defines these territories with "low" erosion. In this watershed, another methodology for assessment actual and potential soil erosion risk was applied and the results showed that the forest territories are with "moderate" potential risk and "low to moderate" actual soil erosion risk (Pavlova-Traykova et al., 2021). From these results, we could make a conclusion that the EPM method underestimates erosion rates. The underestimation of EPM is also found by other authors (Lense et al., 2020).

The calculated soil loss varied a lot but average soil loss is 15.28m^3/km^2/year. This result also defines erosion as "low", which is expected, because the methodology is applied only to the forest territories, but from the spatial distribution (fig.2), there are territories with soil lose more than 100 m^3/km^2/year. These territories are mainly around the tributaries of the river which are the territories with "high" risk from the other applied methodology (Pavlova-Traykova et al., 2021), this is due to the presence of coastal erosion, which both methodologies manage to capture. Although the assessment obtained is lower with EPM, both methods direct our attention to the same forest territories with a high potential of erosion, which shows that EPM also gives relatively good results for our country.

The coefficient of retention Ru was calculated at 0.844, which means that 8.44% of the sediments generated in the forest territories reach the watercourses. According to this, the average annual amount of transferred (transported) sediment from the forest territory is 12.90 m^3/km^2/year, but in this distribution, there is also the presence of sediment of more than 100 m^3/km^2/year. The territories with high quantity of sediment are white pine afforestation and in coppice forest with beech *(Fagus sylvatica* L.*)*

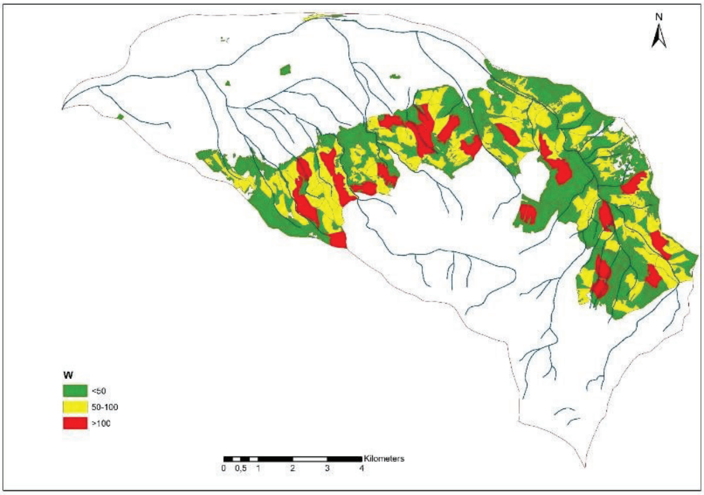

Figure 2. Spatial distribution of W in the forest territories of the upper part of Dzherman river

Table 1 .

Intensity of soil erosion Интензивност на почвената ерозия	Z
Very low Много слаба	<0.19
Low Слаба	0.20-0.40
Moderate Средна	0.41-0.70
High Силна	0.71-1.0
Very high Много силна	>1.0

in the lower part of the forest and in the upper part of the territory with fur (*Abies alba* Mill.) and spruce (*Picea abies* Karst.). They have in common the steep slopes, which are the main factor for soil erosion in the Struma river (Martensson et al., 2001; Malinov et al., 2009) watershed and its tributaries (Pavlova-Traykova et al., 2017; PavlovaTraykova, 2019). In this case it means it is also the main factor for the high quantity of transported sediment in this watershed.

Conclusions

The results for the coefficient of erosion Z and the annual volume of soil erosion present the forest territories in the watershed as areas with "low" erosion. However, there are territories with soil loss of more than 100 m^3/km^2/year. These areas coincide with areas assessed with a „high" risk of erosion when applying another methodology. This shows that the selected method for erosion assessment is applicable to the conditions of our country and the results are comparable to the results of other methods used in forest areas.

The considerable ability of forest vegetation to protect territories from soil erosion was confirmed with coefficient of retention.

To ensure the future conservation of forests, not only the territories with higher soil loss must be managed cautiously, but sparing silviculture practices must be applied to the whole territories in view of climate change and its consequences.

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