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# Soil erosion risk assessment on the territory of Botevgrad Valley area (West Bulgaria)

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**Abstract.** The mountainous and semi-mountainous nature of the relief on the territory of Botevgrad Valley (West Bulgaria) is a prerequisite for erosion processes with different intensity. The erosion is mostly hidden, in surface washing and removal of the fertile soil horizons. The degree of erosion in the area is low to moderate. The water erosion is represented as the annual average value of the amount of eroded soil through the Universal Soil Loss Equation (USLE) model integrated into the Geographical Information Systems (GIS). The estimated potential risk of water erosion on a main part (65.92%) of the land is very high. It was evaluated that potential risk can have values about 200 t/ha y eroded soil. The assessment of the estimated actual soil losses from water erosion in the Botevgrad Valley has a low actual risk (class 2). The estimated loss of eroded soil is about 3 t/ha y, which is typical for that region.

**Key words:** rainfall erosivity, soil erodibility, USLE, Botevgrad valley.

## Introduction

Erosion is one of the main processes for soil degradation in Bulgaria. This type of degradation deteriorates the quality of the soil, reduces its productivity and disrupts the balance in ecosystems. The fragmented mountainous and semi-mountainous nature of the relief on the territory of the Botevgrad valley (West Bulgaria), the geological and petrographic construction, intensive grazing in the past and other complex factors have created conditions for erosion processes with different intensity (Hristov, 2020).

Such processes have developed on the deforested slopes of the Botevgrad Pre-Balkan region, those along the Rivers - Bebresh, Vitomeritsa, Novachenska, Borushtitsa and Small Iskar. Surface erosion is hardly visible, in the form of surface washing and removal of fertile soil horizons. Due to the creation of a number of forest belts, as well as the reduction of livestock grazing and tree clear-cutting in threatened areas, the erosion has slowed over the past 20 years. As a result of long-term measures to combat erosion, in most cases the eroded areas are covered with new forest and anti-erosion measures. On the areas on the slopes of the Botevgrad Pre-Balkan part - above the villages of Trudovets and Razliv - on highly eroded terrain, trees such as acacia and black pine have been planted and the erosion in these areas has been controlled (Dragalov, 2013). The situation is similar around the villages of Vrachesh, Kalugerovo, Vidrare, Svode, etc. In general, gully erosion within the borders of the forest territories has been controlled (Panov, 2000). During the last decade period, no new anti-erosion facilities were constructed.

In the lower parts of the valley and along the rivers, the soils are Fluvisols, and Gleysols marshy and leached, and on the peripheral higher parts - Luvisols. The southern slopes are overgrown with oak and beech forests, while the northern ones are deforested and subject to erosion, with the soils being mainly Rendzic Leptosols and Cambisols (Hristov, 2020).

The aim of this study is to assess soil erosion risk for the Botevgrad valley, based on the Universal Soil Loss Equation (Wischmeier & Smith, 1978) integrated with Geographical Information Systems (GIS).

**Materials and Methods**

The object of study is the Botevgrad valley and the surrounding mountain formations. The model applied in this study was developed in the USA for erosion control design purposes (Wischmeier & Smith, 1965; 1978; Woodruff & Siddoway, 1965; Hagen, 1991; Lal, 1994), and is known as the Universal Soil Loss Equation (Universal Soil Loss Equation - USLE). It predicts the tolerable average annual soil losses due to erosion.

***Applied methodology for evaluation of erosion factors and risk:***

The climatic factor (R-factor) was estimated on the basis of published information (Kyuchukova et al., 1986), through the rain erosivity index R (EI30), calculated according to the adapted for Bulgarian conditions (Rousseva, 2002) degree model, defined by Richardson et al. (1983). The calculated rainfall erosivity index values are categorized into eight classes (class 1-very low to class 8 – very strong). The soil factor of water erosion is determined by the index of susceptibility of the soil to erosion K-factor, estimated on the basis of large-scale soil studies by the nomogram of Wischmeier et al. (1971), adapted for the conditions of Bulgaria (Rousseva, 1997; 2001; 2002). Its assessment is based on the mineral, chemical, mechanical and aggregate composition of the soil, the stability of the soil structure, the content of organic matter and the water conductivity of the soil profile. The soil erodibility factor values categorized into six classes (class 1 – very low; class 2 – low; class 3 – medium; class 4 – medium to high; class 5 – high; class 6 – very high).

The topographic index (LS) combines the influence of slope and slope length on soil erosion losses. Topographic factor values were calculated using the formula of Moore et al. (1993), in which LS combines the influence of slope ($\theta$, °) and specific area from which runoff forms (As, $m^2/m$). C-factor (index for soil protection effect of vegetation) is defined by the average annual value of the quotient of soil losses from a given plant species and those from soil without vegetation. Estimates of the soil protective effect of vegetation are based on the distribution of lands according to the permanent cover obtained as a result of the implementation of the CORINE project (2018).

The potential risk of water erosion was estimated as the average annual value of the amount of eroded soil (t/ha y) in the absence of vegetation cover. For mapping purposes, the potential risk of water erosion is classified according to the estimated amount of eroded soil into seven classes. The actual risk of water erosion is represented as the annual average value of the amount of eroded soil with vegetation cover determined in accordance with the permanent cover map. The described models for assessing the factors and risk of water erosion have been evaluated in GIS.

**Results and Discussion**

Different types of data are integrated with different predictive erosion models to assess the erosion processes. Soil erosion modeling is becoming increasingly important in the development and implementation of soil conservation management practices. (Selmy et al., 2021). For a more detailed study of the process, familiarity with its dynamics in time and space is necessary.

***Rainfall erosivity (R-Factor)***

The results of the assessment of the rain erosivity index illustrated in Fig. 1 show that the Botevgrad region falls into three classes - 5, 6 and 7. Rains with the highest prevalence (41.91%) for the territory of the monitored site are strong to very strong erosivity - > 1500 ≤2000 MJ mm/ha h. The next with the highest percentage share (39.87%) are the rains of class 6 - with strong erosivity - > 1000 ≤1500 MJ mm/ha h, and with 18.21 % presence are rains with medium to strong erosivity - > 800 ≤1000 MJ mm/ha h.

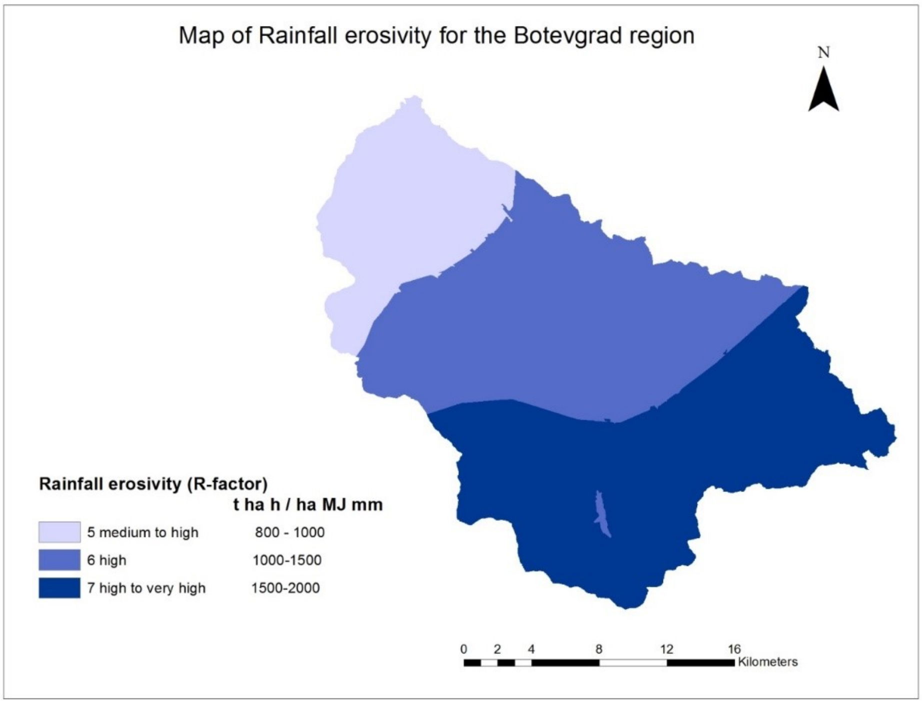


**Fig. 1.** Spatial distribution of rain erosivity classes for the Botevgrad region.

***Index of susceptibility of soil to erosion (Soil erodibility (K-factor))***

The assessment of the soil factor (Fig. 2) represented by the index of susceptibility of the soil to erosion indicates that two classes of susceptibility are spread over the territory of the studied area - dominant class 4 with 69.52% (medium to high susceptibility - > 0.03 ≤0.04 t ha h/ ha MJ/ mm) and class 6 (30.48%) – very strong susceptibility to erosion > 0.05 t ha h/ha MJ/ mm.

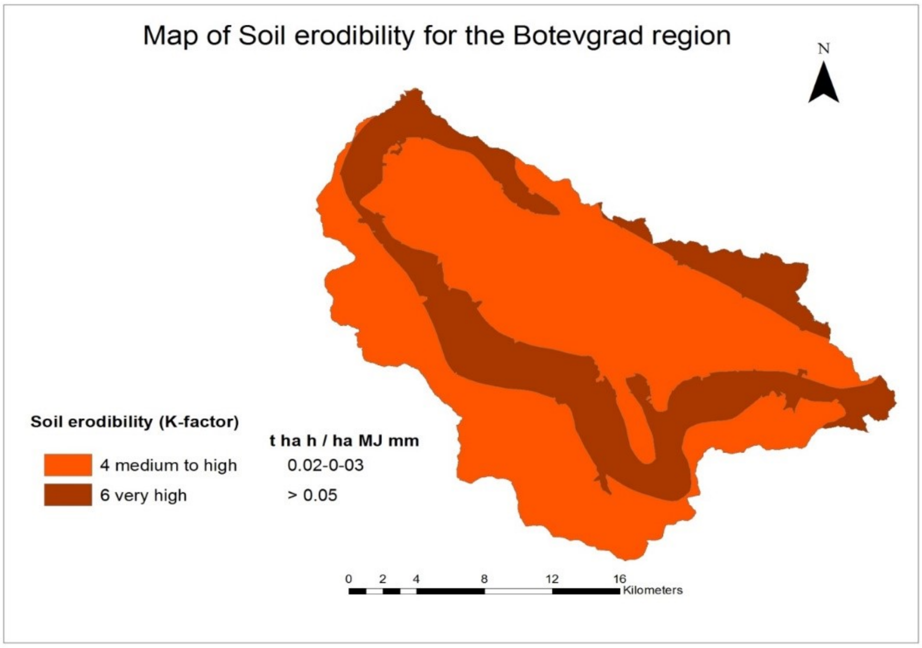


**Fig. 2.** Spatial distribution of classes of soil susceptibility to erosion for the Botevgrad region (K-factor).

***Length and influence of slope (LS-factor - Topographic index)***

The group of slopes that cover more than half of the territory of Botevgrad (57.65%) are between 15 - 18°, which creates a serious prerequisite for intense erosion processes (Fig. 3). The distribution of the other slope groups for the studied territory has the following form - 20.17% is occupied by land with a slope of 0°-3° (Fig. 3). Lands with a slope of 3°-6° occupy 9.12% of the area, followed by lands with a slope of 6°-9° occupying about 5% of the territory.

The distribution of the remaining groups of slopes (Fig. 4.) is as follows: >18° - 3.67%; 9°-12° - 2.56%; and 2.619% of the area of the studied site occupy lands with a slope between 12°-15°.

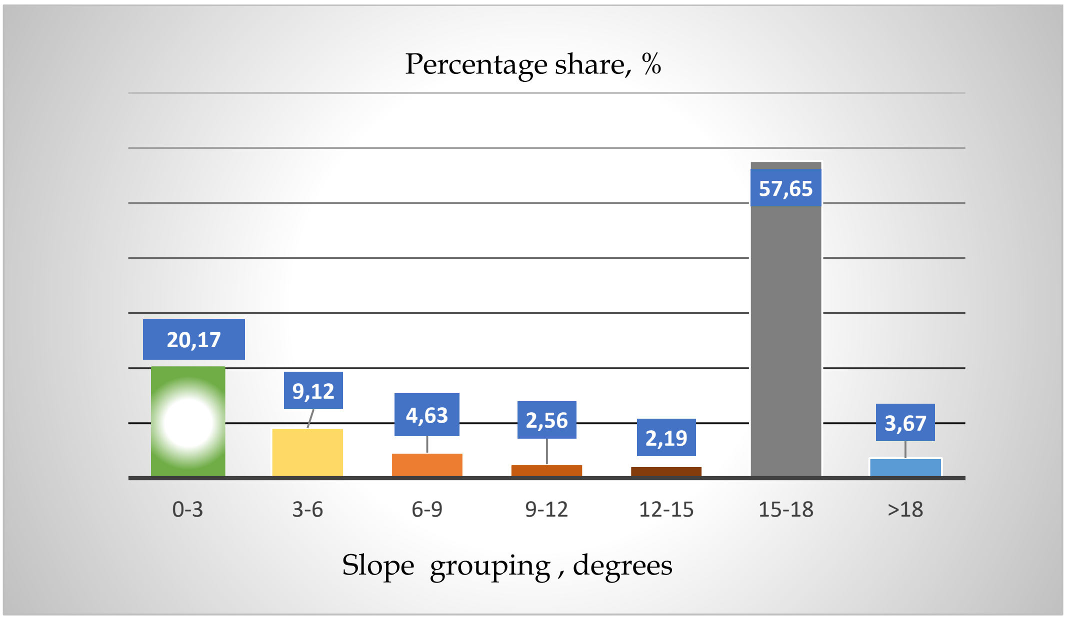


**Fig. 3**. Distribution of the territory of Botevgrad by slope groups.

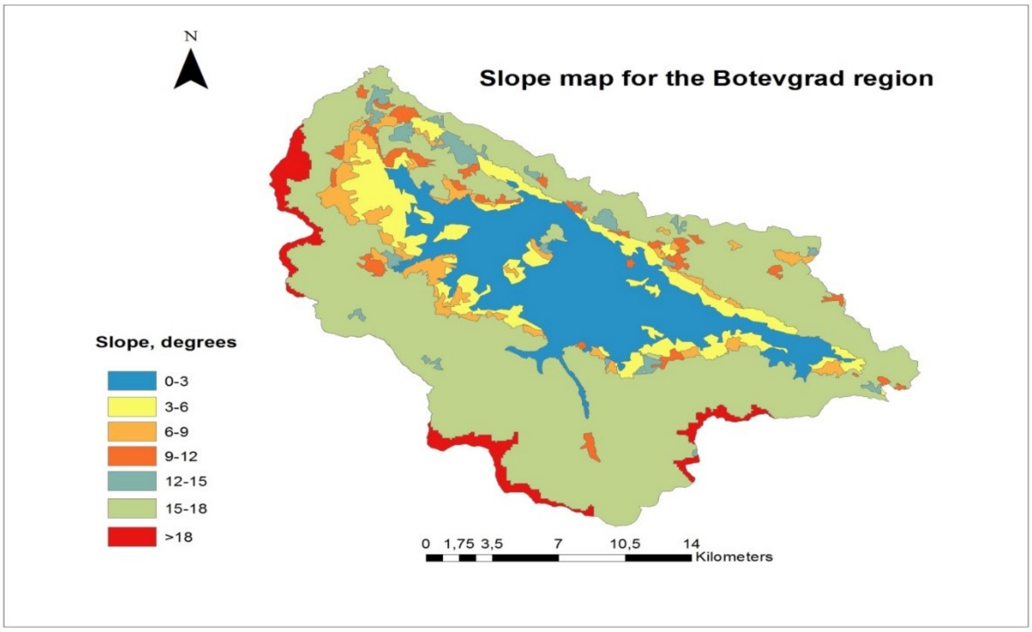


**Fig. 4.** Spatial distribution of the territory for the Botevgrad valley by slope grouping (LS – topographic index).

***Potential risk of water erosion***

According to the classification of the potential risk of water erosion (Table 1), the territory of the Botevgrad valley is divided into five classes. A very high potential risk of water erosion (class 7; Table 2) with an amount of eroded soil > 200 t/ha y have 65.92% of the studied region, followed by low to moderate potential risk with 15.97% (class 3). The lands with moderate to high risk cover 8.34% of the territory, high - 5.57% and with the smallest percentage share (4.20%) are the lands on which a moderate potential risk is spread for the Botevgrad region. Assessing the potential risk of water erosion helps identify areas that are more vulnerable to erosion and prioritize conservation measures.

**Table 1.** Classification of the potential risk of water erosion

| | Class of potential risk of water erosion | Amount of soil eroded, t / ha y |
|---|---|---|
| 1 | Very low potential risk | >0≤5 |
| 2 | Low potential risk | >5≤10 |
| 3 | Low to moderate potential risk | >10≤20 |
| 4 | Moderate potential risk | >20≤40 |
| 5 | Moderate to high potential risk | >40≤100 |
| 6 | High potential risk | >100≤200 |
| 7 | Very high potential risk | > 200 |

**Table 2.** Percentage distribution of the territory for the Botevgrad region according to the class of potential risk of water erosion

| Class potential risk of water erosion, t / ha y | Area, dka | Percentage share of the area, % |
|---|---|---|
| 3 | 83623.083 | 15.97 |
| 4 | 21987.095 | 4.20 |
| 5 | 43647.744 | 8.34 |
| 6 | 29135.611 | 5.57 |
| 7 | 345093.264 | 65.92 |

***Evaluation of the index for soil protection effect of vegetation (The cover management factor (C-factor))***

The distribution of the territory of the pilot site according to the permanent land use is based on satellite data (CORINE, 2018). Deciduous forests are the most widespread in the Botevgrad region - 40.20% (Fig. 5). Fields are represented by 18.34%, followed by mixed forests, which occupy 12% of the studied territory. 10.80% occupy other non-agricultural lands, followed by rare vegetation - 9.21%. Urbanized lands and pastures occupy respectively - 4.63% and 3.08% of the area. Coniferous forests, water areas, fruit trees, sands and vineyards occupy an insignificant share of the studied site - with 0.87%, 0.29%, 0.25%, 0.23% and 0.11%.

***Actual risk of water erosion***

The actual risk of water erosion in the territory of Botevgrad region depends on factors such as soil type, slope steepness, land use, vegetation cover, and climate. Actual soil losses from water erosion are estimated according to the established classification (Table 3). The results show that the lands with low actual risk (class 2) of water erosion with an amount of eroded soil between the allowable annual soil loss from erosion (T) and 3 t/ha y occupy 44.50%. Lands with moderate actual risk occupy 14.12% with 5-10 t/ha y eroded soil. Lands with a high actual risk between 20-40 t/ ha y occupy 10.45% of the studied area, followed by lands with low to moderate (8.34%), very low (5.70%), moderate to high actual risk (4.45%) and urbanized lands (5.15%) (Table 4, Fig. 6).

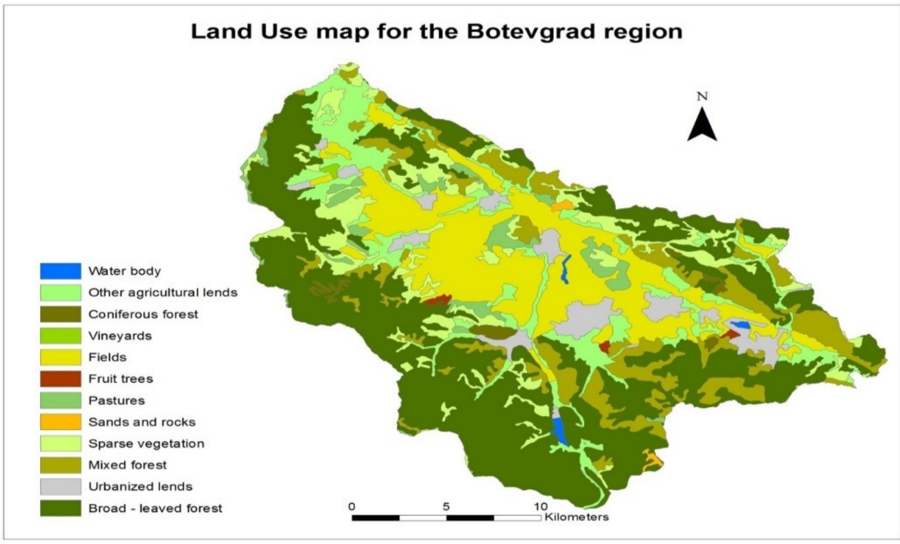


**Fig. 5.** Spatial distribution of the territory for the Botevgrad region according to the permanent land use (CORINE, 2018).

**Table 3.** Classification of the actual risk of water erosion.

| Class of actual risk of water erosion | | Amount of soil eroded, t / ha y |
|---|---|---|
| 1 | Very low actual risk | > 0≤T* |
| 2 | Low actual risk | > T≤3 |
| 3 | Low to moderate actual risk | > 3≤5 |
| 4 | Moderate actual risk | > 5≤10 |
| 5 | Moderate to high actual risk | > 10≤20 |
| 6 | High actual risk | > 20≤40 |
| 7 | Very high actual risk | > 40 |

T*- tolerable soil loss

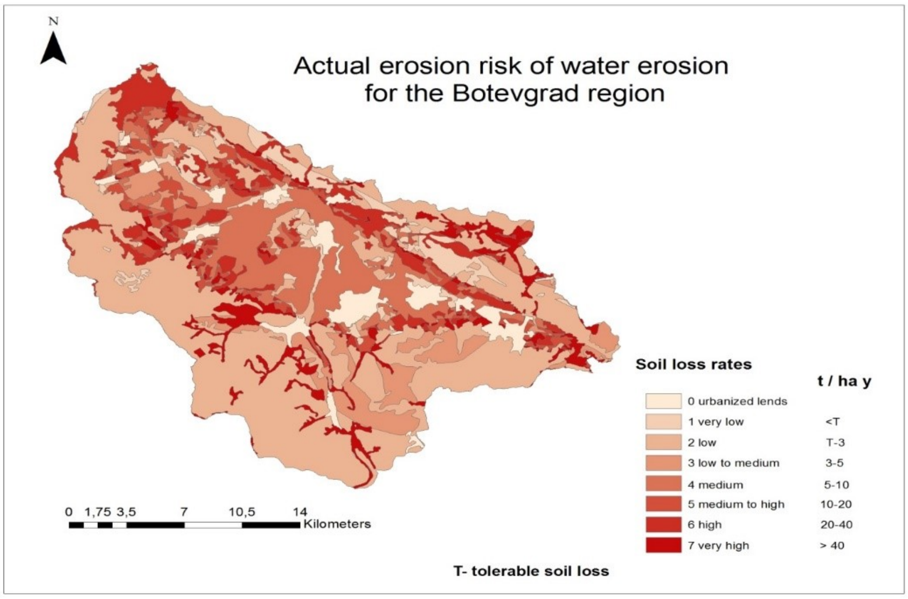


**Fig. 6.** Spatial distribution of the territory of Botevgrad Valley according to the class of actual risk of water erosion.

**Table 4.** Percentage distribution of the territory for the Botevgrad region according to the class of actual risk of water erosion.

| Class actual risk of water erosion, t/ha y | Area, ha | Percentage share of the area, % |
|---|---|---|
| 0 | 2696.587979 | 5.15 |
| 1 | 2984.2881 | 5.70 |
| 2 | 23297.1513 | 44.50 |
| 3 | 4368.3585 | 8.34 |
| 4 | 7393.2675 | 14,12 |
| 5 | 2327.2246 | 4.45 |
| 6 | 5472.0811 | 10.45 |
| 7 | 3809.7207 | 7.28 |

**Conclusions**

The results of the assessment of the rain erosivity index illustrated that the Botevgrad area falls into three classes - 5, 6 and 7. The highest prevalence (41.91%) for the territory of the observed object is the rains with strong to very strong erosivity > 1500 ≤ 2000 MJ mm/ha h.

The index of susceptibility of the soil to erosion indicates that on the territory of the researched area, class 4 dominates with 69.52% (medium to high susceptibility - > 0.03 ≤ 0.04 t ha h/ha MJ/ mm). Accordingly, the potential risk of water erosion on a predominant part of the lands (65.92%) in the territory of the research site is spread very high potential risk of water erosion with the amount of eroded soil > 200 t/ha y, followed by low to moderate potential risk with 15.97% (3rd class).

The results of the assessment of the estimated actual soil losses from water erosion over the predominant part of the lands of the Botevgrad valley have low actual risk class 2. The water erosion can reach an amount of eroded soil of about 3 t/ha y.

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