Erosion regulation capacity of different habitats in Vitosha Mountain

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Abstract. The area of interest is located in the Western Srednogogie region of Bulgaria and is entirely covered by the Vitosha (BG 0000113) site of the ecological network NATURA 2000. The aim of the presented research is to assess the erosion regulation capacity of different habitats and mosaics in Vitosha Mountain. Habitat data is provided by the Ministry of Environment and Water of Bulgaria. Drainage network is extracted from the digital elevation model by GIS software. Values of drainage density per square kilometer within different habitats are calculated. Spatial pattern of the drainage network and its density are presented and discussed.

Key words: drainage network, ecosystem services, habitats, Vitosha Mountain

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Introduction

Adoption of the Council Directive 92/42/EEC underlies the nature conservation activities in Bulgaria as a member-country of the European Union. As an ecological network, NATURA 2000 was introduced in the country in 2002. Presently, it includes 234 sites that are part of the Habitat Directive covering more than 30% of the country's total area. Habitats in Bulgaria have been studied by Sopotlieva & al. (2018), Grigorov (2021) and Grigorov & al. (2021). Natural habitats within the NATURA 2000 network identified in Vitosha Mountain are characterized by Gussev & al. (2005).

The aim of the this paper is to assess the erosion regulation capacity of different habitats and mosaics in Vitosha Mountain. The higher the density in a habitat or a mosaic of habitats is, the higher is the potential of channelizing overland flow. Erosion regulation capacity is expected to be lower in areas with dense drainage network.

The studied area is almost entirely covered by the Vitosha (BG 0000113) site. Data is provided by the Ministry of Environment and Water. Habitats within the zone cover a total area of 164.32 (km^2). Forest habitats are claiming the largest share of the territory: 52.9%. Shrubland habitats (excluding mosaics) cover 11.3%. Grassland habitats (excluding mosa-

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ics) take up to 25.3% and mosaics cover 4.5%. The remaining 6% are divided between the other habitat groups, including freshwater habitats, rocky habitats, caves, etc. (Fig. 1, Table 1).

Fig. 1. Location and habitat diversity of the study area.

Legend of Fig. 1:

- Rivers
- Vitosha (BG 0000113) site
- Study area

Habitats

- Natural eutrophic and dystrophic lakes (3150 and 3160)
- Alpine and boreal heaths, bushes with *Pinus mugo*, sub-arctic scrubs with *Salix* spp. (4060, 4070, 4080 and mosaics)
- *Juniperus communis* formations (5130)
- Natural and seminatural grass formations (61**, 62**, 64**, 65**)
- Transition mires and bogs (7140 and mosaics)
- Rocky habitats and caves (8110, 8210, 8220, 8230)
- Beech forests, oak-hornbeam forests and mixed forests (9110, 9130, 9150, 9170, 9180)
- Bog woodlands and alluvial forests (91D0, 91E0)
- Pannonian woods with *Quercus pubescens* (91H0)
- Pannonian and Balkanic forests with *Q.cerris* and *Q. frainetto* (91M0)
- Acidophilous *Picea* forests (9410)

Table 1. Habitat diversity of Vitosha Mountain

Habitat Type	Habitat code	Area (km²)
Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* -type vegetation	3150	0.004
Natural dystrophic lakes and ponds	3160	0.009
Alpine and boreal heaths	4060	17.88
Mosaics	4060/6150	0.53
Mosaics	4060/6230	0.36
Mosaics	4060/6410	0.1
Bushes with *Pinus mugo* and *Rhododendron hirsutum* (*Mugo-Rhododendretum hirsuti*)	4070	0.09
Subarctic *Salix* spp scrub	4080	0.14
Juniperus communis formations on heaths or calcareous grasslands	5130	0.48
Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*	6110	0.11
Mosaics	6110/62A0	0.18
Siliceous alpine and boreal grasslands	6150	0.11
Seminatural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites)	6210	5.74
Mosaics	6210/62A0	6.2
Species-rich *Nardus* grasslands on silicious substrates in mountain areas (and submountain areas in Continental Europe)	6230	27.81
Mosaics	6230/6410	0.0002
Mosaics	6230/6520	0.007
Eastern sub-Mediteranean dry grasslands (Scorzoneratalia villosae)	62A0	0.94
Oro-Moesian acidophilous grasslands	62D0	1.38
Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	6410	2.97
Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	6430	0.06
Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)	6510	0.09
Mountain hay meadows	6520	2.41
Transition mires and quaking bogs	7140	1.16
Mosaics	7140/91D0	0.006
Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)	8110	7.61
Calcareous rocky slopes with chasmophytic vegetation	8210	0.09
Caves, not open to the public	8310	-
Siliceous rocky slopes with chasmophytic vegetation	8220	0.8
Siliceous rocks with pioneer vegetation of *Sedo-Scleranthion* or of *Sedo albi-Veronicion dillenii*	8230	0.004
Luzulo-Fagetum beech forests	9110	31.45
Asperulo-Fagetum beech forests	9130	12.49
Medio-European limestone beech forests of *Cephalanthero-Fagion*	9150	3.70
Galio-Carpinetum oak-hornbeam forests	9170	10.53
Tilio-Acerion forests of slopes, screes and ravines	9180	0.79
Bog woodlands	91D0	0.07
Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)	91E0	0.71
Pannonian woods with *Quercus pubescens*	91H0	3.52
Pannonian-Balkanic turkey oak –sessile oak forests	91M0	9.59
Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)	9410	14.23

Materials and methods

Habitat data is provided by the Ministry of Environment and Water of Bulgaria as separate sets of geospatial vector data (shapefiles), which have been merged in order to produce a single layer containing all habitat types. This procedure allows mapping out habitat diversity within the mountain's extent. All habitat codes (Table 1) and descriptions follow the *Guide to the Identification of Habitats of European Significance in Bulgaria*. (Kavrakova & al. 2009).

Drainage network is extracted from the Digital Elevation Model SRTM1N42E023V3) with cell size 30 m (1 Arc Second) available by Shuttle Radar Topography Mission (at http://earthexplorer.usgs.gov/). Hydrological analysis follows the workflow presented by several papers (Morris & Heerdegen 1988; Tarboton & al. 1991; Gurnell & Montgomery 2000). The entire hydromodelling and spatial analysis is done in GIS (ESRI ArcMap 10.1 software). The derived vector layer, representing stream channels, is used to calculate drainage density in the area of interest.

A polygon grid with a cell size of 1 km^2 was used in order to calculate the drainage density per each cell. Channel density is related to habitats and mosaics by extracting the mean, maximum and minimum values of drainage density within each habitat type represented by at least two or more polygons. Similar technique was used in an earlier study (Bozhkov & al. 2020) dedicated to flood regulation capacity of different land cover classes. The main disadvantage of it is related to the minimal spatial extent of the polygons. Therefore, an assessment of erosion regulation capacity of habitats with territory less than 1 km^2 is simply impossible. However, those habitats also retain overland flow and prevent its transformation into a channelized flow.

The obtained results provide the necessary scientific basis for assessment of erosion risk and overland flow retention capacity of seven types of deciduous forest habitats, one kind of coniferous forest (9410), four types of grass formations (6210/62A0, 6410, 6210 and 6230), and a single type of rocky habitat (8110). Assessment is based on the mean drainage density within each habitat type, whereas the minimum and maximum values tend to vary within a wide range among the polygons representing each habitat and/or mosaic.

Results

There are available habitat data for Vitosha Mountain for about 60% of its area (Fig. 1). The remaining 40% of the area have not been defined as representative habitat types (areas with no available data), which makes the assessment of erosion regulation capacity difficult. Furthermore, drainage density is calculated per square kilometer, while most habitats (represented by one or more polygons) have an area of less than one square kilometer. Only 13 habitat types have an area greater than 1 km^2 (Table 2), which does not allow mapping the erosion regulation capacity at habitat level.

Significant spatial differences in the density of erosion forms have been observed in the different habitats. For example, in forest habitats (9110, 9410, 9130), density of the erosion forms varies within a wide range. Alpine and boreal heaths (4060) and montane grasslands (6230) have similar values (Table 2), which are two of the habitats with the largest areas (Table 1).

In the Pannonian woods with *Quercus pubescens* (91H0) and the thermophilous beech forests (9150), density of the erosional forms varies within a limited range of 2.1 and 2.8 (Table 2). A similar situation has been observed in the grassland habitats (6210 and 6210/62A0). Therefore, it has been more representative to examine the average values of the indicator drainage density calculated per square kilometer in the different habitats.

After plotting the layer with streams and other erosional landforms on the habitat map (Fig. 1), a specific drainage network pattern and density have been observed in the different habitats. It was evident that some habitats, whether forest or grasslands, had high drainage density values. In other habitats the development and incision of fluvial landforms was not as intense, as indicated by the lower drainage density values.

The total area of a habitat type is an important indicator for the assessment of its erosion regulation capacity. Each habitat has a specific value of mean drainage density per square kilometer. High values of drainage density indicate the low erosion regulation capacity and vice versa. The larger the total area of a habitat, the more significant its role is in regulating erosion and in development of fluvial landforms.

According to the total area, the largest habitats in Vitosha Mountain are 9110, 6230, 4060, 9410, and 9130 (Table 1). Each habitat is presented by specific plant communities and species.

Acidophilous *Picea* forests of montane to alpine levels (Vaccinio-Piceetea) (habitat type 9410) are boreal forests on silicates. In the coniferous forests (9410), due to the nature of the undergrowth, intense rill erosion is common. Consequently, the role of coniferous vegetation in erosion regulation is less than the capacity of flow retention of deciduous forests. Habitat 9410 is defined by high value of mean stream density: about 3.4 km/km^2 (Table 2).

Alpine and boreal heaths (habitat type 4060) are situated typically in the subalpine area, in open spaces. Values of drainage density vary significantly in these types of areas, which is caused by incision and development of various erosional landforms. High mean values (about 3.5 km/km^2) of drainage density within that habitat indicate low erosion regulation capacity. In these areas, channelized flow predominates over overland flow.

Species-rich *Nardus* grasslands on silicious substrates in mountain areas (and submountain areas in Continental Europe) (habitat type 6230) represent closed xerophytic to mesophytic perennial grassland communities, dominated by *Nardus stricta*. They are normally found on silicates and are rich in species. Although values of drainage density in this habitat vary within a wide range, the mean values of this parameter are relatively low (2.7 km/km^2).

Luzulo-Fagetum beech forests (habitat type 9110) are growing on poor eroded soils with a low pH, and they can be discovered both with sunny and with shady exposition. *Asperulo-Fagetum* beech forests (habitat type 9130) represent mesophylic beech forests, mainly developed on neutral soils. They are similar to Central European beech forests. Both habitat types are characterized by similar values of mean drainage density (Table 2).

Table 2. Drainage density (km/km^2) within habitats in Vitosha Mountain

Habitat code	Area (km^2)	Area (%)	Drainage density [km/km^2]				
			Min*	Max**	Range	Mean	StD***
9110	30.892	11.477	1.085	6.234	5.150	2.677	0.898
6230	27.437	10.193	0.540	6.100	5.560	2.772	0.955
4060	17.880	6.643	0.760	6.610	5.850	3.485	0.908
9410	14.226	5.285	0.543	7.012	6.469	3.377	1.138
9130	12.051	4.477	0.763	6.593	5.830	2.831	1.133
9170	9.999	3.715	0.836	5.549	4.713	2.531	0.829
91M0	9.364	3.479	0.788	4.330	3.542	2.304	0.429
8110	7.608	2.826	0.761	6.170	5.410	3.326	0.951
6210/62A0	5.805	2.156	0.596	3.397	2.801	1.867	0.477
6210	4.910	1.824	0.807	3.284	2.476	2.068	0.389
9150	3.547	1.318	0.894	3.661	2.767	1.936	0.544
91H0	3.516	1.306	1.239	3.420	2.181	2.038	0.446
6410	2.967	1.102	1.090	5.245	4.155	2.770	0.555
Other habitats (< 1 km^2) and mosaics	10.289	3.823	-	-	-	-	-
Unidentified areas	108.677	40.375	0.421	6.935	6.514	2.736	0.851
Total	269.166	100.000					

Notes: * – minimum value; ** – maximum value; *** – standard deviation

Fig. 2. Drainage density per square kilometer in Vitosha Mountain.

Stream length data has been used to map out drainage density per square kilometer in Vitosha Mountain (Fig. 2). The values of this indicator range from 0.42 to 7.02 km/km^2. About 10.92% of the study area has shown values of drainage density per square kilometer above 5 km/km^2. Such values are characteristic of the source parts of the rivers Vladayska, Yanchovska, Palakaria and Struma, as well as the catchment area of river Boyanska (a tributary of Perlovska river). In 68.28% of the study area, this indicator varies between 2 and 4 km/km^2. The obtained data should be analyzed at the catchment level (a subject of subsequent studies) to examine the spatial differences in the river systems. Such differences could be related to the morphotectonic development of the area, climatic conditions, vegetation cover, and other physiographic characteristics of the catchments.

Discussion

The obtained results were used to assess erosion regulation capacity of the different habitat types based on mean drainage density. Thus, all habitats exceeding 1 km^2 were divided into three categories: habitats with low, moderate, and high erosion regulation capacity. A similar approach was used in an earlier study related to the assessment of flood risk based on land cover data (Bozhkov & al. 2020).

Habitats with high erosion regulation capacity have mean drainage density up to 2.1 km/km^2. Such areas are covered by various types of vegetation canopy such as grasslands and deciduous forests. This group of territories includes habitat types 6210/62A0, 6210, 9150 and 91H0 (Fig. 3). In these areas, rill erosion and gully incision are rear phenomena due to the presence of a continuous vegetation cover and/or litter which protect the upper soil horizon.

Six habitats, including natural grass formations and forests, have medium erosion regulation, i.e., drainage density between 2.1 and 2.99 km/km^2. Erosion is a predominant process in the deciduous forests (habitats 91M0, 9170, 9110 and 9130) covering the steep slopes of Vitosha Mountain, whereas meadows and grasslands (6410 and 6230) have continuous canopy which prevents the transformation of surface flow into linear flow. Therefore, rill erosion is limited as habitats in this group cover about 34.4% of the study area.

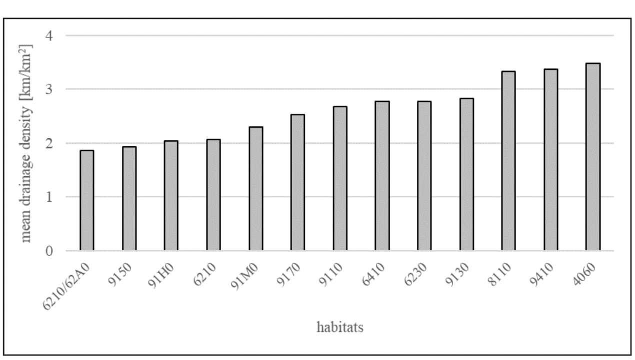

Fig. 3. Mean values of drainage density in various habitat types.

Low erosion regulation capacity is defined by the wide presence of fluvial landforms in a given region, which leads to high values of drainage density per unit of area. Generally, lowlands have lower drainage density than mountain regions. In Vitosha Mountain, only three habitats have drainage density exceeding 3.00 km/km^2 (Fig. 3). That group includes screes (8110), spruce forests (9410) and alpine and boreal heaths (4060) covering about 15% of the area of interest.

Unfortunately, habitat spatial data does not cover the entire study area, which prevented any attempt of mapping out the erosion capacity as an ecosystem service. The collected data is used to assess the capacity of flow regulation of each habitat separately. In order to make such an assessment credible, further research is needed in other NATURA 2000 sites, with the same or similar habitat diversity. Only then would such an assessment be generalizable.

Conclusion

Low drainage density (less than 2.1 km/km^2) has been observed in both deciduous forests and grassland habitats covering the lower part of the mountain slopes. That type of vegetation canopy is related to prolonged infiltration of rainfall and mitigation of overland flow.

Mountain grasslands (6230) and meadows on peat soils (6410) have medium erosion regulation capacity due to a thick organic soil horizon which infiltrates rain and, therefore, increases the subsurface flow. Beech forests (9130, 9110) and oak-hornbeam forests (9170), with their dense root system and intermittent litter cover, also restrict the development of erosional features such as rills. Therefore, drainage density per square kilometer is between 2.1 and 2.99 km/km^2.

Low erosion regulation capacity and high drainage density (exceeding 3.00 km/km^2) have been observed in several habitat types such as screes (8110), without any dense vegetation cover, except for individual patches of annual or perennial plants. Spruce forests (9410) and alpine and boreal heaths (4060) are also prone to erosion, which results in a dense network of erosional landforms. Alpine and boreal heaths cannot retain the surface soil layer due to the specifics of their root system, whereas spruce formations have a bare to very sparsely vegetated forest floor which is a prerequisite for rill incision.

Difference in habitat diversity at a drainage basin level reflects a difference in mean drainage density. The northern mountain slopes covered with coniferous forests are incised by rills and streams, which are visible on the drainage density map. In these areas, the highest values of drainage density have been observed.

Habitats can be used as a geographical framework and for assessment of ecosystem services. The main disadvantage of this approach is related to the spatial coverage of the habitat data. Unidentified areas cannot be interpreted in terms of flow regulation capacity of the ecosystems. Thus, continuous data such as CORINE land cover should be used to complement the available habitat data.

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