GIS APPLICATION IN ANALYSIS OF NATURAL CONDITIONS FOR THE GENESIS OF TORRENTS IN TERRITORY OF LOEQ „VLASINA“

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Abstract

In this paper predisposition of the terrain for the emergence of torrents by application of Geographic Informational Systems (GIS) was made. Due to great ecological importance of this area, it is necessary to continuously monitor the state of the environment. High rainfall over a short period of time is the main cause of torrential floods, and because of the high elevation of Vlasina, the average annual rainfall exceeds 800 mm. The method used to determine the predisposition of a landscape of exceptional qualities (LOEQ) „Vlasina“ on occurrence of torrential flood is the Flash Flood Potential Index (FFPI). To identify the possibility of torrential floods occurence, natural conditions were analyzed: slope of the terrain, types of geological substrate, vegetation density and the way the land use. Using the GIS tool, a map of the susceptibility of terrain to the occurrence of torrents in the territory of LOEQ „Vlasina“ was obtained, and the classification of rivers was made based on the probability of occurrence of torrential floods on them.

Keywords: Torrents, GIS, LOEQ „Vlasina“, FFPI

Introduction

Natural or anthropogenic calamities may cause huge material damage and, unfortunately, the loss of human lives. Quantifying the extent and coverage of damage due to flooding is extremely difficult (Alcantara, 2002; Toya and Skidmore, 2007; Spalevic et al., 2017; Blöschl et al., 2019; Lovrić et al., 2019). The occurrence of natural and anthropogenic extreme phenomena all around the world makes us pay more attention to their environmental and economic impacts (Guzzetti et al., 2005; Schmidt et al., 2006; Lerner, 2007). Floods, in all their various forms, are the most frequent natural catastrophic events that occur throughout the world (Berz et al., 2001; Barredo, 2007). Among natural hazards with serious risks for people and their activities, torrential (flash) floods are the most common hazard in Serbia (Ristić and Nikić, 2007; Ristić et al., 2012) and the most significant regarding huge material damage and loss of human lives. The frequency of these events, their intensity and diffusion in the whole country make them a permanent threat with severe consequences to environmental, economic and social spheres (Ristić et al., 2012).

The most commonly used both globally and in our region, is the Flash Flood Potential Index (FFPI). This method was developed at the Colorado Basin River Forecast Centre (USA). Its main purpose is to supplement the conventional tools, such as Flash Flood Monitoring & Prediction System (FFMP). The Flash Flood Potential Index (FFPI) is determined by using GIS software tools through a statistical approach based on the principle of established correlations between the factors and the spatial distribution of drainage basins of the flash flood basin, or heuristic approach, indexing weighting factors, i.e. assigning a weight to individual factors which cause flash floods on the basis of empirical experience (Smith, 2003; Ristić et al., 2009;

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Prăvălie & Costache, 2014; Minea et al., 2016; Kostadinov et al., 2017; Novković et al., 2018).

Serbia has not been included in the most recent studies that have examined flood hazards within the territory of Europe and globally (Barredo, 2007; Mosquera-Machado and Dilley, 2009).

The Vlasina area is very interesting for testing the susceptibility to torrents due to the large floods that have occurred in this area before. The most famous one is from 1988, when the Vlasina River took bridges, destroyed homes and damaged hundreds of acres of arable land.

Material and methods

Study area

Natural property, the landscape of exceptional qualities of "Vlasina", is located in southeastern Serbia, mostly in the territory of the municipality of Surdulica, and with small parts in the territory of the municipality of Crna Trava (Момчиловић, 2019). The area of exceptional qualities of "Vlasina" covers an area of 12,815 acres. There are 12,302.4 acres or 96% in the territory of the municipality of Surdulica, and 512.6 acres or 4% in the territory of the municipality of Crna Trava (ЗЗПС, ПИО „Власина", 2014).

Vlasina Plateau is located in southeastern Serbia, not far from the Serbian-Bulgarian border. According to its surface (with coastal sides about 150 km^2) and the above sea level altitude (the lowest point of the plateau is about 1,200 m), it is one of the most extensive and highest plateaus in Serbia. It is about 30 km away from the South Moravian basin. The plateau is surrounded by high mountains and often scattered between their peaks.

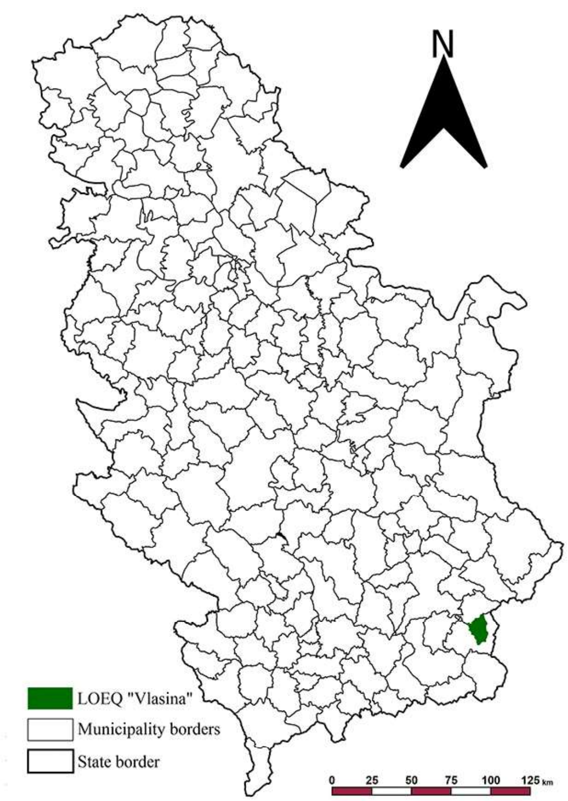

Figure 1. Study area - LOEQ „Vlasina"

On the north side of the Vlasina plateau rises the Gramada mountain (1,721 m), on the west the mountain ranges of Cemernik (1,638 m) and Vardenika (Veliki Streser 1,876 m), on the south side of the Milev mountain (1,733 m), and on the east, towards the Jerma basin, there is a relatively lower area at about 1,400 m (ЗЗПС, ПИО „Власина", 2014).

Metodology

The method used to determine susceptibility to the occurrence of torrential flood is Flash Flood Potential Index (FFPI). It was developed primarily because that torrential flood prediction, based on a survey of meteorological parameters, did not give adequate results and did not define connection between the occurrence of this disaster and certain physical-geographical characteristics of some territory. The structure and texture of the soil are characteristics that define water retention and infiltration. Slope and basin geometry determine the speed and concentration of runoff. Vegetation and structure of the canopy equalize the entering of the atmospheric water in the surface. Land use and urbanization in particular, have an important role in the infiltration of water, concentration and behavior of runoff. Together, these rather static qualities, provide information on the possibility of a torrential flood in a certain area (Smith, 2003).

Of course, they are also subject to dynamic changes. For example, seasonal changes in the vegetation of deciduous forests significantly affect the possibility of the development of mentioned process, and forest fires, in addition to changes in the vegetation, adversely affect the soil, in which, due to the burning of organic matter infiltration power is reduced. The use of this method, as an evaluation methodology of the potential of flash-floods formation, has a special importance, because they represent actual issue in the contemporary society. The pragmatic result of the proposed index is in the spatial representation of the areas with a flash-flood risk, therefore, giving possibility to prevent the negative effects (Prăvălie & Costache, 2014; Lovrić et al., 2019). Calculation of FFPI is performed according to the formula (Smith, 2003):

$$FFPI = \frac{M+S+L+V}{4}, \text{where}$$

M is slope index, S is rock type index, L is land use index, V is vegetation density index.

The slope index (M) is calculated in GIS, based on 25 m digital elevation model (DEM). At first slope is calculated, expressed in percentage, and then following formula is applied:

$$M = 10^{n/30}$$

where n is slope in %. If n is greater or equal to 30%, then M value is always 10.

Geological maps of 1: 100,000 of The Socialist Federal Republic of Yugoslavia scale were used for the analysis of rock types (S). A classification was made based on the predisposition of the geological base to the torrents.

Land use index (L) is calculated on the basis of CORINE Land Cover data (2018), where certain types of land cover were given values from 1 to 10, depending on the characteristics important for the emergence and development torrential processes.

For vegetation density index (V) was using the bare-soil index (BSI). For the purpose of obtaining the said index, the multispectral satellite images of the SENTINEL 2 satellite that belongs to the Copernicus were used. The remote detection technique has unparalleled advantages and potential in the field of regional land erosion assessment and torrents (Vrieling, 2006; Le Roux et al., 2007; Guo & Li, 2009; Mutekanga et al., 2010; El Haj El Tahir et al., 2010, Durlević et al., 2019). The bare-soil index is obtained by the following formula:

$$BSI = \frac{(B6+B4)-(B5+B2)}{(B6+B4)+(B5+B2)} + 1$$

where $B6$ is the shortwave infrared spectral channel (SWIR 1), $B4$ is the red spectral channel, $B5$ is the near infrared spectral channel (NIR), and $B2$ is the blue spectral channel.

To obtain the V coefficient, the formula was also used:

$$V = 7.68 \cdot \ln(BSI) + 8$$

Results and discussion

The slope of the terrain is a very important factor in the analysis of natural conditions for the occurrence of torrents. As the degree of inclination of the terrain increases, the susceptibility to torrential floods increases.

The most common slope of the terrain is from 7.5 to 12.5º. The highest slope was recorded in the northwest and northeast part of the protected area, while the area of the lake and the terrain around the lake is characterized by flat, or slightly inclined terrain. On terrains above 10 degrees slope, combined with other natural conditions, there is a real chance of torrents. The mean slope of the terrain is 8.73º.

Of the rock types, metamorphic rocks account for the highest proportion of representation, while slight magmatic rock formations occur in the southern and western parts. Of the total protected area (127.4 km^2), metamorphic rocks occupy as much as 110.36 km^2. Vlasina Lake covers an area of 14.12 km^2. Magmatic rocks cover 3.55 km^2 of territory and alluvial sediments cover the area of 0.11 km^2. Alluvial sediments occur around river watercourses. A geological substrate made up of metamorphic rocks increases the chances (combined with other geohazards) of torrents.

The map of land use shows heterogeneity in the use of space. A significant part of the surface is occupied by deciduous forests. The thicker the forest floor and the root system, the chances of torrents are less likely. Only one larger settlement was observed. Woody-

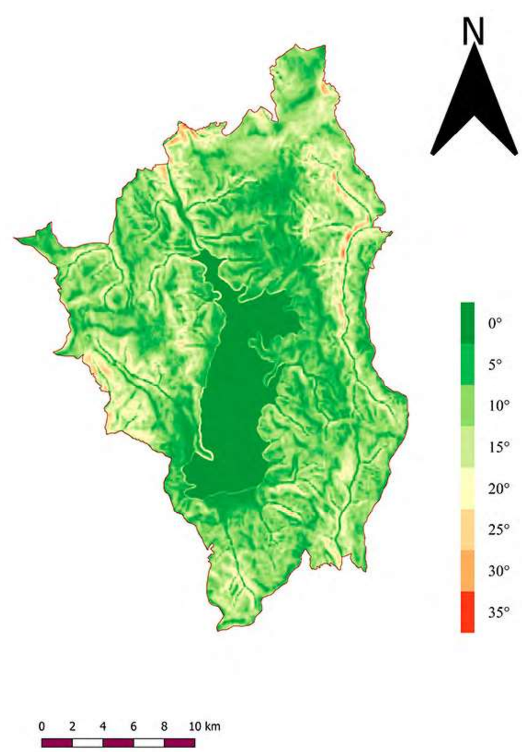

Figure 2. Terrain slope map

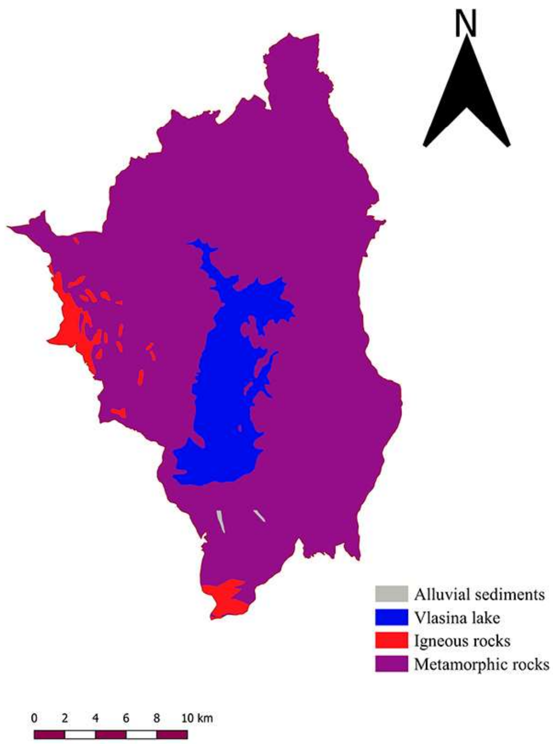

Figure 3. Geological map

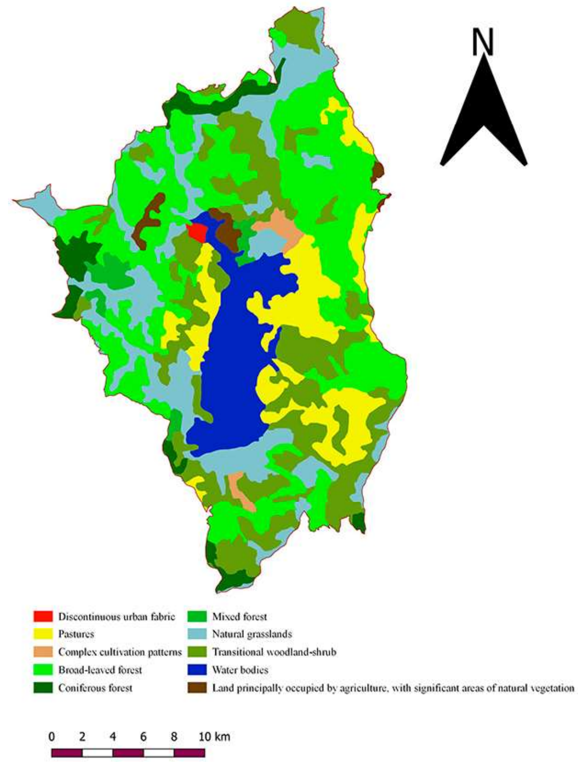

Figure 4. Map of land purpose

shrubby vegetation, as well as pastures, are also present in a larger percentage in the territory of the Protected Areas of Vlasina. The water surface is expressed in the form of Vlasina Lake.

Different levels of land without vegetation can be observed on the terrain map. Terrain dominated by forest ecosystems is represented by the lowest values due to dense vegetation. The orange depicts the

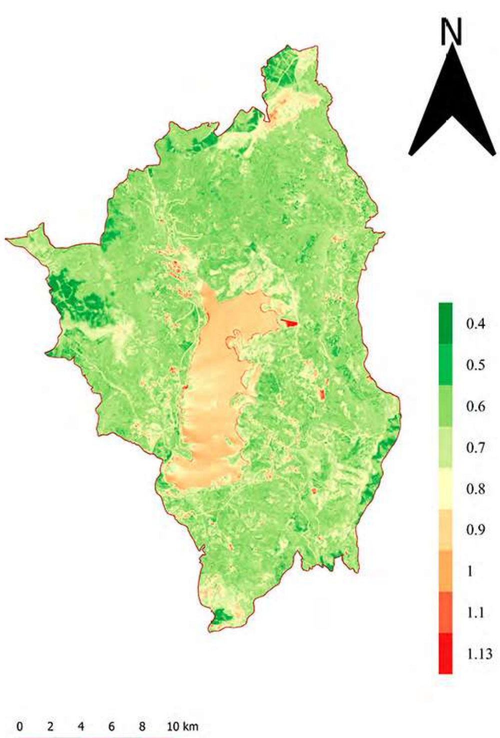

Figure 5. Map of the degree of the terrain denudation (BSI)

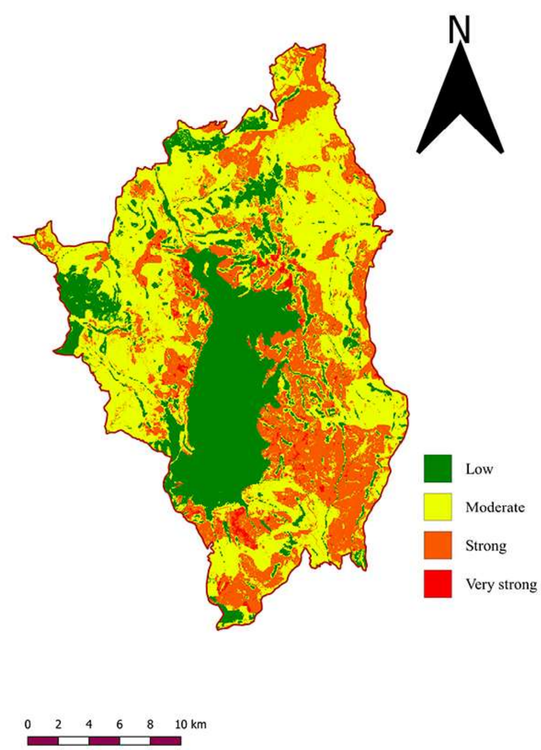

Figure 6. Torrential susceptibility model based on the Flash Flood Potential Index (FFPI) method

bare land, along with Vlasina Lake. The terrains that may be cited as areas with the highest degree of land without vegetation are the areas in the coastal zone whose relief is partially altered by exogenous processes. Also, the process of forest deforestation has a significant effect on increasing the level of land without vegetation, and thus increasing the chances of torrents.

As a final product of this model of torrent calculation, a synthesis map of terrain threatened by torrential floods is presented. The results obtained show the possibility of torrents under appropriate conditions. Whether this will really be the case, depends on a number of factors, which is why we are talking about the predisposition, that is, the susceptibility of the space for the emergence and development of this disaster (Новковић, 2016). After the classification of the Flash Flood Potential Index (FFPI) values obtained, it was found that the very high susceptibility class is represented at 1.5 km^2 of area and the high susceptibility class is 34.9 km^2 of area.

Table 1. Area of terrain threat classes by torrential floods according to the Flash Flood Potential Index method

Susceptibility to torrents	Area (km^2)	Share in total area (%)
Very strong	1.5	1.2
Strong	34.9	27.3
Moderate	58.4	45.6
Low	33.1	25.9
Total	127.9	100

The obtained data show that in 28.5% of the terrain there is a strong and very strongsusceptibility to torrents, mostly to the east of Vlasina Lake. Moderate susceptibility is represented to a large extent (45.6%), while low susceptibility belongs to 33.1% of the territory.

Conclusion

Based on the processing of data in geographic information systems using the Flash Flood Potential Index method, classes of terrain threatened by torrential floods have been defined for the Protected Areas of Vlasina. Additional field research needs to be conducted in an area characterized by being strongly and very strongly susceptible to torrents. Intensification of anti-erosion works in the form of biological, biotechnical and technical works with the aim of reducing the intensity of erosion would greatly contribute to eliminating the damage caused by erosion and torrential floods.

Additional testing is required in the area of smaller tributaries of Vlasina Lake, which flow into the lake from the east side. Afforestation of the terrain and adequate management of agricultural land would lead to a decrease in the percentage of terrain under strong and very strong susceptibility to torrents. Continuous monitoring of the environmental situation in the Protected Areas of Vlasina will enable timely analysis and proper management of this protected area, especially about torrential floods.

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