Original scientific article UDC: 614.823:[007:912]:004](497.11 opština Sokobanja)
Received: 5. May 2022; doi: 10.5937/zrgfub2270005J
Received in revised form: 15. May 2022;
Accepted: 20. May 2022;
Available online: 26. May 2022.

GIS ANALYSIS OF VULNERABILTY FROM LANDSLIDES: A CASE STUDY OF SOKOBANJA MUNICIPALITY

Dušica Jovanović*[1]

*University of Belgrade – Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia

Abstract: This paper analyses area endangered by the process of landslides is in the municipality of Sokobanja. The process of landslides is very important from the aspect of environmental protection, considering that it can occur both naturally and under the influence of anthropogenic factors. For the purposes of this analysis data about geological structure, relief characteristics of the terrain (slope, aspect and terrain curvature), distance from rivers, land cover and values of the bare soil index were processed in the GIS environment. The Probability Method (PM) and the Landslide Susceptibility Index (LSI) were used to calculate the predisposition in relation to existing landslides in the study area. The obtained results indicate a high degree of reliability of these statistical methods for landslide prediction.

Key words: landslide, endangerment, Probability Method (PM), Landslide Susceptibility Index (LSI)

Introduction

Landslides represent a geomorphological process of movement of the surface loose layer and occur as a result of the interaction of certain natural conditions and processes, but also by the action of anthropogenic influences (Драгићевић and Филиповић, 2016). They also play a significant role in the evolution of relief. The impact of man on the occurrence of landslides today plays a significant role because in many areas, although they have a natural predisposition to the occurrence of the landslide process, they will not occur if all of the factors that cause this process are in balance.

[1] Corresponding author: Prof. dr Dušica Jovanović, Univestiy of Belgrade – Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia; e-mail: dusica.jovanovic1012@gmail.com

The term "landslide" includes a wide range of slope movements, such as landslides, mudslides, rockslides, etc. (Varnes, 1978; Pierson and Costa, 1987; Hutchinson, 1988; Cruden and Varnes, 1996; Hungr, Evans, Bovis and Hutchinson, 2001). Landslides are usually associated with triggers, such as earthquakes, sudden snowmelt, or heavy rainfall (Malamud, Turcotte, Guzzetti and Reichenbach, 2004). Like other natural disasters, landslides seriously endanger the safety of life and property of people and directly affect harmonious stability of society and sustainable economic development (Song, Srinivasan, Sookoor and Jeschke, 2017).

Various qualitative and quantitative methods in the GIS environment are used in the contemporary literature to analyse landslide susceptibility (Yalcin, 2008; He, Beighley, 2008; Rabby and Li, 2020; Li, Wang and Chen, 2021). For the purposes of this research, the quantitative statistical method *Probability Method (PM)* was used. Probability method is based on the assumption that landslides are caused by certain factors and that future landslides will occur under the same conditions as existing ones (Новковић, 2016). The analysed factors in this paper are geological structure, slope, aspect, curvature, distance from river flows, land cover and bare soil index.

Also, the *Landslide Susceptibility Index (LSI)* was used to integrate these factors and classes into a single index of susceptibility to the process of landslides. This well-known and widely used statistical method for zoning landslide susceptibility (Tien Bui, Lofman, Revhaug and Dick, 2011; Chalkias and Ferentinou, 2014; Polykretis, Ferentinou and Chalkis, 2015) results in a susceptibility map of the study area and the probability level of landslide occurrence.

In this paper, the research was conducted using open source software QGIS. Geographic Information Systems (GIS) are systems that enable the entry, search, analysis, manipulation, management and presentation of geographic information. Although GIS provides the use of additional information from various sources (Ракић, 2007), today, according to many authors, one of the biggest problems in Serbia is the lack of quality and up-to-date data (Stojković, 2017; Vagić, 2018).

The main goal of this paper is to create landslide susceptibility map of Sokobanja municipality using statistical methods in the GIS environment. The map obtained was used to identify roads and facilities that are subjected to damage from future landslides, and can be used to take the necessary measures to prevent landslides.

Materials and methods

Study area

The study area is located in the region of Eastern Serbia in the Zaječar district (Figure 1). The municipality of Sokobanja is located in the southwestern part of the Zaječar district between 43°31´41.1´´N and 43° 46´51.9´´N and 21°40´33.2´´E and 22°5´36´´E. It borders the municipality of Ražanj in the northwest, the municipality of Knjaževac in the northeast, the municipality of Aleksinac in the southwest and the municipality of Svrljig in the southeast.

The area of the municipality of Sokobanja occupies 525 km^2, and according to the 2011 cnesus it has 16 021 inhabitants, while the average population density is 27.95 inhabitants/km^2 (Republički zavod za statistiku, 2011). There are a total of 25 settlements in the municipality. The center of the municipality is the settlement of Sokobanja, which has the largest number of inhabitants, occupies the biggest area and also represents the administrative, economic and cultural center of the municipality. The most important roads within the municipality are the state roads of the second A order with the labels 217 and 218 and the state road of the second B order with the label 420, which connects to the state road with the label 217 (JP "Putevi Srbije", 2021).

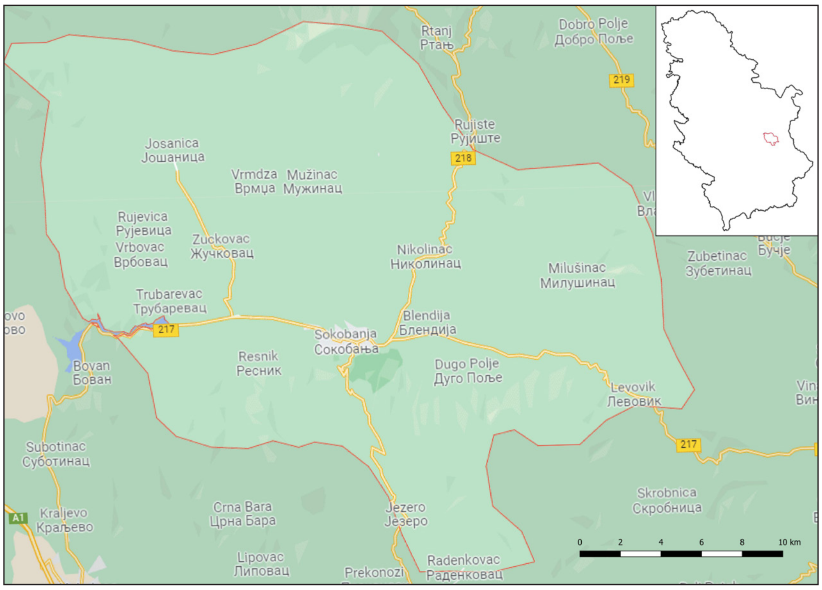


Figure 1. Geographical position of the municipality of Sokobanja in Serbia

On the territory of the municipality the most common relief type is the karst relief form. The river network is well developed, but most of it consists of occasional flows. The most important river, as well as the largest, which flows through this municipality is the river Moravica. The municipality of Sokobanja is also known for its thermal springs, which are used for balneological purposes.

Methodology

The used methodology includes the application of the Probability Method and the Landslide Susceptibility Index. Probability method determines the possibility of the landslides occurance in a particular class and is calculated by the formula (Van Westen, 1997):

$$Wij = \frac{Aij\prime * (A - A\prime)}{A' * (Aij - Aij')}, \qquad (1)$$

where *Wij* – is the value of class i of the parameter *j*; *Aij′* –landslides surface in a certain class *i* of the parameter *j*; *Aij* –area of a certain class *i* of the parameter *j*; *A′* –total landslide surface in the study area; *A* – total are of the study area.

The higher the obtained value is, the stronger the dependence of the landslide occurrence is on a given factor and vice versa (Lee and Pradhan, 2006). The integration of different factors and classes into a single Landslide Susceptibility Index is achieved based on the formula (Voogd, 1983):

$$LSI = \sum n \ W_j * \ W_{\substack{ij \\ j=1}} \qquad (2)$$

where W_j – parameter value; W_{ij} – value of the class *i* of the parameter *j*; *n* – number of parameters.

Finally, all of the obtained index values are divided into four classes which represent four categories of landslide potential (low, medium, high and very high). There are no established rules for this division, so it is done subjectively, either on the basis of the researchers assessment or on the basis of some statistical method that is contained in the GIS software – e. g. based on equal intervals, natural breaks, standard deviation etc. (Новковић, 2016)

The application of the Probability Method was performed based on the data about geological structure, relief characteristics (slope, aspect and curvature), distance from rivers, land cover (CORINE Land Cover[2]) and values of BSI (bare soil index[2]).

The basis of the calculation consists of a raster digital model with a resolution of 25 m from which the data about slope, aspect and curvature were extracted and then divided into classes based on the importance of participation in the emergence and development of the landslides process. Data on the value of bare soil index were obtained by analysis of multispectral images from Landsat 8 satellite. Geological structure, land cover and distance from rivers were rasterized based on a vector data model because of the calculation needs. Tables 1-7. shows all used parameters.

Table 1. Display of LSI values for geological formations

	Area		**Landslides**		**Wij**
	km2	%	km2	%	PM
Landslides	529	100	62.1	11.74	
Geological formation					
Rock creep	6.2	1.17	1.18	1.9	1.76
Tuff rock	0.55	0.1	0.28	0.45	7.61
Alluvial sediment rocks	13.13	2.48	0.46	0.74	0.27
Sediments of the river terrace	2.74	0.52	0.16	0.26	0.47
Tertiary carbonate sediment rocks	1	0.19	0	0	0
Tertiary clastic sediment rocks	214.26	40.5	51.26	82.54	2.36
Mesozoic clastic sediment rocks	8.26	1.56	0.32	0.52	0.3
Mesozoic clastic and carbonate sediment rocks	75.95	14.36	3.93	6.33	0.41
Mesozoic carbonate sediment rocks	105.41	19.93	1.46	2.36	0.11
Volcaniclastics	5.13	0.97	0	0	0
Igneoous rocks	1.47	0.28	0.33	0.53	2.16
Paleozoic clastic sediment rocks	36.3	6.86	0.89	1.43	0.19
Paleozoic carbonate sediment rocks	1.8	0.34	0.03	0.05	0.14
Metamorphic rocks	56.79	10.74	1.8	2.9	0.25

[2] The map of geological structure of the study area was obtained by digitizing the contents of basic geological maps, sheets: Boljevac K34-8, Zaječar K34-9, Žagubica L34-140 and Bor L34-141, scale 1: 100,000, issued by the Federal Geological Survey in 1975, using an interpreter to analyse the contents of the map. The river network was digitized from topographic maps of the sheets Aleksinac 1, 2, 3, 4 and Zaječar 3. The digital elevation model and land cover were downloaded from the website https://land.copernicus.eu/, and satellite images from https://www.usgs.gov/

Table 2. Display of LSI values for slope

	Area		Landslides		Wij
Slope	km2	%	km2	%	PM
<2°	27.33	5.17	2.3	3.72	0.7
2-5°	90.6	17.13	10.39	16.83	0.98
5-10°	186.5	35.25	28.84	46.72	1.38
15-20°	118.95	22.49	13.38	21.67	0.96
15-20°	61.29	11.59	3.86	6.25	0.51
20-30°	39.47	7.46	2.38	3.86	0.49
>30°	4.88	0.92	0.59	0.96	1.04

Table 3. Display of LSI values for aspect

	Area		Landslides		Wij
Aspect	km2	%	km2	%	PM
N	61.32	11.59	15.74	25.49	2.61
NE	59.76	11.3	4.18	6.77	0.57
E	54.21	10.25	2.91	4.71	0.43
SE	60.99	11.53	5.55	8.99	0.76
S	84.46	15.96	4.88	7.9	0.46
SW	87.65	16.57	3.99	6.47	0.36
W	66.34	12.54	4.49	7.28	0.55
NW	53.6	10.13	4.74	7.68	0.73
Not exposed	0.69	0.13	15.26	24.71	0

Table 4. Display of LSI values for curvature classes

	Area		Landslides		Wij
Curvature	km2	%	km2	%	PM
1 - vertically concave, horizontally concave	131.29	24.82	15.74	25.49	1.03
2 - vertically flat, horizontally concave	33.12	6.26	4.18	6.77	1.09
3 - vertically convex, horizontally concave	31.8	6.01	2.91	4.71	0.76
4 - vertically concave, horizontally flat	40.45	7.65	5.55	8.99	1.2
5- vertically flat, horizontally flat	37.39	7.07	4.88	7.9	1.14
6 - vertically convex, horizontally flat	35.45	6.7	3.99	6.47	0.96
7 - vertically concave, horizontally convex	37.92	7.17	4.49	7.28	1.02
8 - vertically flat, horizontally convex	37.41	7.07	4.74	7.68	1.1
9 - vertically convex, horizontally convex	144.19	27.26	15.26	24.71	0.9

Table 5. Display of LSI values for distance from rivers [m]

	Area		Landslides		Wij
Distance	km2	%	km2	%	PM
<100	128.91	24.37	18.68	30.07	1.27
100-200	112.76	21.32	15.85	25.52	1.23
200-300	89.01	16.83	11.43	18.4	1.11
300-400	62.81	11.87	7.11	11.45	0.96
400-500	41.49	7.84	4.33	6.98	0.88
>500	94.03	17.77	4.7	7.58	0.4

Table 6. Display of LSI values for Corine land cover 2018

	Area		Landslides		Wij
Land Cover	km2	%	km2	%	PM
Bigger settlements	8	1.51	2.56	4.16	3.57
Sport and leisure facilities	0.33	0.06	0	0	0
Agricultural areal	40.7	7.69	3.21	5.21	0.65
Orchards	0.27	0.05	0	0	0
Meadows	5.96	1.13	1.72	2.78	3.06
Complex of agricultural plots	67.12	12.69	20.62	33.47	3.36
Agricultural areas with a significant share of natural vegetation	95.5	18.05	23.73	38.51	2.51
Deciduous forests	180.22	34.07	6.8	11.04	0.3
Coniferous forests	2.17	0.41	0.04	0.06	0.13
Mixed forests	11.95	2.26	0.16	0.27	0.11
Grasslands	44.68	8.45	0	0	0
Transitional woodland-shrub vegetation	66.76	12.62	2.77	4.49	0.33
Sparsely vegetated areas	4.19	0.79	0	0	0
Water bodies	1.15	0.22	0.01	0.01	0.04

Table 7. Display of LSI values for BSI

	Area		**Landslides**		**Wij**
BSI	km2	%	km2	%	PM
<0.5	0.52	0.1	0.01	0.01	0
0.5-0.6	44.35	8.38	3.74	6.02	0.06
0.6-0.7	209.55	39.61	16.77	27	0.27
0.7-0.8	100.09	18.92	15.32	24.66	0.25
0.8-0.9	94.39	17.84	15.26	24.56	0.25
0.9-1.0	65.27	12.34	8.8	14.17	0.14
1.0-1.1	14.35	2.71	1.83	2.94	0.03
>1.1	0.17	0.03	0.02	0.04	0

The PM method application implies the existence of landslides spatial distribution data and for the purposes of this paper landslides data for Eastern Serbia were used. (Dragićević, Novković, Carević, Živković and Tošić, 2011). The landslide distribution data were overlapped with all individual parameters according to the formulas for each parameter. The pixels in each of the rasters representing the parameter classes were then reclassified. The value of the spatial distribution of LSI for the study area was obtained by summing the raster of all parameters.

Results and discussion

The results of the statistical (LSI) analysis for the study area, as well as the distribution of existing landslides are shown in Figure 2.

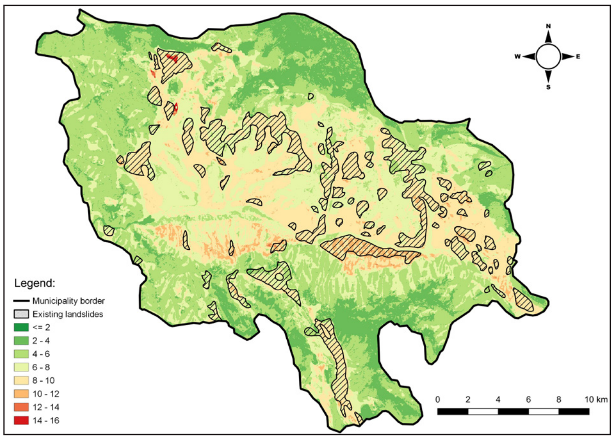


Figure 2. Spatial distribution of LSI on the territory of the municipality of Sokobanja

After the LSI index classification, 4 classes of susceptibility to the sliding process were obtained (Figure 3), and the average value of LSI for the territory of the municipality is 6.91.

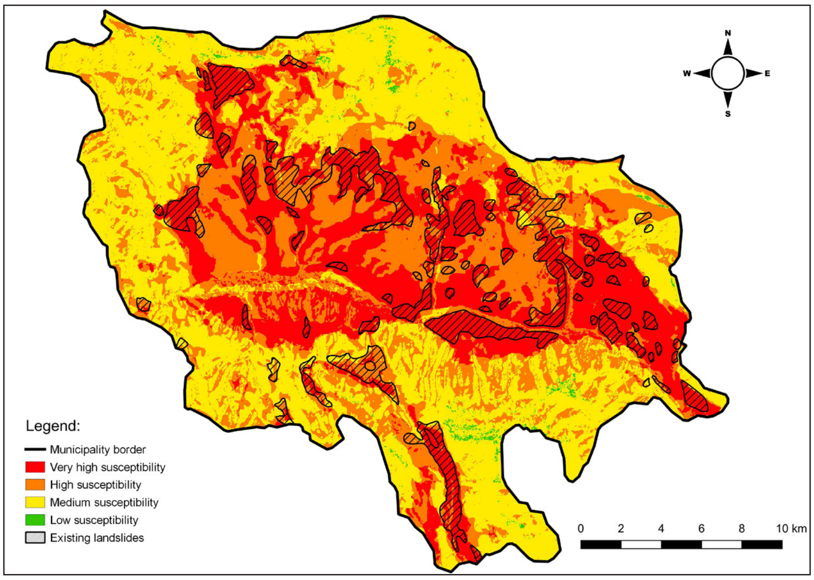


Figure 3. LSI by susceptibility classes

According to the estimations, very high susceptibility occurs in 28.19% of the territory, while low susceptibility occupies the smallest part of the territory (table 8). The largest part of the territory belongs to the class of medium susceptibility (41.02%).

Table 8. Contribution of susceptibility classes to the process of landslides in the Sokobanja municipality

Landslides susceptibility	km^2	%
Very high	148.80	28.19
High	159.70	30.26
Medium	216.51	41.02
Low	2.78	0.53
Total	527.79	100

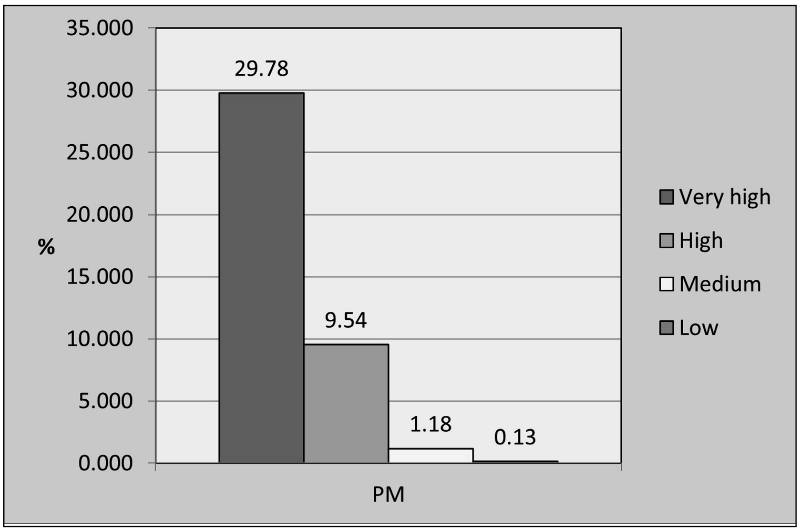
Further comparison of the obtained PM values was performed by overlapping the existing landslides and the formed classes of susceptibility to the soil sliding process (table 9).

Table 9. Contribution of soil susceptibility classes in Sokobanja municipality landslides

Landslides in susceptibility classes	**km²**	**%**
Very high	44.31	71.36
High	15.24	24.54
Mediuma	2.55	4.10
Low	0.00	0.01
Total	62..09	100

Based on Table 9, it can be concluded that the most common is the very high susceptibility within the already existing landslides.

Graph 1 shows the percentage of each susceptibility class that landslides occur in. In the class of very high susceptibility, landslides occur on 29.78% of the territory, and in the class of low susceptibility, only 0.13%.



Graph 1. The share of landslides in the classes landslides of susceptibility

Based on the LSI value for the municipality territory, it is possible to determine the average value of vulnerability for each cadastral municipality. Table 10 shows the average values of LSI by cadastral municipalities.

Table 10. Overview of LSI average values by settlements

Name of cadastral municipality	Average value of LSI
Beli Potok	8.08
Blendija	6.77
Bogdinac	7.77
Vrbovac	5.69
Vrmdža	5.87
Dugo Polje	6.69
Žučkovac	7.87
Jezero	5.56
Jošanica	5.62
Levovik	5.84
Milušinac	6.46
Mužinac	5.64
Nikolinac	7.59
Novo Selo	4.92
Poružnica	5.58
Radenkovac	5.22
Resnik	6.29
Rujevica	5.26
Sesalac	6.47
Sokobanja	7.00
Trgovište	7.94
Trubarevac	5.78
Cerovica	6.76
Čitluk	7.86
Šarbanovac	5.89

Based on Table 10 and Figure 4, it can be concluded that in the municipality none of the average value fall into the low category. Six cadastral municipalities are in the category of very high susceptibility according to the mean value, 18 in the category of high susceptibility, and only one is in the category of medium susceptibility. The highest susceptibility according to the mean value is found within cadastral municipalities where landslides already exist, which are mostly located within tertiary clastic sediment rocks.

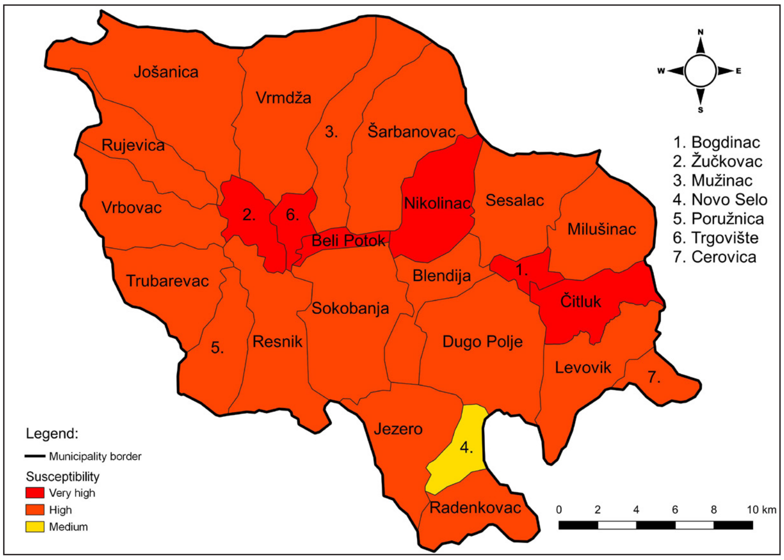


Figure 4. Mean value of LSI by cadastral municipalities

The endangerment of traffic infrastructure and facilities on the territory of the municipality is shown in Figures 5 and 6. Figure 5 shows that landslides mostly occupy areas within uncategorized roads or directly next to state roads of the second order. The length of roads endangered by landslides is 369.5 km.

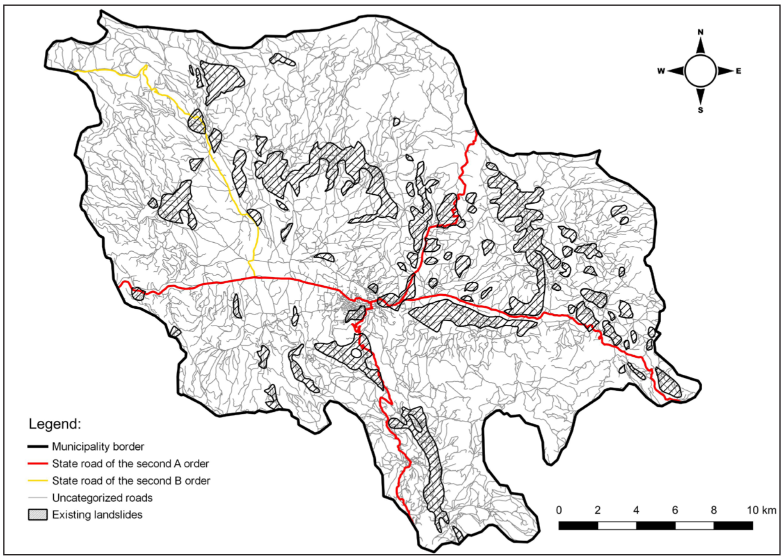


Figure 5. Endangerment of traffic infrastructure with landslides

Figure 6 shows the facilities overlapping with the existing landslides.

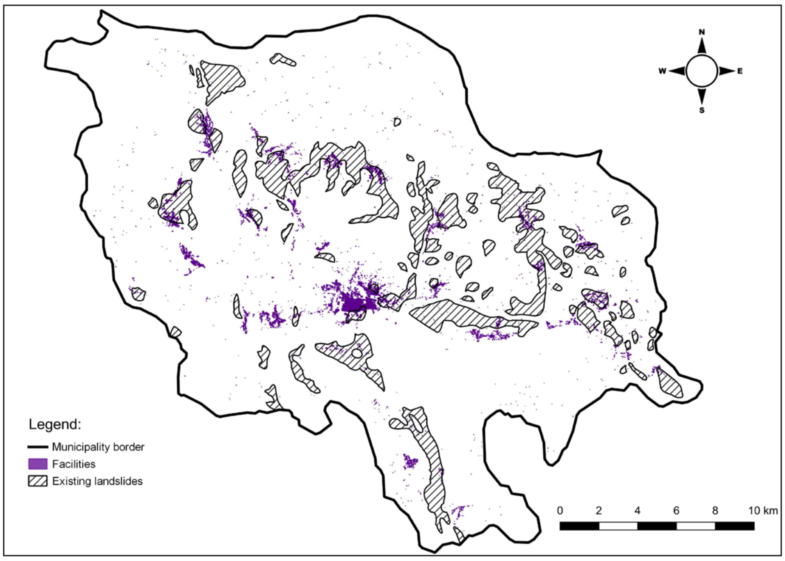


Figure 6. Vulnerability of facilities to landslides

The area of the landslide occupied by the facilities is 0.71 km^2. This may indicate that landslides were caused by anthropogenic impact on terrains that were already naturally predisposed to the occurrence of a landslide process.

Conclusion

Landslide susceptibility mapping is extremely important for the identification of landslide susceptibility areas in order to reduce future landslides and damage to infrastructure and facilities. The application of statistical analysis in the GIS environment evaluate the relationship between the occurrence of landslides and various influencing factors. In this paper, seven factors that affect the occurrence of landslides were used (geological structure, slope, aspect, curvature, distance from rivers, land cover and bare soil index), which were collected and processed in the GIS environment.

The choice of these factors plays a major role in the relative accuracy of the analysis outcome, regardless of the model applied. Based on the obtained results, it is obvious that the most important factors for the occurrence of landslides in the municipality of Sokobanja are the geological structure and the manner of land use. A large number of already existing landslides occur on built and agricultural areas, which indicates omissions in the analysis of the terrain during process of land use decisions making.

The applied methodology, more specifically the Probability Method, shows a high degree of reliability in predicting the occurrence of landslides, because already existing landslides are in classes in which the value of PM is highest, or in classes of very high or high susceptibility. In a very high susceptibility class there are 71.36% of already existing landslides, and a very small percentage are in the middle and low susceptibility class.

Regardless of the high quality of the obtained results, it is necessary to point out some limitations of the applied methodology. Adequate data are most important for quality GIS analysis. The problem arises if required data are not available or do not exist. Given the changes in natural and anthropogenic factors that are important for these processes, it would be best to establish a system of periodic or continuous monitoring and verification of the situation on the terrain. Also, it should be noted that, according to this analysis, the output map represents only the predicted spatial distribution of landslides, and not their time probability.

By applying modern technologies, it is possible to collect detailed data on the analyzed area, and then, using GIS, perform both the processing of such collected data and the development of a model of the future situation. This way of analysis can prevent potential disasters if implemented in time or at least reduce their negative effects. Despite the observed limitations, the produced map could be very useful for the selection of suitable locations for future land use planning and the development of the municipality of Sokobanja.

References

Драгићевић, С., Филиповић, Д., (2016). *Природни услови и непогоде у планирању изаштити простора*. Београд: Универзитет у Београду, Географски факултет.

Новковић, И. (2016*). Природни услови као детерминанте геохазарда на примеру сливова Љига, Јошаничке и Врањскобањске реке (Необјављена докторска дисертација)*. Универзитет у Београду, Географски факултет, Београд.

Republički zavod za statistiku. (2011). *Popis sttanovništva, domaćinstava i stanova 2011. u Republici Srbiji – Uporedni pregled broja stanovnika 1948, 1953, 1961, 1971, 1981, 1991, 2002. и 2011*. Beograd: Republički zavod za statistiku

Ракић, У. (2007). *ГИС и инфективне болести*. Зборник радова – Географски факултет Универзитета у Београду, 55, 217-230.,

Dragićević S., Novković I., Carević I., Živković N., Tošić R. (2011): *Geohazard Assessment in the Eastern Serbia*. Forum Geografic, 10 (1): 10-19.

Chalkias, C., Ferentinou, M., Polykretis, C. (2014). *GIS-Based Landslide Susceptibility Mapping on the Peloponnese Peninsula, Greece*. Geosciences, 4, 176-190. doi:10.3390/geosciences4030176

Cruden, DM., Varnes, DJ. (1996*). Landslide types and processes. In Landslides, Investigation and Mitigation.* In: Turner, AK., Schuster, RL. (eds). Special Report 247. Transportation Research Board: Washington DC; 36–75.

He, Y.; Beighley, R.E. (2008). GIS-based regional landslide susceptibility mapping: A case study in southern California. Earth Surf. Process. Landf., 33, 380–393.

Hungr, O., Evans, SG., Bovis, MJ., Hutchnison, NJ. (2001). *A review of the classification of landslides of the flow type.* Environmental and Engineering Geoscience 7:3 221–238.

Hutchinson, JN. (1988). *General Report: morphological and geotechnical parameters of landslides in relation to geology and hydrogeology*. In Proceedings Fifth International Symposium on Landslides vol. 1. In: Bommard C (ed.). Balkema: Rotterdam; 3–36.

Lee S., Pradhan B. (2006). *Probabilistic landslide hazards and risk mapping on Penang. Island, Malaysia.* Earth System Science, 115(6): 661-672.

Li, B., Wang, N., Chen, J. (2021). *GIS-Based Landslide Susceptibility Mapping Using Information, Frequency Ratio, and Artificial Neural Network Methods in Qinghai Province, Northwestern China.* Advances in Civil Engineering, vol. 2021, Article ID 4758062, 14 pages. https://doi.org/10.1155/2021/4758062

Malamud, B., Turcotte, D., Guzzetti, F., Reichenbach, P.(2004). *Landslide inventories and their statistical properties. Earth Surf.* Process. Landforms 29, 687–711

Pierson, CP., Costa, JE. (1987). *Arheologic classification of subaerial sediment-water flows. In Debris Flows/Avalanches: Process, Recognition and Mitigation.* In: Costa, JE., Wieczorek, GF. (eds). Reviews in Engineering Geology VII. Geological Society of America: 1–12.

Polykretis, C.; Ferentinou, M.; Chalkias, C. (2015). *A comparative study of landslide susceptibility mapping using landslide susceptibility index and artificial neural networks in the Krios River and Krathis River catchments (northern Peloponnesus, Greece)*. Bulletin of Engineering Geology and the Environment 74(1):27-45. DOI:10.1007/s10064-014-0607-7

Rabby, YW, Li, Y. (2020). *Landslide Susceptibility Mapping Using Integrated Methods: A Case Study in the Chittagong Hilly Areas, Bangladesh*, Geosciences 2020, 10, 483. doi:10.3390/geosciences10120483

Song, H., Srinivasan, R., Sookoor, T., Jeschke, S. (2017). *Smart Cities: Foundations, Principles and Applications*. ISBN: 978-1-119-22639-0, Hoboken, NJ:Wiley, pp. 1–906.

Stojković, S. (2017). *GIS Analysis of Land Use Changes – Case Study: the Stara Pazova Municipality, Serbia.* Collection of Papers - Faculty of Geography at the University of Belgrade, 65 (1a), 295-306.

Tien Bui, D.; Lofman, O.; Revhaug, I.; Dick, O. (2011). *Landslide susceptibility analysis in the Hoa Binh province of Vietnam using statistical index and logistic regression.* Nat. Hazards, 59, 1413–1444.

Vagić, N. (2018). *Comparative Analysis of NDVI Index and Different Satellite Images Classifications in Determination the Vegetation Inventory of Vrčin Settlemen*t. Collection of Papers - Faculty of Geography at the University of Belgrade, 66-2, 63-83.

Varnes DJ. (1978). *Slope movements, type and processes. In Landslide Analysis and Control.* In: Schuster RL, Krizek RJ (eds). Transportation Research Board, Special Report 176. National Academy of Sciences: Washington; 11–33.

Van Westen, C. (1997). *Statistical Landslide Hazard Analysis. ILWIS 2.1 for Windows application guide.* ITC Publication, Enschede: 73-84;

Voogd, H. (1983) *Multicriteria Evaluation for Urban and Regional Planning.* Pion Ltd., London.

Yalcin, A. (2008). *GIS-based landslide susceptibility mapping using analytical process and bivariate statistics in Ardesen (Turkey): Comparisons of results and confirmations.* Catena, 72, 1–12.

European Environment Agency. (2018). CORINE Land Cover (CLC). Retrieved from https://land.copernicus.eu/pan-european/corine-land-cover

European Environment Agency. (2021). European Digital Elevation Model (EU-DEM), version 1.1 Retrieved from https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1?tab=download

JP "Putevi Srbije". (2021). II A – Spisak državnih puteva. Retrieved from https://www.putevi-srbije.rs/images/pdf/referentni-sistem/2.2.3_spisak_drzavnih_puteva_IIAreda.pdf

JP "Putevi Srbije". (2021). II B - Spisak državnih puteva. Retrieved from https://www.putevi-srbije.rs/images/pdf/referentni-sistem/2.2.4_spisak_drzavnih_puteva_IIBreda.pdf

U.S. Geological Survey. (2021). Earth Explorer. Retrieved from https://www.usgs.gov/