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Landslide susceptibility assessment of the Teslić municipality, in the Republic of Srpska, B&H

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Abstract This paper presents the landslide susceptibility assessment of the Teslić municipality. The paper also presents information on engineering geological properties and landslides in this area, based on field data collection and input into the digital GIS cadaster of landslides. Landslides are a common phenomenon in this area, but they are poorly treated in the spatial planning documentation. Landslides are mostly shallow, with a depth of up to 2 m, and they are most often activated in areas of intense human activity, in areas of roads and by the river courses. Landslide susceptibility assessment was performed, after the field registration and the establishment of a digital cadaster of landslides, in polygonal form. All influential factors were taken into account, such as lithology, slope, precipitation, distance to watercourses, land use, aspect and curvature. Modelling was performed using the multi-criteria AHP method in the scale of 25x25 m.

Keywords landslide, database, susceptibility, Teslić

Introduction

Landslides represent one of the most significant modern geological processes in the world (Glade et al., 2004; Guzzetti, 2005; 2020). Landslides represent a very complex problem that is common within the territory of the Republic of Srpska, B&H (Sandić, 2015). The municipality of Teslić is one of the municipalities in the Republic of Srpska, where this problem is very pronounces.

Through field mapping in the last year, 128 occurrences of landslides were registered on the field and entered into the database. Landslides which were mapped in detail, according to the Cruden and Varnes classification (1996) and actual instructions and the Rulebook for entering data into the digital landslide cadastral (Official Gazette of Republic of Srpska No. 113/22).

Study area

The municipality of Teslić is located in the western part of the Republic of Srpska, i.e. in the central part of Bosnia and Herzegovina (Fig. 1). Teslić is one of the largest municipalities in the Republic of Srpska. It covers an area of 846 km².

According to earlier research, this area was characterized as prone to landslides, with large material damages in the previous period (Mitrović& Sandić, 2011; Sandić, 2015).

The geological setting is very complex, but diabase - chert formation and Oligo-Miocene complex of conglomerate, marl and clay, have the largest share in the percentage of registered landslides. It is very important to mention the very pronounced engineering and human activity in most of the municipality. It is also the reason for the activation of a large number of landslides.

Landslides are mostly shallow, with a depth of up to 2 m. Sliding occurs when contact between the decomposed cover and the underlying rock mass. The cover is mostly clayey-sandy (52%) and debris type (48%), (Sandić & Leka, 2023).

Figure 1 Geographical position of the Teslić municipality.

Applied Methodology

The development of methodologies for landslide susceptibility, hazard and risk assessment, dates back to the 70's of the XXI century (Nilsen et al., 1979), intensively continued and applied during the nineties (Aleotti & Chowdhury, 1999), and today become the "main tool" used in the combat against these natural disasters, primarily in spatial planning (AGS, 2007; Cascini, 2008; Fell et al. 2008; Anderson & Holcombe, 2013; Abolmasov, 2016).

Preparing the landslide susceptibility maps generally includes the following steps: preparing a detailed inventory of the landslides present in the study area, and the identification of the conditions and processes controlling them as well as the triggering factors (Sandić et al., 2017).

The landslide susceptibility assessment and map for the Teslić municipality were generated according to the Analytical Hierarchy Process (AHP) principles (Saaty 2003). The first step was to determine the causative factors and their relative-normalized importance, considering the scale of the landslide susceptibility map.

For modelling seven main parameters were identified such as: lithology (L), slope (S), slope aspect (A), slope curvature (C), land cover (LU), distance to water boundaries (W) and average historical precipitation (P).

Table 1 Causative parameters (factors), parameters class and their weighting factor (WF).

L	Lithological unit	WF
al	Alluvial sediments; River terrace	1
J	Jurassic igneous and metamorphic rocks	2
T_2	Limestones	3
^2T, J	Marly limestones, cherts, clays, sandstones	4
J, K	Marls and limestones	5
J, K	Breccias, clays, marls, sands, clays, gravels	6
$T_{2,3}$; J	Layered marls, coal, clay, sand	7
Pl, Q; dpr	Conglomerates, gravel, sand, gravels, clays, cherts	8
M	Marls, sandstones, conglomerates, tuffs, coal	9
Ol, M	Sandstones, marls, conglomerates, clays, coal	10
S	**Slope (°)**	**WF**
1	>30	4
2	0-5	5
3	5-10	6
4	20-30	7
5	15-20	9
6	10-15	10
P	**Precipitation (mm/year) - average**	**WF**
1	<900	5
2	900-1000	6
3	1000-1100	8
4	>1100	10
W	**Distance to water boudaries (m)**	**WF**
1	>1000	3
2	800-1000	7
3	500-800	8
4	200-500	9
5	0-200	10
LU	**Land Use (Category)**	**WF**
1	Forests and natural areas	2
2	Shrubs and/or grassy plant cover	4
3	Agricultural areas, pastures, bushes	5
4	Urban area	8
A	**Aspect**	**WF**
1	Flat	1
2	E; SE; S; W	3
3	SW	6
4	N; NE;NW	9
C	**Curvature**	**WF**
1	(-1) - 1	1
2	(-18,12) – (-1)	3
3	1 – 37,06	6

All parameters were modelled as a grid (raster) in a GIS environment. AHP was selected as a suitable procedure for multi-criteria modelling with rasters, and analysis of spatial data on landslides and other influencing factors (Marjanović, 2013).

Each parameter class was evaluated and their relationships were weighted (Tab 1).

The modelling procedure was generally done by comparing the above causative parameters in terms of importance for the development of the landslide process based on expert judgment. It should be emphasized that the data on the spatial distribution of landslides represent the key and most important information needed for the creation of this type of map. Each parameter included in the analysis was validated (checked) with spatial data on landslides.

Table 2 Landslide susceptibility AHP matrix for Teslić municipality.

AHP	L	S	P	W	LU	A	C	
L	1	2	5	5	6	7	8	
S	0,5	1	4	4	5	6	8	
P	0,2	0,25	1	2	3	4	6	
W	0,2	0,25	0,5	1	2	3	4	
LU	0,16	0,2	0,33	0,5	1	2	4	
A	0,14	0,16	0,25	0,33	0,5	1	3	
C	0,12	0,12	0,16	0,25	0,25	0,33	1	
Σ	2,3	3,9	11,2	13,1	17,7	23,3	34	
AHP	**L**	**S**	**P**	**W**	**LU**	**A**	**C**	**Sr**
L	0,43	0,50	0,44	0,38	0,33	0,30	0,23	**0,376**
S	0,21	0,25	0,35	0,30	0,28	0,25	0,23	**0,271**
P	0,08	0,06	0,08	0,15	0,17	0,17	0,17	**0,130**
W	0,08	0,05	0,04	0,07	0,11	0,12	0,11	**0,090**
LU	0,07	0,05	0,03	0,03	0,05	0,08	0,11	**0,064**
A	0,06	0,04	0,02	0,02	0,02	0,04	0,08	**0,044**
C	0,05	0,03	0,01	0,01	0,01	0,01	0,02	**0,025**
Σ	1	1	1	1	1	1	1	1

A corresponding equation of landslide susceptibility was developed through the AHP matrix (Tab 2) as a:

$$LS = 0{,}376xL + 0{,}271xS + 0{,}130xP + 0{,}094xW + 0{,}060xLU + 0{,}044xA + 0{,}025xC \qquad [1]$$

wherein:
LS-Landslide susceptibility
L-Lithological data
S-Slope angle data
P-Precipitation data
W-Distance to watercourses
LU-Land use data
A-Slope aspect
C-Slope curvature

For each parameter included in the analysis, analytical maps were made, according to the adopted criteria, i.e. weighting factors values (Fig. 2, part a-g).

As we can see from Eq. 1 and Tab. 2, lithological data has the greatest influence on modelling (Fig. 2, part a). During the field mapping of landslides, engineering-geological mapping of the terrain was carried out, which produced a map on a scale of 1:25000. Weighting factors were assigned by overlapping with the registered landslides. Higher weighting factors were assigned to units with a higher number of registered landslides.

A similar procedure was applied to the rest of the causative factors: slope (Fig. 2, part b), precipitation (Fig. 2, part c), distance to water boundaries (Fig. 2, part d), land cover (Fig. 2, part e), slope aspect (Fig. 2, part f), and slope curvature (Fig. 2, part g).

Results and conclusion

A landslide susceptibility map was obtained through a procedure carried out in a GIS environment (Fig. 2, part h). The map has been divided (reclassified) into five (5) classes, from very low to very high class of susceptibility.

The analysis of the obtained results showed that most landslides were activated in the "high" and "very high susceptibility" categories and that they occupy 21% and 3% of the territory of the Teslić municipality (Fig.3). This somewhat coincides with the opinion that about 30% of the territory of Teslić municipality has high landslide susceptibility.

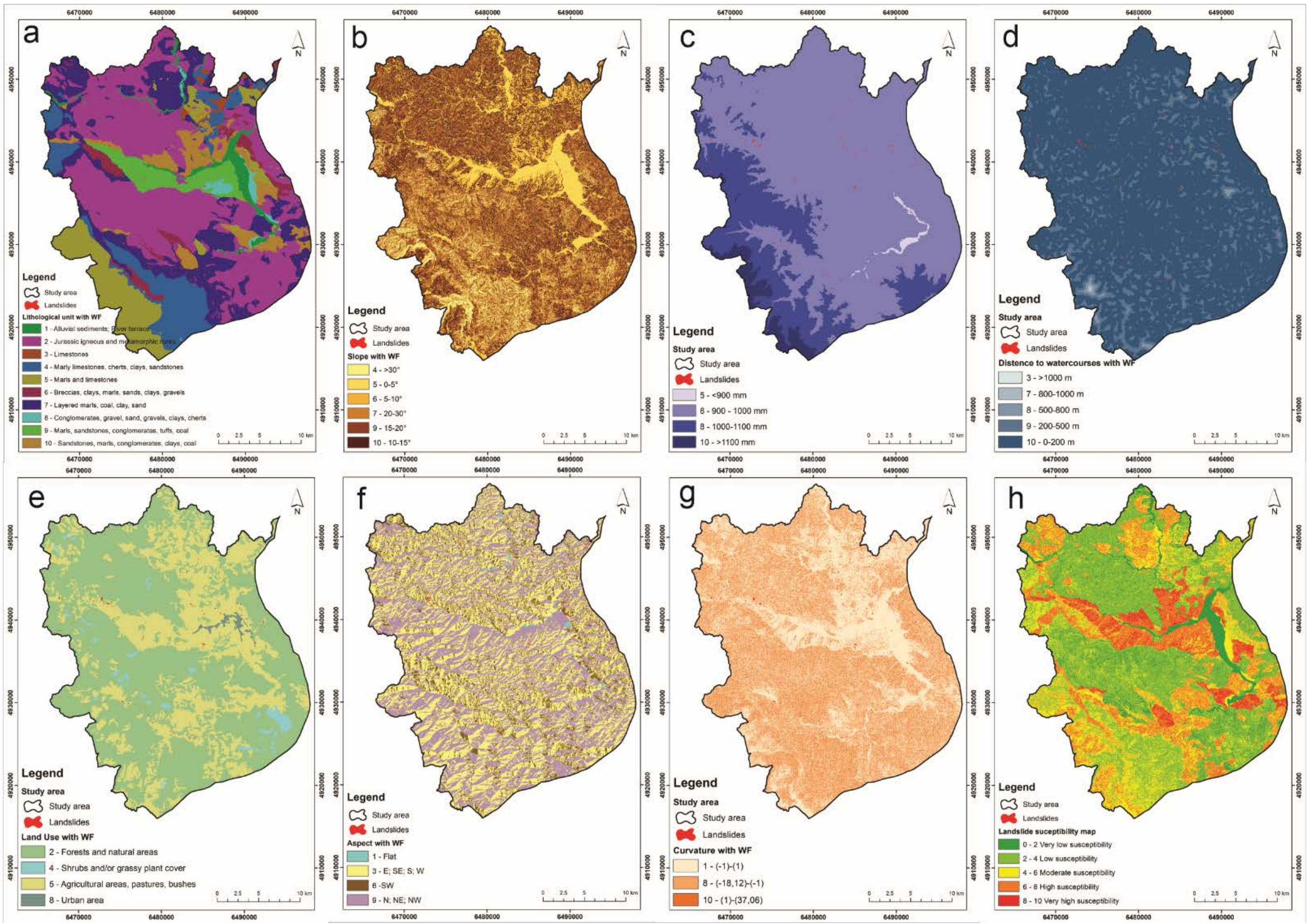

Figure 2 Causative (triggering) parameters (a-g), and landslide susceptibility map (h).

Given that the Teslić municipality, in the past, did not have planned exploration in the area of landslide susceptibility and systematic mitigation, this can serve as a basic assessment. First of all, this refers to zones with a high class of susceptibility in which preventive action should be taken. Although it can be said that these assessments are in the beginning in the Republic of Srpska, it is necessary to include them as an obligation in spatial planning documents on national and local levels. With the development of new techniques, it is necessary to increase their precision and level of detail.

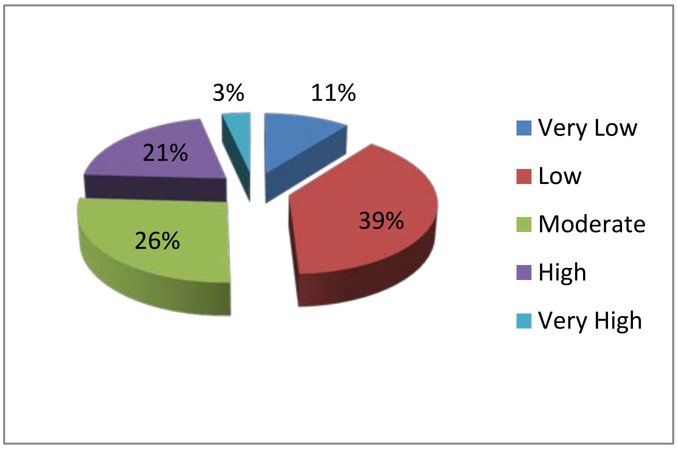

Figure 3 Susceptibility percentage by class.

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