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GIS Based Landslide Susceptibility Zonation - A Case Study in Western Albania

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Abstract: ***In this paper, a simple GIS-based methodology is used to assess the landslide susceptibility in Western Albania. The methodology is based on the spatial distribution of landslides and of causal factors. This method called bivariate, proposed by van Westen, 1993 has provided good results. Seven factors including geology, slope, aspect, land cover, distance from drainage, distance from roads and precipitation were used. Landslide inventory map is prepared based on topographic and geologic maps as well as satellite images and orthophotos. The relationships between the detected landslide locations and the controlling factors were identified by using ArcMap 10.3. Six classes of susceptibility were identified as follow: No Susceptible, Very Low, Low, Moderate, High and Very High Susceptible. The produced map can be used for better urban planning.***

Keywords: Landslide Susceptibility, GIS, Albania

1. Introduction

Landslide susceptibility is the possibility that a landslide will occur in a particular area onthe basis of the local environmental conditions [5]. The method used to assess the landslide susceptibility is based on an accurate evaluation of the spatial distribution of both the "causal factors", for failure, and/or of the past landslides [6]. This procedure requires the interpretation of a large spatial data of the study area. To assess landslide susceptibility, in most cases numerical weighting values are assigned to each class of the considered causal factors [6], thus GIS represent a powerful tool in landslide susceptibility mapping procedures.

Different approaches in assigning weighting values can be used. We have chosen to use bivariate statistical analysis, in which each causal factor map is combined with the landslide inventory map and weighting values based on landslide densities are calculated for each causal factor class [7].

2. Study Area

The study area is located in the western part of Albania, between the Karpen and Ballaj village, in its western part is Adriatic Sea and in the east is the lowland of Kavaja. It has a length of about 7.2 Km and a width about 6.5 Km, the total area is 28 Km^2. The terrain is mostly hilly (Figure 2).

The study area is characterized by a Mediterranean climate. The average temperature ranges from 8 to 9 °C in January to 22-23 °C in July with an average annual temperature of 16 °C. The annual average rainfall is 931.2 mm / year and the maximum rainfall observed during the last 30 years ranges from 1200 to 1500 mm / year.

We have chosen this area because it is highly affected by landslides phenomenon. These phenomena have also caused damages in houses, road infrastructure, loss of agricultural land, etc. (Figure 1).

Figure 1: Examples of landslides in the study area.

3. Methodology

This paper presents the results of the GIS-based statistical analysis for generation of landslide susceptibility mapping using Geographic Information System (GIS) for Karpen-Ballaj area in Western Albania (Figure 2).

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Seven factors, such as Geology, slope, aspect, land cover, distance from river, distance from roads and precipitation, are taken into account for the analysis.

The relationships between the detected landslide locations and these seven factors were identified and analysed by using GIS-based Bivariate statistical method. The analysis was based in the following formula [3]:

$$Wi = \ln\frac{DensClas}{DensMap} = \ln\left(\frac{NpixXi}{NpixNi} / \frac{\sum NpixXi}{\sum NpixNi}\right)$$

Where:
Wi = the weight given to a certain parameter class,
DensClas = the landslide density within the parameter class,
DensMap = the landslide density within the entire map,
Npix (Xi) = number of pixels, which contain landslides, in a certain parameter class.,
Npix (Ni) = total number of pixels in a certain parameter class.

The Figure 3 shows the procedure used to prepare landslide inventory map, relevant factor maps, weighted factor maps and the susceptibility map.

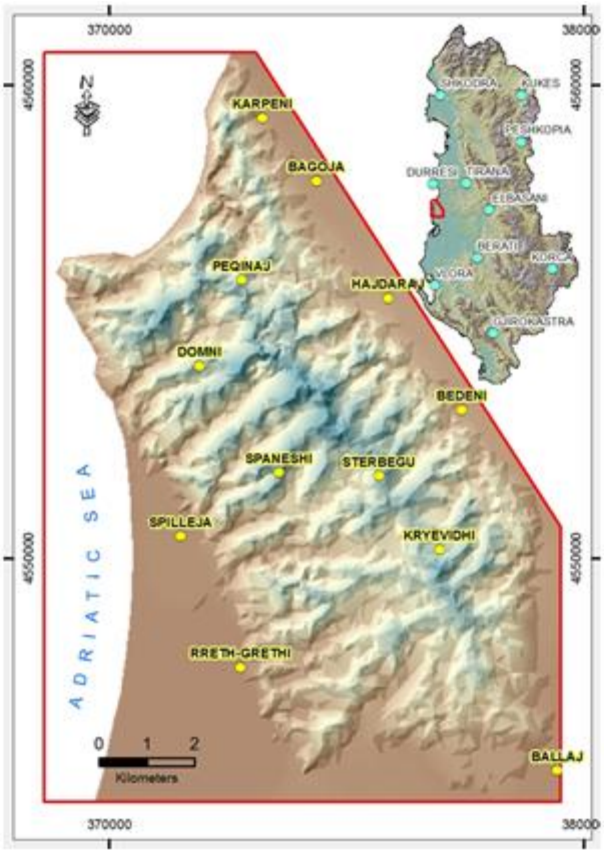

Figure 2: Geographic location of study area

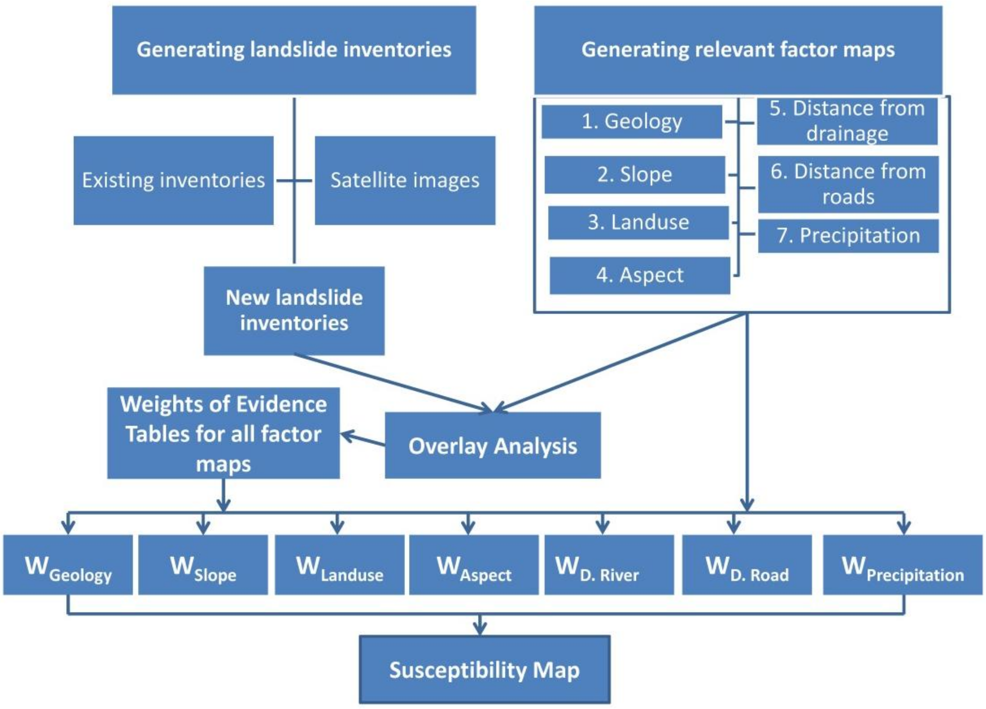

Figure 3: The methodology flowchart

4. Preparing of Spatial Database

4.1 Landslide Inventory map

The existing landslide inventory map is very important for analysing the relationship between landslides distribution and causing factors. In order to prepare a detailed landslide inventory map, several sources of data such as topographical map, 1: 10.000 scale, satellite images, orthophotos, etc. and several field surveys were used. In total 240 landslides were mapped (Figure 4).

4.2 Geology

Landslides are generally controlled by the lithology of the land surface. Lithology is very important in providing data for susceptibility mapping, for this reason is very important to group the lithological types [1]. Therefore, a geological map of the study area is digitized from the existing geology map at 1: 25.000 scale prepared by Albanian Geological Survey (AGS).

Neogenedeposits, consisting in two formations such as “Helmësi” (N_2^1h) and “Rrogozhina” (N_2^2 rr), as well as the quaternary deposits (Q) are clearly distinguished (Figure 5). *"Helmësi“ Formation* $(N_2^1 - (h))$, these deposits are predominated by clays, which are light gray to bluish gray color and from soft to compact.

“Rrogozhina” Formation $(N_2^2 - (rr))$, these deposits are characterized by gravel, coarse grained sandstones, conglomerates with clay intercalations.

Quaternary deposits (Q), consist mainly in weathering products (gravels, sands and clays). Alluvial, marshy and lagoon deposits are encountered in the foot of the hills.

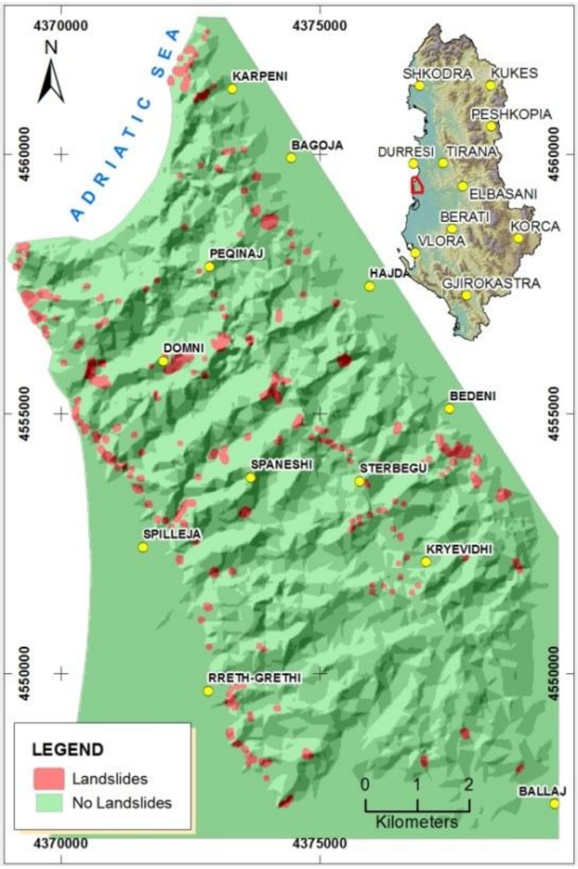

Figure 4: Landslide inventory map

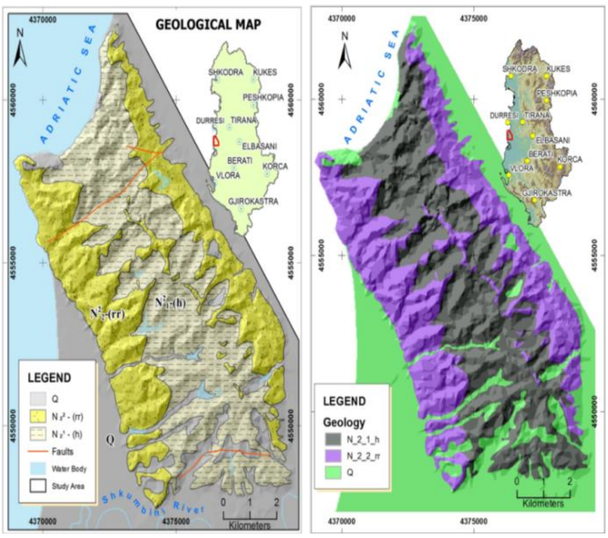

Figure 5: Geological map of the study area

Table 1: Weighting values (Wi) of the considered causal factors classes.

Factor	Class	Ranking	Npix (Ni)	Npix (Xi)	% Npix (Xi)	Wi
Geology	N_2^1-h	1	58552	252	20.8	-0.203
	N_2^2-r	2	50523	923	76.2	0.425
	Q	3	67200	36	3	-1.108
Slope (°)	0-5	1	79772	134	11.1	-0.612
	5-10	2	51050	422	34.8	0.08
	10-20	3	42205	570	47.1	0.294
	>20	4	3248	85	7	0.581
Land cover	Artificial Surfaces	1	11233	108	8.9	0.146
	Agricultural areas	2	130692	596	49.2	-0.178
	Forest and semi natural areas	3	32881	507	41.9	0.351
	Water bodies	4	1469	0	0	0
Aspect	Flat	1	40715	7	0.6	-1.602
	North	2	8576	68	5.7	0.062
	North-East	3	11239	87	7.3	0.052
	East	4	15696	158	13.2	0.166
	South-East	5	22426	162	13.6	0.022
	South	6	15784	162	13.6	0.174
	South-West	7	11117	86	7.2	0.052
	West	8	17590	117	9.8	-0.014
	North-West	9	24035	222	18.6	0.129
	North	10	9097	124	10.4	0.298
Distance from drainage (m)	0-50	1	30252	453	37.4	0.338
	50-100	2	19775	322	26.6	0.375
	100-200	3	22838	321	26.5	0.311
	200-300	4	90784	50	4.1	-1.096
	>300	5	12626	65	5.4	-0.125
Distance from roads (m)	0-50	1	10258	134	11.1	0.279
	50-100	2	17473	223	18.4	0.269
	100-200	3	33457	304	25.1	0.121
	200-300	4	26746	156	12.9	-0.071
	>300	5	88341	394	32.5	-0.188
Precipitation (mm)	1028-1119	1	97674	307	25.4	-0.34
	>1119	2	78601	904	74.6	0.224

4.3 Slope

Slope angle is the most important parameter in the slope stability analysis [2]. The slope map of the study area, prepared from DEM, is shown in Figure 6; four classes of slopes are identified.

4.4 Land cover

In this study the land cover map is taken from CORINE land cover map, 2006. Land cover is divided into four categories (Figure 7,

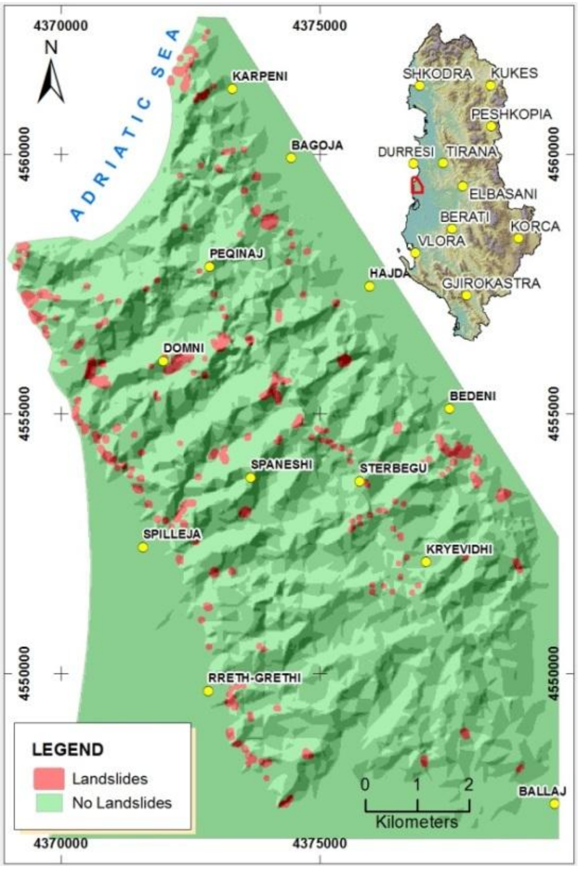

Figure 4: Landslide inventory map

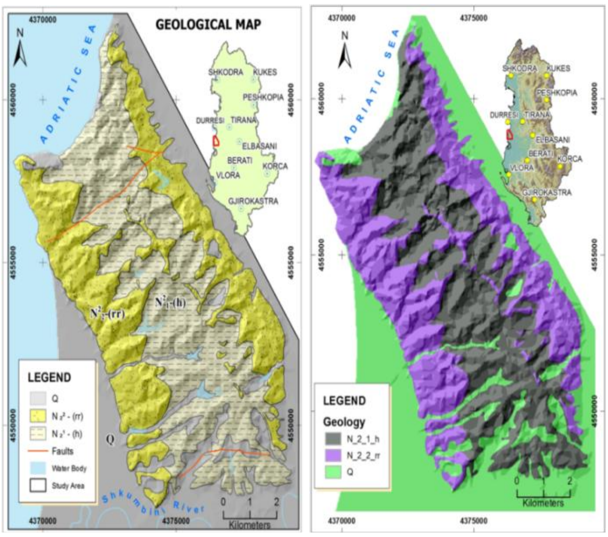

Figure 5: Geological map of the study area

Table 1).

4.5 Aspect

Aspect is considered as a landslide controlling factor. The aspect map is prepared based on DEM and is divided into ten categories (Figure 8,

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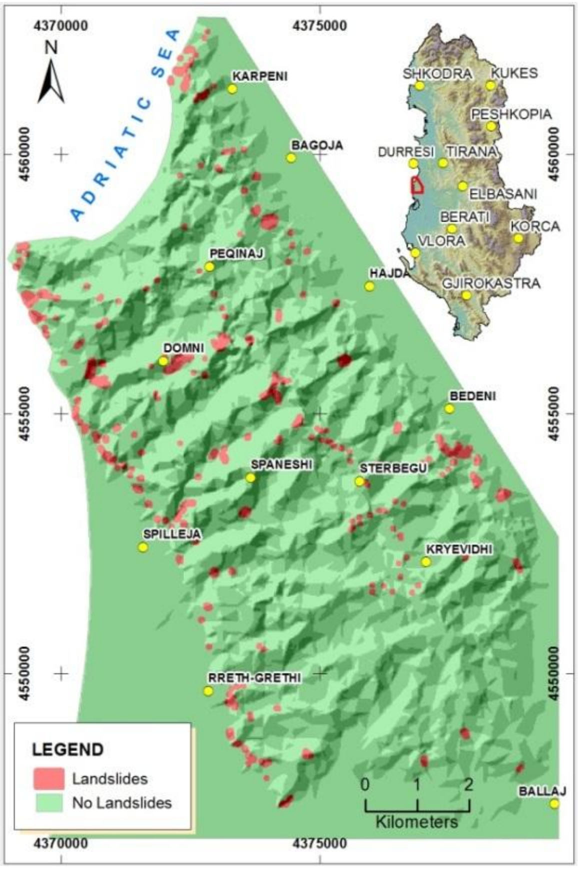

Figure 4: Landslide inventory map

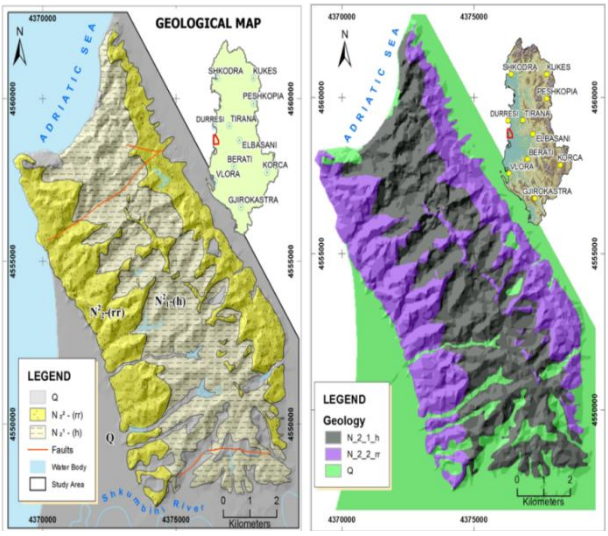

Figure 5: Geological map of the study area

Table 1).

4.6 Distance from drainage

Water streams may affect the slope stability by eroding the slopes or by saturating the lower part, thus the slope is less stable. Five different buffer zones are identified (Figure 9,

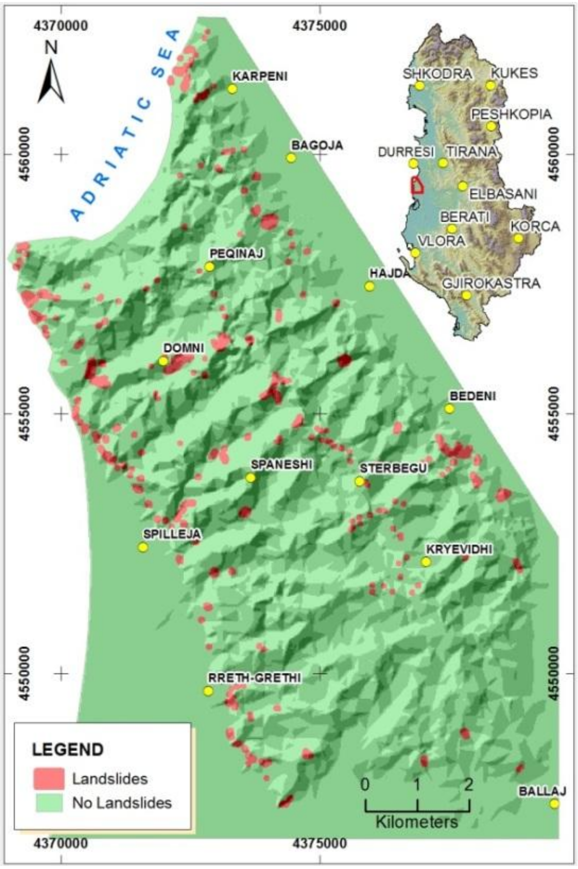

Figure 4: Landslide inventory map

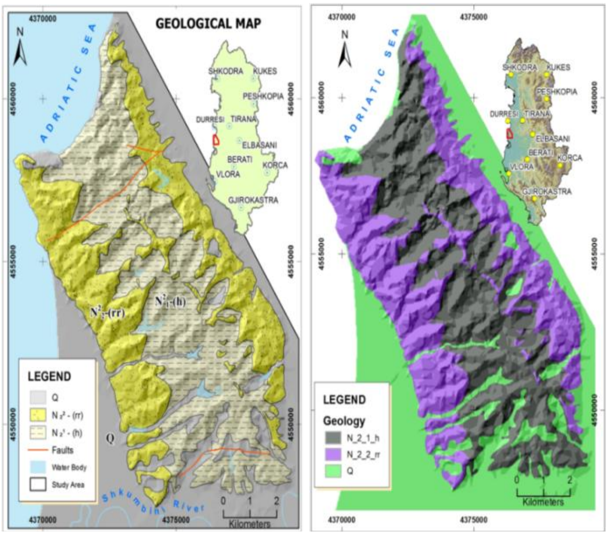

Figure 5: Geological map of the study area

Table 1).

4.7 Distance from roads

Similar to the effect of the distance from drainage, landslides may occur on the road and on the side of the slopes affected by roads. Taking into account this factor five different buffer zones are created on the path of the road to determine the effect of the road in the stability of the slope (Figure 9,

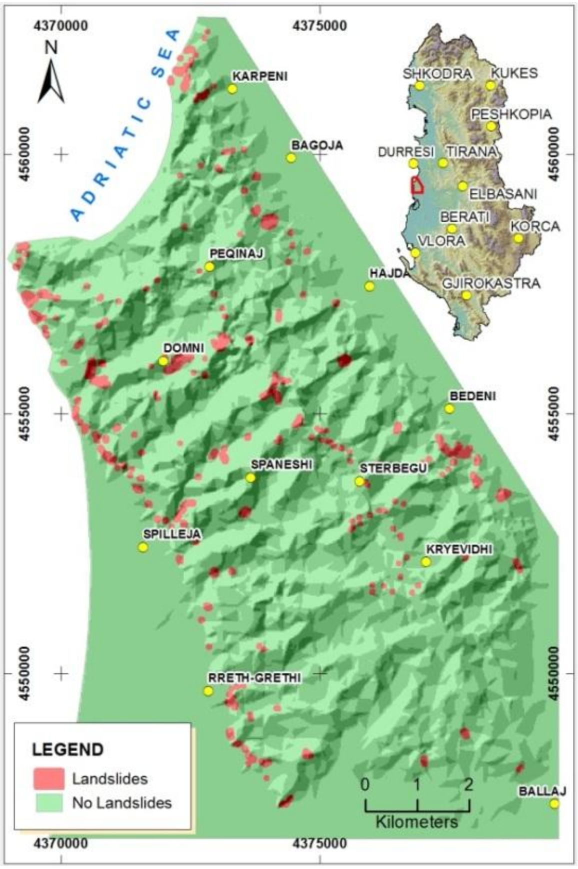

Figure 4: Landslide inventory map

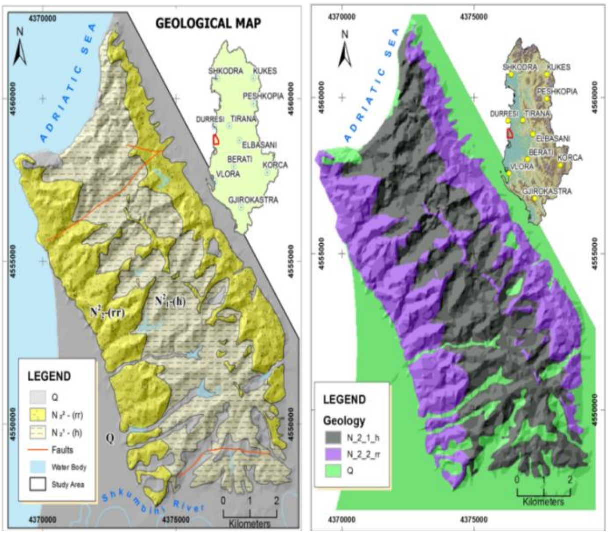

Figure 5: Geological map of the study area

Table 1). The roads map is prepared using the recent satellite images and orthophotos.

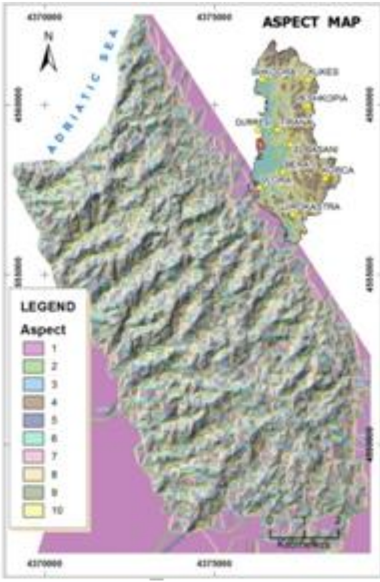

Figure 6: Slope map **Figure 7:** Land cover map **Figure 8:** Aspect map

Figure 7: Distance from drainage map **Figure 8:** Distance from roads map **Figure 9:** Precipitation map

4.8 Precipitation

The saturation degree of the material in the slope is an important parameter that controls its stability. Precipitation plays an important role in landslide initiation. The data used are taken from hydrometeorological station of Durres and Kryevidh, [9].

5. Landslide Susceptibility Mapping

In this paper, the bivariate method is used to prepare a landslide susceptibility map. All factors are classified into groups for a better and faster calculation. The factors taking into account are geology, slope, land cover, aspect, distance from drainage, distance from roads and precipitation. For each factor is prepared a raster map.

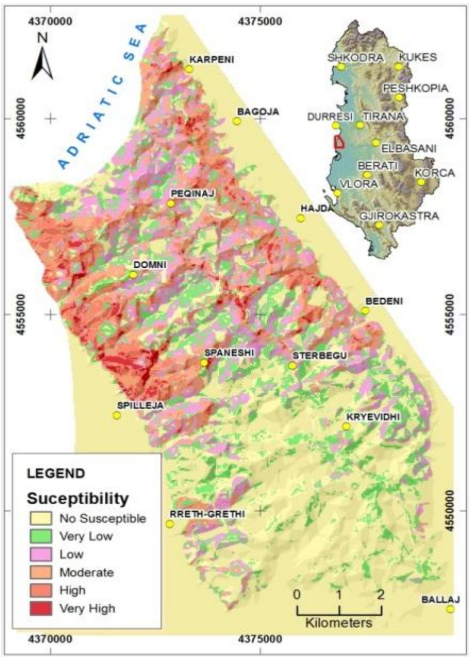

Figure 10: Susceptibility map

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Table 2: Landslide susceptibility classes

Class	*Npix*	*% Npix*
No Susceptible	103818	58.9
Very Low	21742	30.0
Low	22456	31.0
Moderate	17153	23.7
High	9193	12.7
Very High	1913	2.6
Total	**72457**	**100**

After preparing all the factor raster's map an overlay analysis in GIS was performed between each factor map with landslide inventory map. For each factor class, the weighting factor was calculated by the ratio between the number of pixels corresponding with landslides and the total number of pixels. This procedure is repeated for all factors and the results are shown in

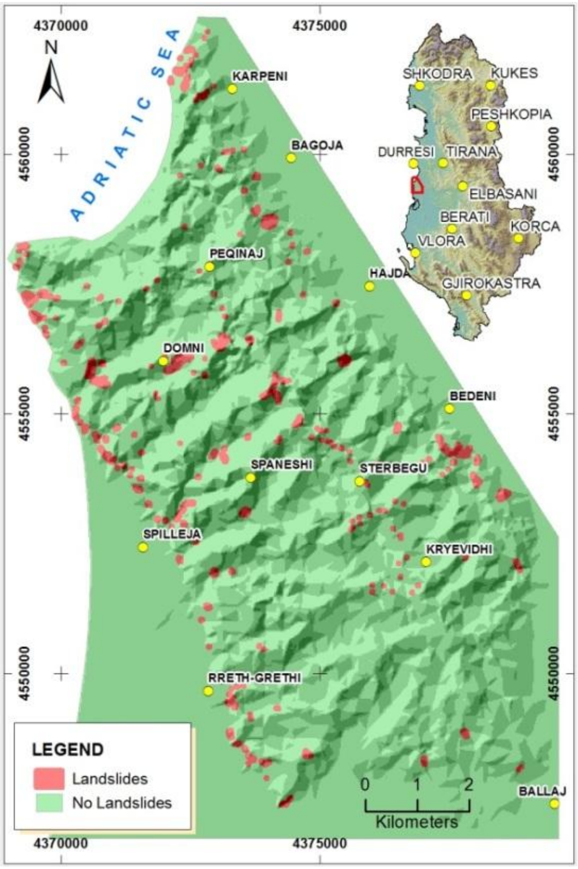

Figure 4: Landslide inventory map

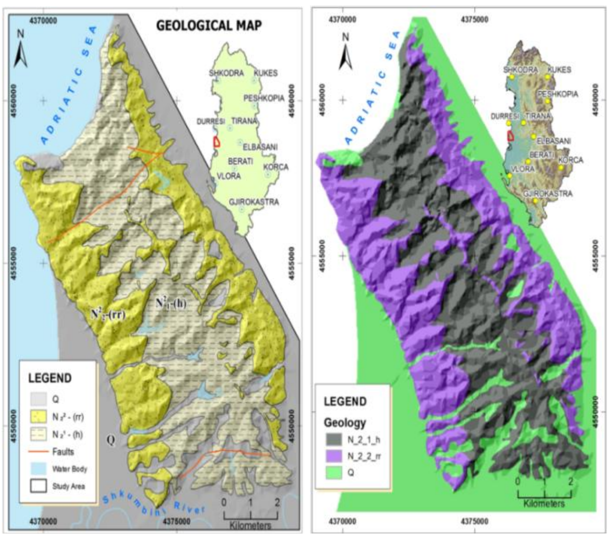

Figure 5: Geological map of the study area

Table 1.

A Susceptibility Landslide Index is calculated by summarizing of weighting factors for each pixel. The range of SLI variation was divided into six classes of susceptibility as follow: No Susceptible, Very Low, Low, Moderate, High and very High Susceptible, as shown in

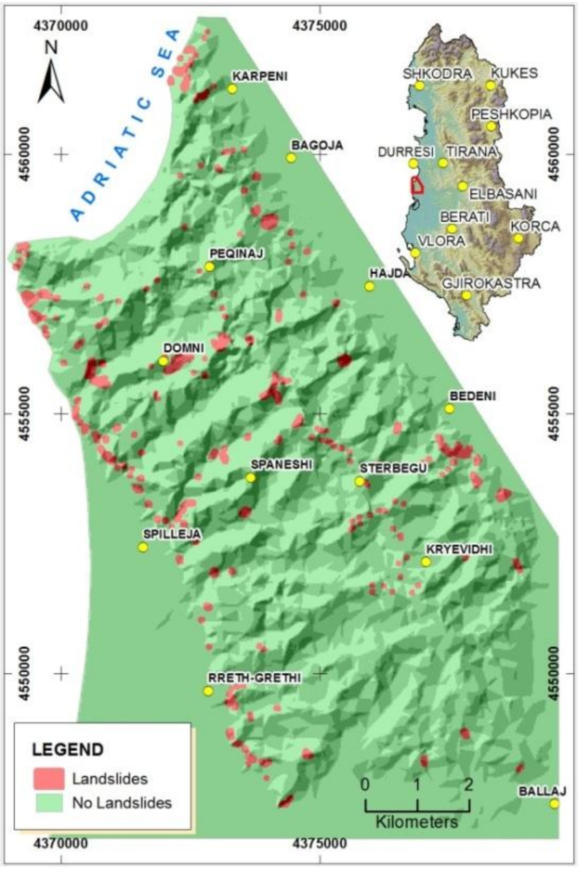

Figure 4: Landslide inventory map

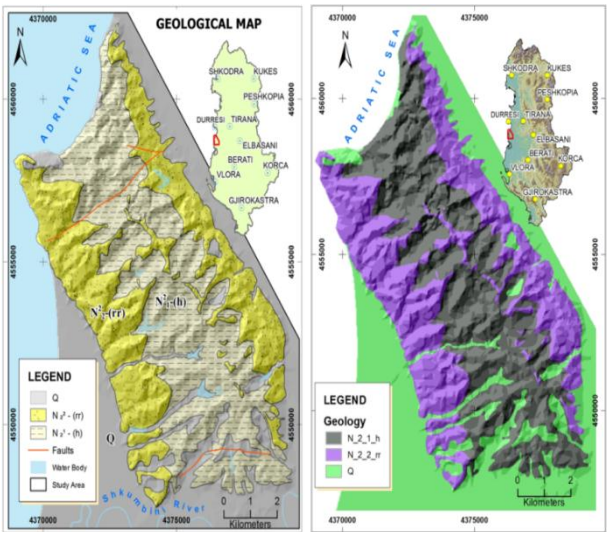

Figure 5: Geological map of the study area

Table 1 and Figure 12.

6. Conclusion

In the factors taking into account the categories with higher weighed value, W_i are as follows: Geology: N_2^2-rr, Slope: >20°, Land cover: Forest and semi natural areas, Aspect: North, Distance from drainage: 50÷100 m, Distance from roads: 0÷50 m, Precipitation: >1119 mm.

The susceptibility map shows that58.9 % of the study area corresponds to Susceptible, 30 %Very Low, 31 % Low, 23.7 % Moderate, 12.7 % High and 2.6 % Very High. Landslides susceptibility mapping is very necessary today due to the strong impact of these processes on people and their goods.

The obtained result shows that statistical methods are very useful for preparing landslide susceptibility maps. These results can be used for better urban planning.

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