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ANALYSIS OF THE IMPACT OF NATURAL HAZARDS ON TOURISM ON THE LEFT BANK OF LAKE IZVORU MUNTELUI (NORTH-EASTERN ROMANIA)

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Abstract: One of the areas with great touristic potential in Romania's mountains is Izvoru Muntelui Lake (Neamt county) from the western slopes of the Stânișoara Mountains in the Eastern Carpathians. The area is remarkably picturesque in terms of both the natural surroundings and history, including traditions, folklore, and ethnography. Nevertheless, the region is exposed to natural risk phenomena such as floods, landslides, crumbling, etc., which can affect different economic fields, including tourism. The present study aims to analyze the relationship between this zone's natural hazards and tourism activities and their impact. Our approach is based on quantitative and qualitative analysis, interview and questionnaire techniques, but also on literature review, field research, statistics, overlay and spatial mapping of data using GIS techniques and critical interpretation of results through mathematical statistics using Covariance Product of Deviations from the mean and the Bravais-Pearson linear correlation coefficient to measure the intensity of the interdependence between the degree of damage to the road infrastructure and the tourist infrastructure. The results show that the landslides significantly impact the public infrastructures between Poiana Teiului and Bicaz, heavily affecting the national road DN15. A total of 73 impact points were inventoried, representing sections of roads and road infrastructure elements affected by landslides. At the same time, the analysis of the responses to the questionnaire revealed that natural hazards, especially landslides and floods, are perceived as a threat by most tourism operators in the area. The classification of the vulnerability of tourism infrastructure into four categories (low, medium, high, and very high), based on susceptibility maps, has led to the determination of vulnerability to landslides, revealing the following findings: four accommodation units have a medium vulnerability index, two have a high vulnerability index, and one records a very high vulnerability index. It is highlighted that an accurate perception of natural hazards can contribute to increasing the awareness and preparedness of vulnerable people, thus increasing the resilience of present and future generations.

Keywords: natural hazards, landslides, vulnerability, tourism, Izvoru Muntelui Lake, Romania

1. INTRODUCTION

In recent decades, tourism has become one of the most important economic sectors, mainly due to technology, access to information, and the reduction of borders (Peric, 2005). It has a constantly growing economic contribution (UNWTO, 2018; Agulles et al., 2022). World Travel and Tourism Council estimations show the tourism sector's contribution to the global economy in 2019 as 10.3 trillion USD (10.4% of global GDP) and 334 million jobs (10.5 % of work from around the world) (WTTC, 2023). Because of its close dependence on the natural environment, tourism is vulnerable to the occurrence of various climatic, hydrological, and geomorphological risk factors, which induce visible effects on the sustainability of tourism activities.

A series of authors (Ritchie, 2004; Pforr & Hosie, 2008; Becken et al., 2015; Aliperti et al., 2019; Bhaskara et al., 2021) reveals that tourism is

particularly exposed and vulnerable to natural hazards, especially to its impact. Globally, the annual number of officially recorded hazards is growing (Ritchie & Rosado, 2022), and sustainability can be negatively affected by reducing the potential and disrupting tourist activity (Aji et al., 2021). Some regions of the globe with high tourism potential suffer due to exposure to various natural hazards, which may discourage visitors from travelling to the affected destinations (Bhati et al., 2016).

The impact of natural hazards on the economic sector can be direct or indirect; direct impact can include physical injury to people and damage to property, infrastructure, and other assets or elements of the environment (Smith & Ward, 1998; Meyer et al., 2013; Pfurtscheller & Genovese, 2019) as well as natural parks and geosites (Dragićević et al., 2013; Miljković et al., 2018; Ivanović et al., 2023; Papp 2023; Aleksova et al., 2024) while indirect effects may have long-term consequences (Alimohammadlou et al., 2013), including devaluation of property, decrease in commercial traffic, psychological trauma among the population, and reduction in tourist flow and potential (Vranken et al., 2013; Dhakal et al., 2020).

Therefore, the European Spatial Planning Observation Network (ESPON) has requested information on spatial patterns and territorial trends regarding hazards and risks across the European Union; the results revealed that the Alpine regions are prone to multi-hazards, such as landslides and floods, but this combination of hazards can also occur in various areas, including southern Germany, the Ardennes in France, the Rhône Valley, and the Carpathian Mountains in Romania (Schmidt-Thomé & Kallio, 2006).

For instance, a recent study by Papp (2023) confirms the risk of degradation of eleven selected touristic-valued geosites in the Northern Apuseni Mountains of Romania, indicating that sites are more vulnerable, facing more significant threats than other locations.

For the Serbian Danube region, Dragićević et al. (2013) evaluated the vulnerability of Fruška Gora and Djerdap National Parks and emphasized the necessity of a multi-hazard map for effective prevention and that natural hazards transcend political boundaries, highlighting the necessity of developing a vulnerability map for Southeast Europe.

Also, Aleksova et al. (2024) consider that it is necessary to develop models for assessing areas susceptible to erosion, landslides, and flash floods within the Kratovska Reka catchment in North Macedonia, and the multi-hazard model developed in this study underlines the urgent need to address these risks, especially in vulnerable areas.

Assessing the impact of natural risks on tourism involves analyzing hazards, vulnerability, and exposure to evaluate potential effects (Genovese & Przyluski, 2013; Pfurtscheller & Genovese, 2019) and resilience (Crovelli & Coe, 2009; Wills et al., 2016; Pfurtscheller & Genovese, 2019).

According to Filimonau & Coteau (2020), natural hazards impact tourism in three ways: damage to tourist infrastructure, impact on access routes, which alters perceptions of destination safety, and intensification of impact by the media, which spreads the negative effects of disasters.

Brown et al. (2017) offer a literature review with particular reference to the hotel industry and conclude that hotels usually tend to be under-prepared and unable to adapt to hazards, leading to low resilience and increased vulnerability. Therefore, in regions with tourism potential, proper management of natural hazards is necessary to maintain the sustainability of tourism (Dey et al., 2018).

The present study aims to analyze the relationship between natural hazards and tourism activities in an area well known for its high tourism potential in the mountain area of Neamt County, Romania, but susceptible to natural hazards such as floods, landslides, crumbling etc., which can affect different economic sectors, including tourism. Accordingly, it is necessary to consider the effects of natural hazards, implicitly assessing the level of risk induced on public and tourist infrastructure. In order to evaluate the degree of susceptibility to various natural hazards, the vulnerability of infrastructure elements and accommodation facilities, the possible consequences of certain risk phenomena, expressed in terms of direct or indirect damage, and the correlation between the degree of damage to public infrastructure and the degree of damage to tourist infrastructure, must be determined.

2. STUDY AREA

Our research is focused on an essential sector of the western slope of the Stânișoarei Mountains in the Eastern Carpathians, north-eastern Romania, along the left bank of the Izvoru Muntelui Lake on the valley of the Bistrița River, in the central-western part of Neamt County (Figure 1).

The lake was created by the construction of the Bicaz dam in 1960 to exploit the hydropower potential of the Bistrița river, being the largest artificial lake (35 km long, 3125 ha surface, 1.23 billion m^3 of water volume) on the inland rivers of Romania (Bâra & Grasu, 1981). The lake's creation forced the authorities to relocate the villages to higher

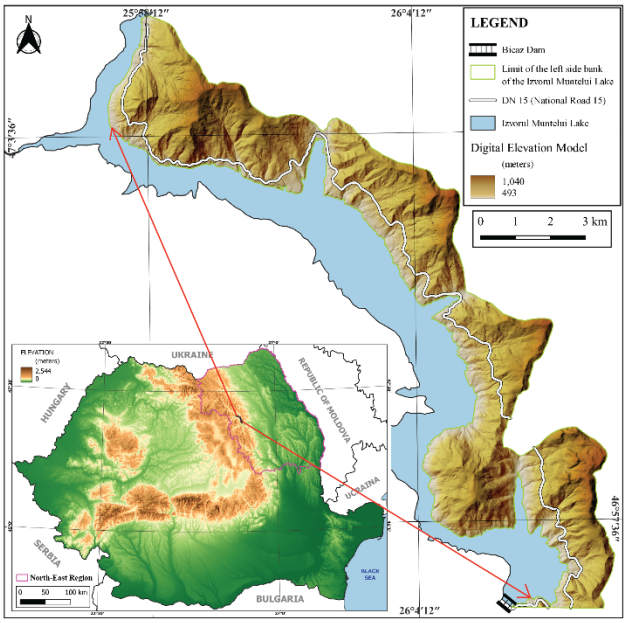

Figure 1. Position of the studied area within north-east Romania.

elevations on the mountain slopes and to construct in 1964 the national road DN 15, which is about 38 km long on the Bicaz - Poiana Largului sector. At present, the lake is characterized by complex functions (hydropower, water supply, fisheries, tourism, flood mitigation) with significant economic implications (Acrâşmăriţei et al., 1971; Albotă, 1991; Ficlenescu et al., 2011).

Regarding tourism potential, Bojoi & Ichim (1974) present the area as remarkably picturesque, mainly due to the lake resembling a real intermontane "sea". Bâra & Grasu (1981) consider that this "huge reservoir" at the base of the Ceahlău Massif is of tourist interest both for the nature surrounding it and for traditions, folklore and ethnography, the area having been known before the dam was built as an "oasis of patriarchal life" in which some traditions from times long gone by were still preserved.

Presently, the lake and the surrounding area are popular holiday destinations, with many alternatives for relaxation and recreation. The lake's main types of tourism are leisure and recreation, adventure, equestrian, hunting, nautical, cultural, rural, and agritourism (Brânduş, 2003; Tanasă, 2013).

The tourist attractions are strongly connected to the traditional architectural style specific to mountain villages (old wooden and stone churches, peasant households with ethnographic value) or represented by large-scale constructions (the dam at Bicaz, the viaduct at Poiana Largului about 1 km long), natural nature monuments like the famous solitary rock called Piatra Teiului (Aptian limestone block), but especially by the landscape of the lake (Bojoi & Ichim, 1974; Bâra & Grasu, 1981; Ghiorghiu, 2001; Tanasă, 2013).

Other popular activities specific to this zone include different types of sports like hiking on various mountain trails, paragliding, mountain biking, water skiing, fishing, and, in the summer season, recreational boating (Bojoi & Ichim, 1974; Pascaru, 2006) or annual cultural events like Navy Day, which is organised on 15th of August at the Bicaz dam (pier) (Murgulescu, 2007; Tanasă, 2013).

As mentioned, the study area is susceptible to natural hazards such as floods, landslides, crumbling, etc. Consequently, several studies have been carried out on the occurrence of geomorphological processes, such as slope stability conditions, with emphasis on landslides and their dynamics (Bojoi, 1962; Donisa, 1968; Martiniuc et al., 1971; Ichim & Surdeanu, 1972; Surdeanu, 1975a, 1975b, 1981, 1982, 1987; Ichim, 1979; Ichim et al., 1979; Rădoane et al., 1979; Surdeanu & Catana, 1985; Ichim & Radoane, 1986; Rădoane, 2004; Gaman, 2013; Muscalu, 2018; Codru & Niacsu, 2022).

Most authors consider the susceptibility to landslides has increased mainly due to intense direct or indirect anthropic intervention.

Martiniuc et al. (1971) consider that the dam's construction and the lake's economic development are determining factors in the occurrence of landslides. Ichim et al., (1979) stated that, before the lake formation, active landslides or landslides in the process of becoming active occupied small areas and that, subsequently, they increased in size through the complex of developments on the left bank between Bicaz and Poiana Largului, along the DN15 national road and in the coastal area.

A close relationship between significant fluctuations in lake water levels and the extent of landslide processes on the slopes in the area is highlighted by Martiniuc et al. (1971), Surdeanu (1975a), Rădoane et al. (1979), Bâra & Grasu (1981). The frequent level fluctuations are caused by the variation of tributary river flows and the Stejaru hydropower plant usage regime.

Over the period 2011-2021, the water volume decreased from August to February, after which it started to increase again in March under the influence of increased tributary flows due to snowmelt and precipitation. The increase in water level continued until June-July (Figure 2); level rises and falls ranged between 10 - 30 m, with daily level changes totaling around 20 cm and rarely reaching an amplitude of 1 m.

A water level reduction of 35 m, under the maximum elevation level of 515 m (Figure 3), results in a decrease in the water depth in the dam zone from 90 m to 55 m, and with the following changes of the

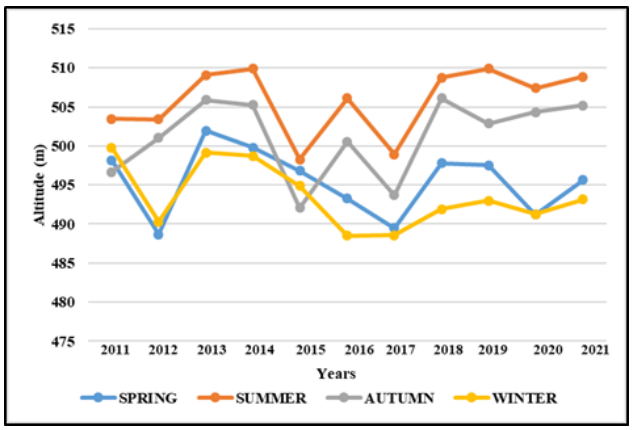

Figure 2. Izvoru Muntelui Lake fluctuations level by seasons between 2011-2021 (CPB, 2022).

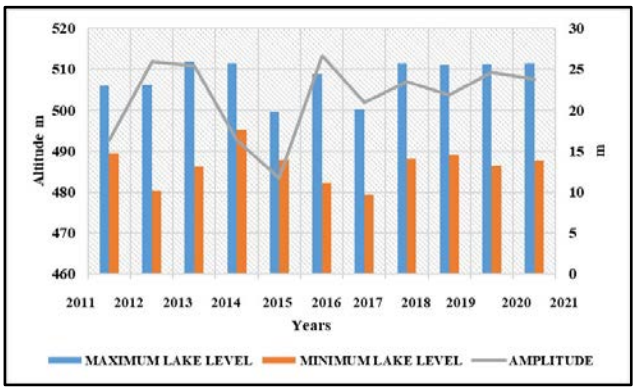

Figure 3. Izvoru Muntelui lake fluctuations level between 2011-2021 (CPB, 2022).

lake area: the length decreases from 35 km to 20 km, the width from 2.2 km to about 0.5 km, the perimeter from 104 km to about 50 km and the surface area from 3125 ha to 1599 ha, with a decrease in the volume of water from 1.23 billion m^3 to about 339 million m^3.

The construction and exploitation of the national road DN15 are also considered sources of slope imbalance, contributing to the extension or occurrence of landslides (Ichim & Surdeanu, 1972; Gaman, 2013; Codru & Niacsu, 2022).

Since its completion in 1965, the national road DN15 has been affected by landslides. About 70 landslide points affected the road surface or buildings, with landslide areas exceeding 10 ha (DRDP, 2022; SDP, 2022).

There are currently numerous reports of landslides with a high impact on public infrastructure. In addition to all these factors, there is also a low level of afforestation, along with a high proportion of meadows and pastures (Martiniuc et al., 1971; Muscalu, 2018), as well as the presence of construction elements, household works, and tourist infrastructure, which prevent the water from draining from the slopes in the perimeter of the settlements that emerged after the formation of the lake (DRDP, 2022).

3. MATERIALS AND METHODS

To assess the degree of susceptibility to natural hazards and their consequences on the tourism sector in the study area, we propose a combination of methods and data aiming at quantitative and qualitative analysis based on interview and questionnaire techniques as well as documentary and statistical investigation, field research and mapping and spatial overlaying of data. It started from a simple outline of the steps in the assessment of natural hazards in tourism as shown in Figure 4 (Tsai & Chen, 2011; Genç, 2018).

Following field research, information collection and database compilation phase, an inventory of accommodation and recreational establishments in the study area was carried out, and 15 units were identified (13 units along the national road DN15 and two along the Hangu stream valley).

A questionnaire completed by interview technique was used for data collection, the target group being the owners of the 15 accommodation units, to quantify the impact of natural hazards on tourism activities and accommodation units based on the perception of owners, interpreted on a scale from 0 to 3, where 0 represents not at all, 1 to a small degree, 2 to a large degree, 3 to a very large degree. Statistical data on the level fluctuations of the Izvoru Muntelui Lake were also collected and interpreted (data provided by Capitania Portului Bicaz), as well as the risk phenomena impacting the condition of the national road DN15 (according to reports DRDP, 2022; SDP, 2022). In total, 73 impact points were identified where landslides affected portions of roads and road infrastructure elements (retaining walls, bridges, and viaducts).

The cartographic materials were generated using QGIS 3.16 software. The Digital Terrain Model (DTM) was obtained by digitizing the contour lines with an equidistance of 5 meters based on the topographic map of Romania with a scale of 1:5000 (1984 edition). Digitization was performed using the semi-automated Raster Tracer digitization plugin in QGIS. Georeferencing was performed with TNTMips GIS software, and error correction, resulting from the

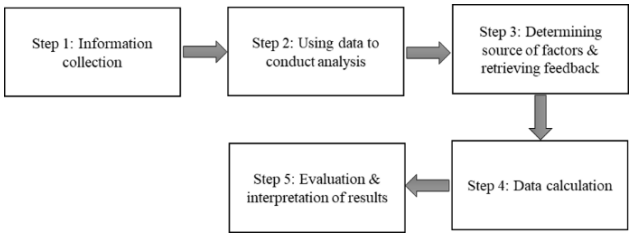

Figure 4. Natural disaster risk assessment steps in tourism (Tsai & Chen, 2011; Genç, 2018).

combination of shapefiles obtained from 50 topographic maps, was performed with QGIS 3.16. (Codru & Niacsu, 2022).

For the landslide vulnerability assessment, we used the landslide susceptibility map from Codru & Niacșu (2022). Mapping the landslide impact points as well as the accommodation units, with the creation of buffers of 50 m, 100 m, 150 m, 200 m, 250 m and 300 m radius around each accommodation unit, allowed us to make the following assessments regarding:

Gs1 - Degree of susceptibility to landslides of the place where the accommodation unit is located;

Gs2 - Medium degree of susceptibility to landslides over a radius of 50 m;

Gs3 - The highest degree of susceptibility to landslides over a radius of 50 m;

Gs4 - Degree of susceptibility to landslides with the highest ponder in a radius of 50 m;

Susceptibility index values (Table 1) were obtained from the susceptibility map algebra by classifying and integrating features according to the position of accommodation units.

The degree of susceptibility to landslides in the place where the accommodation unit is located was assessed on a scale from 0 to 4, where 0 represents a null degree of susceptibility and 4 represents a very high degree of susceptibility.

Vulnerability to landslides (Table 2) was calculated from the equation of the mean value of the degree of susceptibility of the accommodation units' location.

$$V = \frac{Gs1+Gs2+Gs3+Gs4}{4} \quad (1)$$

The collected data was analyzed and processed as graphs in Microsoft Office Excel 2019. The covariance of the product of deviations from the mean (2) and Bravais-Pearson linear correlation coefficient (3) was used to calculate the data (Groza et al., 2003) where Xi is the number of impact points (in the proximity of the accommodation units within a radius of 50 to 300 m) and Yi is the degree of damage to the accommodation units (on a scale of 0 to 3, where 3 is the highest value).

$$Cov(X,Y) = \frac{1}{N}\sum_{i=1}^{N}(Xi - \bar{X}) \cdot (Yi - \bar{Y}) \quad (2)$$

$$\mathrm{r(X,Y)} = \frac{\mathrm{Cov(X,Y)}}{\sigma x * \sigma y} \quad (3)$$

$$\textit{Arithmetic mean: } \overline{x} = \frac{\sum_{i=1}^{n} Xi}{n} \quad (4)$$

$$\textit{Variance: } \sigma^2 = \frac{\sum_{i=1}^{n}(xi-\overline{x})^2}{n} \quad (5)$$

$$\textit{Standard deviation (square root of variance): } \sigma = \sqrt{\sigma^2} \quad (6)$$

The linear correlation coefficient ranges from -1 to +1. The interpretation is as follows:

- if *r* is close to 0, there is no linear relation between X and Y;
- if *r* is close to -1, there is a strong negative linear relation between X and Y;
- if *r* is close to +1, there is a strong positive linear relation between X and Y.

The sign of *r* indicates the meaning of the relationship, while its absolute value indicates the strength of the relationship, that is, the predictive ability of the values of Y relative to those of X.

Table 1. Susceptibility index values.

Susceptibility degree	Index value
Very high	4
High	3.5
Medium-high	3
Medium	2.5
Medium-low	2
Low	1.5
Very low	1
Extremely low	0.5
Null	0

Table 2. Vulnerability index values

Vulnerability	Index value
Very high	3.5 - 4
High	2.5 - 3.4
Medium	1.5 - 2.4
Low	0.5 - 1.4
Null	0

4. RESULTS AND DISCUSSION

The 73 impact points inventory (see four of them in Figure 5) where landslides affect the road infrastructure and the use of the DTM allowed us to draw up a map of the impact points and to position the accommodation units in relation to them (Figure 6). The average density of road sections affected by landslides is 0.52/km. Analyzing the distance of the accommodation units from the impact points on the DN15 shows that, of the 13 units located near the road, ten units have an average of two and a maximum of four portions of the road affected by landslides in their proximity (Table 3).

The questionnaire responses highlight both the occurrence and consequences of risk phenomena. The analysis shows that landslides and floods are perceived as a threat by most tourism operators in the area and that awareness of the danger can make them responsible. It is revealed that tourism on the left bank of Lake Izvoru Muntelui can be considered under the influence of natural risk phenomena (Figure 7): 60 %

Figure 5. Examples of road segments and elements of road infrastructure affected by landslides on the national road DN15 in the Poiana Largului-Bicaz sector: a1 - landslide reactivated in August 2018, with destruction of the bridge and drainage channel; a2 - slide of the pavement with parapet, 3m long and 50 cm high; a3 - degraded retaining wall over a length of 30 m; a4 - coastal bridge 80% clogged upstream and degradation of the downstream retaining wall (SDP, 2022).

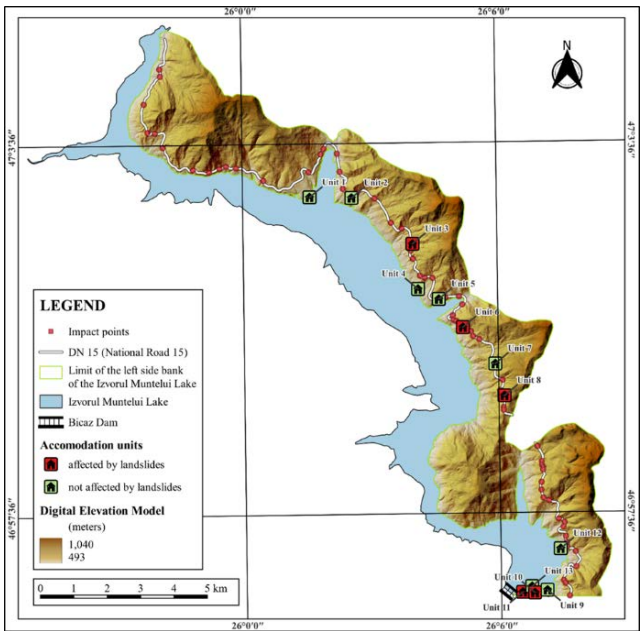

Figure 6. Map of the impact points and accommodation units on the left bank of Lake Izvoru Muntelui.

of respondents feel threatened by natural hazards, 53 % are affected by some of these phenomena, 33 % of the respondents consider themselves as being affected by landslides, and 20 % of them are affected by floods. Also, 53 % of the respondents estimate that tourist flow and income decreased during the period when the national road DN15 was closed (July - December 2019) for land stabilization works and rehabilitation of the road surface affected by landslides. On the other hand, the owners of accommodation units consider property insurance very important.

As Table 4 shows, four of the 15 accommodation units surveyed are affected by landslides, two by landslides and floods, and one by floods only.

In terms of the degree of damage, two are very heavily affected, two are heavily affected, and four are slightly affected (Figure 8).

Regarding the type of impact, access roads (roads, pavements, stairs, parking lot) were most damaged; six of the accommodation units have access roads affected by landslides and two accommodation units have the resistance structure damaged (Figure 9).

Prediction of impact types may also be possible through assessing the vulnerability degree, as it encompasses interdependent human and natural systems that allow a link between these two dimensions (Santos-Lacueva et al., 2017).

The assessment of the accommodation units' vulnerability to landslides on the left bank of Lake Izvoru Muntelui highlights their predisposition to being affected.

The landslide susceptibility map presented by Codru & Niacșu (2022) indicates notably high

Table 3. Distance of accommodation units from impact points on DN15, Poiana Largului-Bicaz sector.

Distance from impact points on DN15	Accommodation Units												
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13
0-50 m	0	0	1	0	0	0	0	0	0	0	0	0	0
50-100 m	0	0	0	0	0	1	1	0	0	1	2	0	0
100-150 m	0	0	0	0	0	0	1	0	0	0	0	0	0
150-200 m	0	0	0	0	1	1	0	0	0	0	0	0	0
200-250 m	0	1	1	0	0	0	0	1	0	0	0	1	0
250-300 m	0	0	0	0	0	2	0	0	0	1	0	1	2
Total impact points number	0	1	2	0	1	4	2	1	0	2	2	2	2

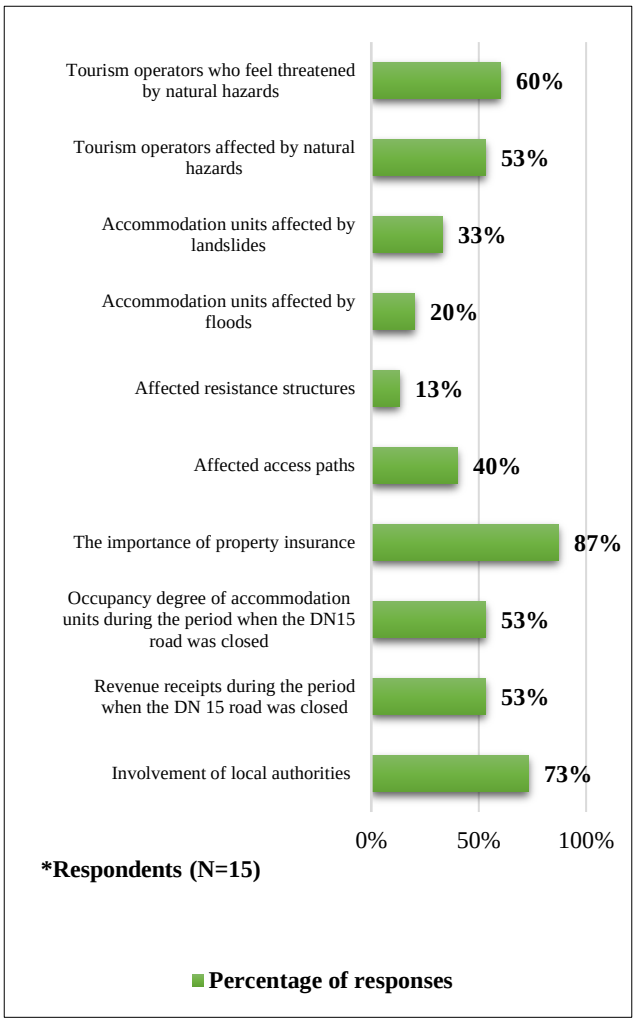

Figure 7. The consequences of natural hazards on the left bank of Izvoru Muntelui Lake highlighted by the responses of tourism operators.

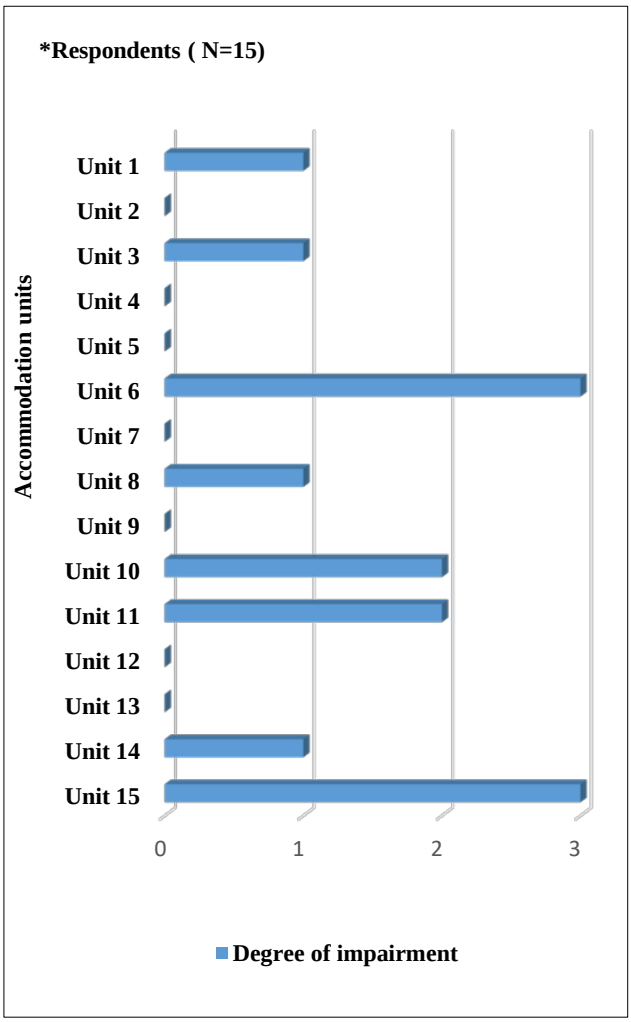

Figure 8. Degree of impairment to accommodation units on the left bank of Lake Izvoru Muntelui.

Table 4. Impacted accommodations inventory of natural hazards on the left bank of Lake Izvoru Muntelui.

Accommodation units	Natural hazards
Unit 1	Other
Unit 2	
Unit 3	Landslides
Unit 4	
Unit 5	
Unit 6	Landslides
Unit 7	
Unit 8	Landslides
Unit 9	
Unit 10	Landslides Floods
Unit 11	Landslides
Unit 12	
Unit 13	
Unit 14	Floods
Unit 15	Landslides Floods

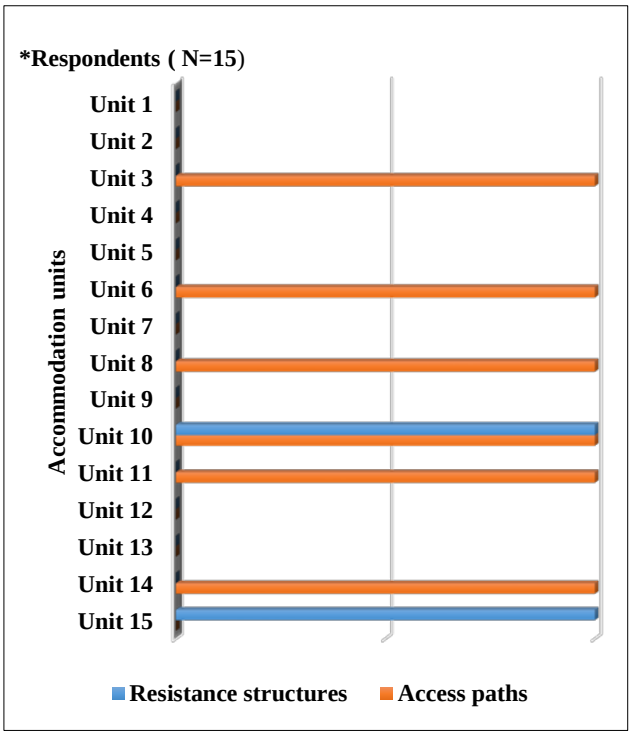

Figure 9. Accommodation units and impact types.

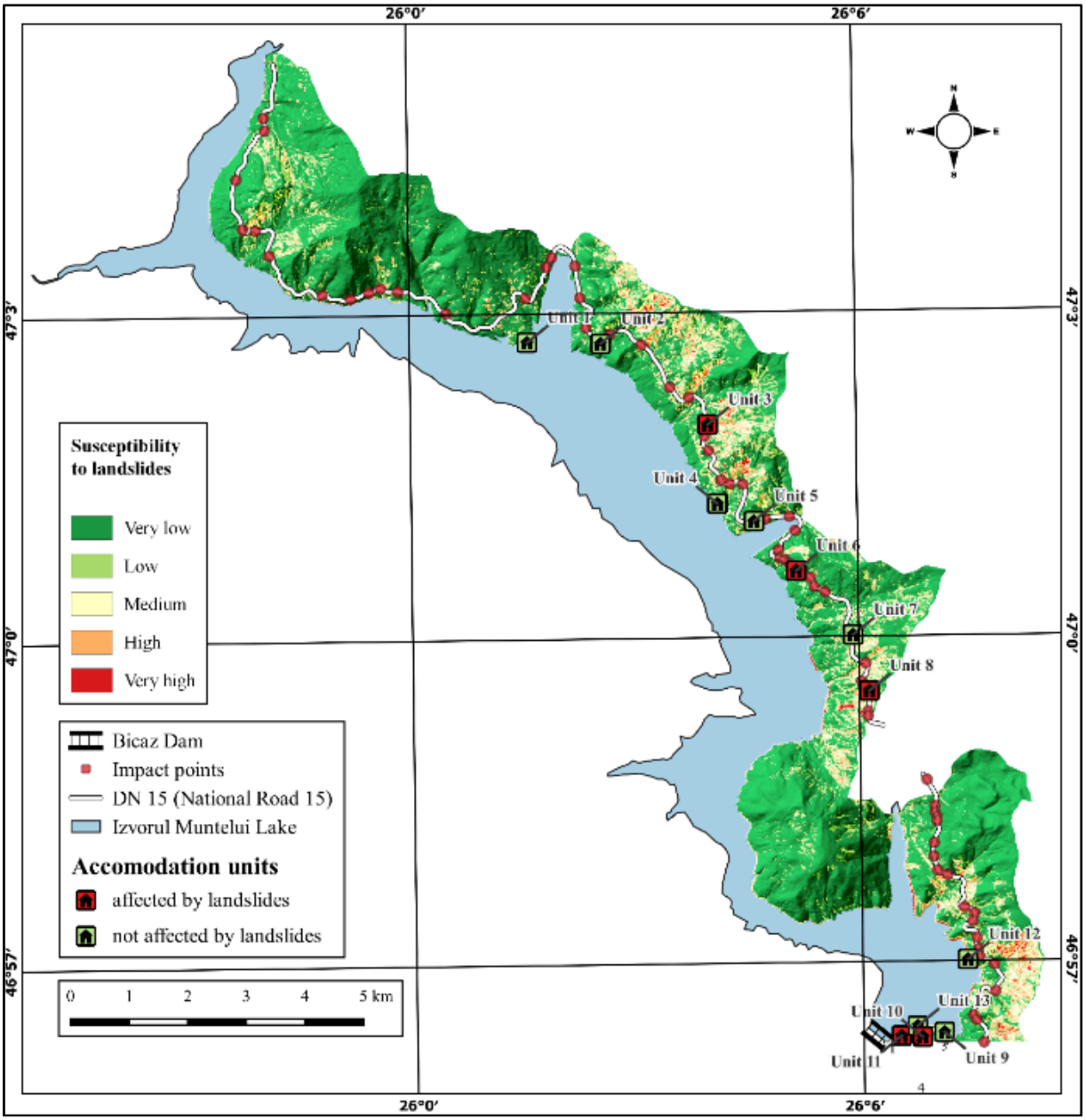

Figure 10. Landslide susceptibility map (according to Codru & Niacsu 2022, with modifications).

susceptibility values near the national road DN15, highlighting a substantial level of exposure and vulnerability for most accommodation units situated in close proximity to this road (Figure 10).

The landslide vulnerability assessment, derived from the arithmetic mean equation of susceptibility at the locations of accommodation units (Equation 1), reveals the following findings: four accommodation units exhibit a medium vulnerability index, two display a high vulnerability index, and one registers a very high vulnerability index (Table 5).

The relationship between the two variables, "impact points" and "degree of damage", was analyzed using correlation. The measure of the intensity of interdependence was performed using Bravais-Pearson correlation coefficients (Table 6), obtained by dividing the covariance by the product of the standard deviation of the variable "impact points" and that of the variable "degree of impairment".

Since the values of the two strings are not randomly distributed, it can be said that the values of Xi (impact points) depend on the values of Yi (degree of impact), as shown by the correlation diagram of the variables analyzed (Figure 11).

The appearance of the "point cloud" allows the relationship to be described; there is a moderate relationship between the two variables of "impact points" and "degree of damage" since the "point cloud" tends to align around a line, resulting in a positive linear relationship. The positive result of correlation coefficient (+0.62) confirms a relationship between the two variables: the more "impact points"

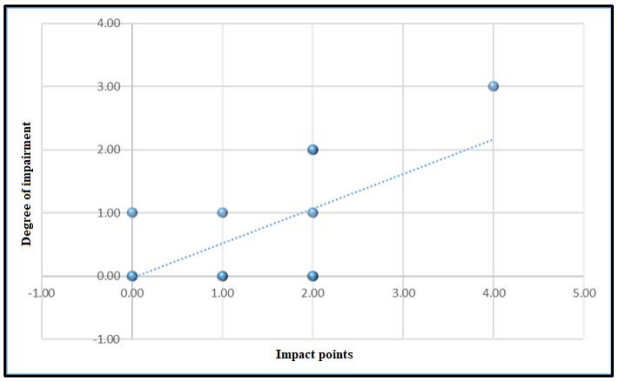

Figure 11. Variables correlation diagram of "impact points" and "degree of impairment"

near the accommodation units, the higher their "degree of impairment".

This analysis complements the studies conducted by Araújo Vila et al. (2019), which examine the flood vulnerability of a significant tourist destination located on the shore of the As Conchas reservoir in Spain's historical heritage. The authors conducted interviews with local experts and technicians and collected data on tourist demand and water level fluctuations; this data was then analyzed using Pearson correlation to determine if there is a statistically significant relationship between these two variables.

The results support the findings of Hamzah et al. (2012) and Bernard & Cook (2015), demonstrating that floods negatively impact the tourism industry by reducing visitor numbers. This decline leads to business losses, damage to local infrastructure, and high reconstruction costs. From a similar perspective, Aji et al. (2021) highlight the importance of preventing landslides in areas with tourism potential to protect the environment and argue that when the environment remains unaffected, the tourism economy can thrive, contributing to local sustainability for communities that rely on tourism for their livelihood.

Landslides are considered among the natural hazards that can cause significant socio-economic environmental damage and even human life losses (Schuster & Highland, 2001; Dilley, 2005; Petley, 2012; Turner, 2018; Miccadei et al., 2022).

Several authors (Hungr et al., 1999; Prina et al., 2004; Bhandary et al., 2013; Klose et al., 2015, 2016; Hungr, 2016) show that landslides have the highest impact on transport infrastructure, which is frequently at risk in many parts of the world.

In Romania, landslides are a frequent reality in the geomorphological landscape, where favorable conditions are mainly determined by geological, geomorphological, hydrogeological, climatic and human factors (Grozavu et al., 2012).

Romania is considered one of the European countries most affected by landslides (Wilde et al., 2018; Grozavu & Patriche, 2021); in regions with a high susceptibility to landslides, agricultural land, human settlements, infrastructure, and economic

Table 5. Vulnerability of accommodation units according to susceptibility to landslides.

Accommodation units	Landslide susceptibility of the accommodation unit	The average degree of susceptibility to landslides within a radius of 50 meters	The highest degree of susceptibility to landslides within a radius of 50 meters	The degree of susceptibility to landslides with the highest weight within a radius of 50 meters	Vulnerability
Unit 1	Low	Extremely low	Low	Extremely low	Low
Unit 2	Low	Very low	High	Extremely low	Low
Unit 3	Low	Low	High	Extremely low	Low
Unit 4	High	Low	High	Extremely low	Medium
Unit 5	Low	Low	Very high	Extremely low	Medium
Unit 6	Medium	Medium-low	Very high	Medium	High
Unit 7	Low	Medium-low	Very high	Extremely low	Medium
Unit 8	Very high	Medium-high	Very high	High	Very high
Unit 9	Medium	Medium-low	High	Medium	Medium
Unit 10	High	Medium-low	Very high	High	High
Unit 11	Low	Low	High	Extremely low	Low
Unit 12	null	null	null	null	null
Unit 13	null	null	null	null	null

Table 6. Bravais - Pearson linear correlation coefficient.

Accommodation units	Impact points (X_i)	Degree of affection (Y_i)	Xi-Me	Yi-Me	(Xi-Me)* (Yi-Me)	(Xi -X)	(Yi -Y)	(Xi-X)* (Yi-Y)
Unit 1	0.00	1.00	-1.50	0.50	-0.75	-1.46	0.23	-0.34
Unit 2	1.00	0.00	-0.50	-0.50	0.25	-0.46	-0.77	0.36
Unit 3	2.00	1.00	0.50	0.50	0.25	0.54	0.23	0.12
Unit 4	0.00	0.00	-1.50	-0.50	0.75	-1.46	-0.77	1.12
Unit 5	1.00	0.00	-0.50	-0.50	0.25	-0.46	-0.77	0.36
Unit 6	4.00	3.00	2.50	2.50	6.25	2.54	2.23	5.66
Unit 7	2.00	0.00	0.50	-0.50	-0.25	0.54	-0.77	-0.41
Unit 8	1.00	1.00	-0.50	0.50	-0.25	-0.46	0.23	-0.11
Unit 9	0.00	0.00	-1.50	-0.50	0.75	-1.46	-0.77	1.12
Unit 10	2.00	2.00	0.50	1.50	0.75	0.54	1.23	0.66
Unit 11	2.00	2.00	0.50	1.50	0.75	0.54	1.23	0.66
Unit 12	2.00	0.00	0.50	-0.50	-0.25	0.54	-0.77	-0.41
Unit 13	2.00	0.00	0.50	-0.50	-0.25	0.54	-0.77	-0.41
Average (Me)	1.50	0.50						
Standard deviation (σ)	1.08	0.97						
$\bar{X}$	1.46							
$\bar{Y}$	0.76							
Variance	1.17	0.97						
Covariance	0.64							
Correlation coefficient	0.62							

facilities are most affected (Grozavu et al., 2010).

The landslides that affected portions of the DN15 national road on the Bicaz-Poiana Largului sector blocked the carriageway in places and contributed to the total closure of traffic for six months, from July to the end of December 2019, to carry out works to stabilize the land and rehabilitate the affected road surface, generating costs of over 300 million RON, approx. 60.318.481 EUR (DRDP, 2022). The improvement, consolidation and rehabilitation of the road infrastructure on the left bank of the Izvoru Muntelui Lake was an important factor for the development of tourism in the area, as it can lead to an increase in the tourist flow, the prosperity of the region and the development of a sustainable form of tourism.

Also, Khadaroo & Seetanah (2008) consider that road infrastructure is a determining factor in the attractiveness of a tourist destination and a prerequisite for tourism development. Kaul (1985) acknowledges the role of the transport network in successful tourism development and states that "transport plays an important role in the development and success of new attractions as well as the growth of existing ones".

From the perspective of plans and strategies for the area's sustainable development for the localities on the left bank of Lake Izvoru Muntelui, tourism is one of the main economic growth points. In the long term, there are plans:

- improve the utilities infrastructure, as the accommodation units are not connected to the sewage system and the methane gas supply system;
- construct new accommodation and leisure or entertainment facilities (swimming pool, ski slope);
- improve tourism marketing/promotion through county and national advertising campaigns.

Assessment of the vulnerability of tourism activity on the left bank of Lake Izvoru Muntelui is thus essential for better management of how tourism investments may be affected. Sustainable exploitation of tourism potential and improvement of the quality of infrastructure (roads, utilities, tourist accommodation, and recreation) can increase the area's attractiveness by contributing to economic development and job opportunities.

5. CONCLUSIONS

In the study area, the manifestation and consequences of risk phenomena directly affecting road and tourism infrastructure are evident on the left bank of Izvoru Muntelui Lake. The area's susceptibility, especially to landslides, has increased as a result of anthropogenic solid interventions, such as the construction of the Izvoru Muntelui dam and the lake's entry into the economic circuit, high water level fluctuations, massive deforestation, the

construction of the DN15 national road, and, last but not least, the emergence of tourist infrastructure.

Landslides play an essential role in the area's evolution and appearance. They significantly impact the public infrastructure between Bicaz and Poiana Largului, especially the national road DN15; 73 impact points have been inventoried where landslides affect portions of the road, with an average density of 0.52/km.

The analysis also reveals that natural hazards, particularly landslides and floods, are perceived as a threat by most tourism operators in the area, with physical damage to tourism infrastructure. Determining the level of susceptibility and vulnerability can increase resilience and reduce the probability that tourism operators in the area will be affected by natural hazards. An accurate perception of the impact of natural hazards can raise awareness among tourism operators on the left bank of the Izvoru Muntelui Lake and can prepare operators by increasing the resilience of their present and future generations.

The methodology used to evaluate the susceptibility and vulnerability to natural risks for the tourism sector in the study area reveals essential insights into the relationships among geological, geomorphological, hydrological, climatic, and human factors. The analysis confirms the interconnectedness between the deterioration of road infrastructure and tourism facilities, highlighting the need for coordinated efforts and management strategies within tourism businesses to mitigate the risks posed by multi-hazards in the area.

Forthcoming research should concentrate on understanding the vulnerabilities in the study area by developing multi-hazard management models. It should also consider the damage to tourism potential and related businesses with various direct and indirect impacts.

Generalizing or extrapolating vulnerability from a local level to a regional scale can enhance decision-making and ensure the durability and resilience of a tourist destination. This approach helps mitigate the effects of natural hazards and is valuable for local authorities overseeing land improvement projects.

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