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ALTERNATIVE APPROACH TO MEASURING THE SOCIAL VULNERABILITY LEVELS OF POPULATIONS IN MUNICIPALITIES AFFECTED BY FLOODS

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Floods are the largest and most frequent natural hazard in Slovakia; they threaten a relatively large portion of the population. The scope and depth of vulnerability in some population groups due to floods pose a significant societal issue. This is particularly problematic for marginalised Roma communities (MRCs) living in environmentally unstable areas that repeatedly flood. Due to their low social and economic status and multiple disadvantages, these communities experience various forms and types of vulnerability. This paper responds to the adverse situation faced by a large part of this ethnic group by measuring and evaluating the social vulnerability (SV) of MRCs in selected municipalities threatened by repeated floods, with a particular focus on the Spišská Nová Ves district. This study sought to understand the differentiated level of SV, identify high-risk municipalities in terms of SV, determine the specific prevailing type of vulnerability, and confirm or refute the existence of a dependency between SV level and the proportion of Roma in the examined municipalities. Results confirmed the hypothesis that the most vulnerable municipalities have the highest proportions of marginalised Roma in their populations. The correlation coefficient showed a strong linear correlation between the level of SV and the proportion of the Roma population in the examined municipalities. All information obtained on the SV of Roma communities (level, risk, nature, specific vulnerabilities, conditions and causes) is a valuable source for assessing flood risks for the Roma ethnic group in Slovakia. The approach used to study the SV of MRCs is applicable to various marginalised groups and other natural risks; it can be generalised across geographic scales, analytical frameworks, different natural hazards, and index-creation methods.

Keywords: social vulnerability (SV), marginalised Roma communities, flood, SV indicators, correlation weighting system, SV index

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АЛТЕРНАТИВЕН ПОДХОД ЗА ИЗМЕРВАНЕ НА НИВАТА НА СОЦИАЛНА УЯЗВИМОСТ НА НАСЕЛЕНИЕТО В ОБЩИНИ В СЛОВАКИЯ, ЗАСЕГНАТИ ОТ НАВОДНЕНИЯ

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Абстракт: Наводненията са най-голямото и най-често срещано природно бедствие в Словакия; те заплашват относително голяма част от населението. Обхватът и дълбочината на уязвимостта в някои групи от населението поради наводнения представляват сериозен обществен проблем. Това е особено проблематично за маргинализираните ромски общности (МРО), живеещи в екологично нестабилни райони, които многократно се наводняват. Поради ниския си социален и икономически статус и множеството неблагоприятни фактори тези общности изпитват различни форми и видове уязвимост. Тази публикация отразява неблагоприятната ситуация, пред която е изправена голяма част от тази етническа група, чрез измерване и оценка на социалната уязвимост на МРО в избрани общини, застрашени от многократни наводнения, с особен акцент върху област Спишска Нова Вес. Това проучване има за цел да разбере диференцираното ниво на социалната уязвимост, да идентифицира общини с висок риск по отношение на социалната уязвимост, да определи специфичния преобладаващ тип уязвимост и да потвърди или опровергае съществуването на зависимост между нивото на социалната уязвимост и дела на ромите в изследваните общини. Резултатите потвърждават хипотезата, че най-уязвимите общини имат най-висок дял на маргинализирани роми в своето население. Коефициентът на корелация показа силна линейна корелация между нивото на социалната уязвимост и дела на ромското население в изследваните общини. Цялата получена информация относно специфичната уязвимост на ромските общности (ниво, риск, характер, специфични уязвимости, условия и причини) е ценен източник за оценка на рисковете от наводнения за ромската етническа група в Словакия. Подходът, използван за изучаване на специфичната уязвимост на ромските общности, е приложим за различни маргинализирани групи и други природни рискове; той може да бъде обобщен в различни географски мащаби, аналитични рамки, различни природни опасности и методи за създаване на индекси.

Ключови думи: социална уязвимост, маргинализирани ромски общности, наводнение, система за корелация на показателите за социална уязвимост, индекс на социална уязвимост.

INTRODUCTION

Natural hazards have a significant impact on people's lives, health and living conditions in both the short and long term. Generally, such hazards worsen the socioeconomic conditions of the population, reduce standards of living and lower the quality of life for affected populations. Identifying the most vulnerable or least resilient individuals (i.e. those most vulnerable to these impacts) can help in planning and managing suitable and targeted interventions (UNDP 2017). In natural hazard research, disaster risk is defined as a function of hazard, exposure and vulnerability (UNDRR 2021), and in many studies, population vulnerability is a major component of disaster risk research (Oppenheimer et al. 2014). Vulnerability represents a social state expressed by the degree of resilience to hazards (Blaikie et al. 1994; Hewitt 1997), and the term social vulnerability (SV) is used to describe existing conditions, characteristics, circumstances and situations of people that affect their (in)ability to prepare for and respond to natural hazards.

A vulnerable group or community within a country is a population with specific characteristics that expose them to higher risk and leave them in greater need of humanitarian assistance than others. The most common way to express SV is through an index that aggregates primarily demographic and socioeconomic factors that adversely affect communities facing natural risks or other stressors (including disasters or events caused by human activities). Existing vulnerability indices encompass and describe various aspects of SV to natural risks. The hazards-of-place model focuses on how geographic context interacts with the social characteristics of society (Cutter, 1996). The pressure and release model describes how vulnerability arises from inequalities in society that create social pressure (Wisner et al., 2004), while the access model focuses on people's access to capacities, assets, and opportunities. In the vulnerability framework, the components of vulnerability (exposure, sensitivity, and resilience) are conditioned and influenced by a range of contextual factors at societal and environmental levels (Turner et al., 2003). Indices generally do not contradict each other; rather, they describe vulnerability from different perspectives and with a different focus (Birkmann et al., 2013). The hazards-of-place model represents the most frequently used theoretical framework and quantitative method for understanding the relative sensitivity of a community and its ability to adapt to natural hazards. Professionals and policymakers widely use the hazards-of-place model based on various indicators that quantify measurable SV indicators (Rufat et al., 2015). Despite certain shortcomings, its usefulness for understanding the environment of SV when planning for natural hazard mitigation has been widely recognised (Spielman et al., 2020).

The dynamic trend of SV modelling over the last decade, in general and concerning floods in particular, has led to the creation and expansion of new social vulnerability indices (SVIs). Despite their diversity, newly developed SVIs show a high degree of uniformity in how they are constructed. This homogeneity reflects a growing methodological consensus among researchers, but it also highlights limitations in the ability to translate SV processes into composite indicators. Despite some design and contextual limitations, SVIs offer many benefits and advantages. Quantifying vulnerability using SVIs can help to identify the most vulnerable areas and the key dimensions and factors that determine them or act as drivers of SV. SVIs generally aggregate relevant factors and indicators meaningfully in the context of vulnerability and quantify their interrelationships, interactions and relative importance for vulnerability. Well-designed SVIs can simplify the multidimensional complexity of SV, which helps in creating measures to increase the resilience of affected populations, allocate resources and prioritize effective and targeted projects (Birkmann, 2006). To improve flood risk/emergency management, it is essential to know the risk, intensity of the threat and variability in the vulnerable population groups exposed to hazards and to incorporate these findings into regional or local emergency plans.

The negative impacts of natural disasters on people's lives, health and property are not evenly distributed across different populations and communities. Marginalised population groups are particularly affected by the adverse impacts and effects of natural risks (Flanagan et al., 2011; Rufat et al., 2015). Researchers in risk and environmental justice have demonstrated clear patterns of flood inequalities faced by people of different ethnicities and minorities (Bolin, 1986; Bolin and Bolton, 1986; Perry and Mushkatel, 1986; Peacock et al., 1997; Bolin and Stanford, 1998; Fothergill et al., 1999; Lindell and Perry, 2004; Zahran, 2008; Collins et al., 2013, Qiang, 2019; Messager et al., 2021, Mazumder et al., 2022; Hinojos et al., 2023). This is largely due to unfair social conditions (marginalisation, social exclusion, systematic restriction of access to resources, living in flood-prone areas, poor and inadequate infrastructure, and other factors) that have a significant adverse impact on these communities (Hinojos et al., 2023). These and other adverse conditions increase the vulnerability of these social groups by reducing their ability to prepare for, respond to and recover from threats (Cutter et al. 2003). Understanding the needs of specific population groups in emergency planning can reduce their vulnerability to natural risks (Flanagan et al., 2011). In Slovakia, marginalised Roma communities (MRCs) living in environmentally unstable areas (floods, landslides, contamination) are one such group. Together with their social status and demographic trend, the Roma community represents the most vulnerable population group in Slovakia. This paper responds to this fact and focuses on assessing the SV of municipalities with MRCs threatened by repeated floods. This study examined SV in municipalities with MRCs affected by floods in the Spišská Nová Ves district.

This paper seeks to highlight different levels of SV, identify high-risk municipalities, determine specific types of vulnerability, and factors determining SV, as well as to confirm or refute the existence of a relationship between the degree/level of SV and the proportion of Roma from MRCs in municipalities. Research on the differing levels and nature of SV to floods in these municipalities has been based on the analysis of values of partial indicators, weighting their importance; their integration leads to a determination of their overall vulnerability level expressed by an SVI. All information on the SV of MRCs (level, extent, nature, specific vulnerabilities, conditions and causes) is valuable and contributes significantly to risk assessment, targeting and directing aid, and understanding the needs of local people. The information may also be used by professionals in preparing mitigation, response and recovery plans, as well as in developing proposals to reduce SV of the examined communities due to flood risk.

STUDY AREA

This paper focuses on analysing the SV of selected Roma communities concentrated in settlements on the periphery of or outside municipalities (i.e. in segregated Roma settlements). The selection of municipalities suitable for analysis was based on the assessment of the flood risk to the Roma settlements expressed by the Flood Risk Index, which consists of two parameters: flood frequency (total number of floods over a 24-year period) and the economic vulnerability parameter for the Roma communities in settlements (based on the type/category of dwellings). Results from this flood risk assessment provided a rational basis for selecting a limited number of municipalities where detailed analyses focusing on population SV were conducted. SV was monitored in selected municipalities of the district identified as suitable for detailed analysis. This case study focuses on 12 municipalities in the Spišská Nová Ves district (Fig. 1), which repeatedly experienced floods during the study period and were characterised by a high level of economic vulnerability. All were classified as municipalities with medium to very high flood risk (Solín, 2024). The selection of these municipalities and their inclusion in the sample suitable for detailed SV analysis is further justified by other significant facts. One is that the municipalities lie within the Hornád River basin, one of the areas with the highest occurrence of floods in Slovakia (MŽP, 2024). Another important fact is that streams flow through these municipalities, which repeatedly overflow their banks due to heavy and/or localised rains, rapid spring snowmelt, and/or sediment build up. The selected municipalities thus represent suitable locations for the concept and methodology used to determine SV, its different levels, types of vulnerability, and to assess the negative potential of municipalities in terms of risk-related social characteristics and the demographic structures of the population.

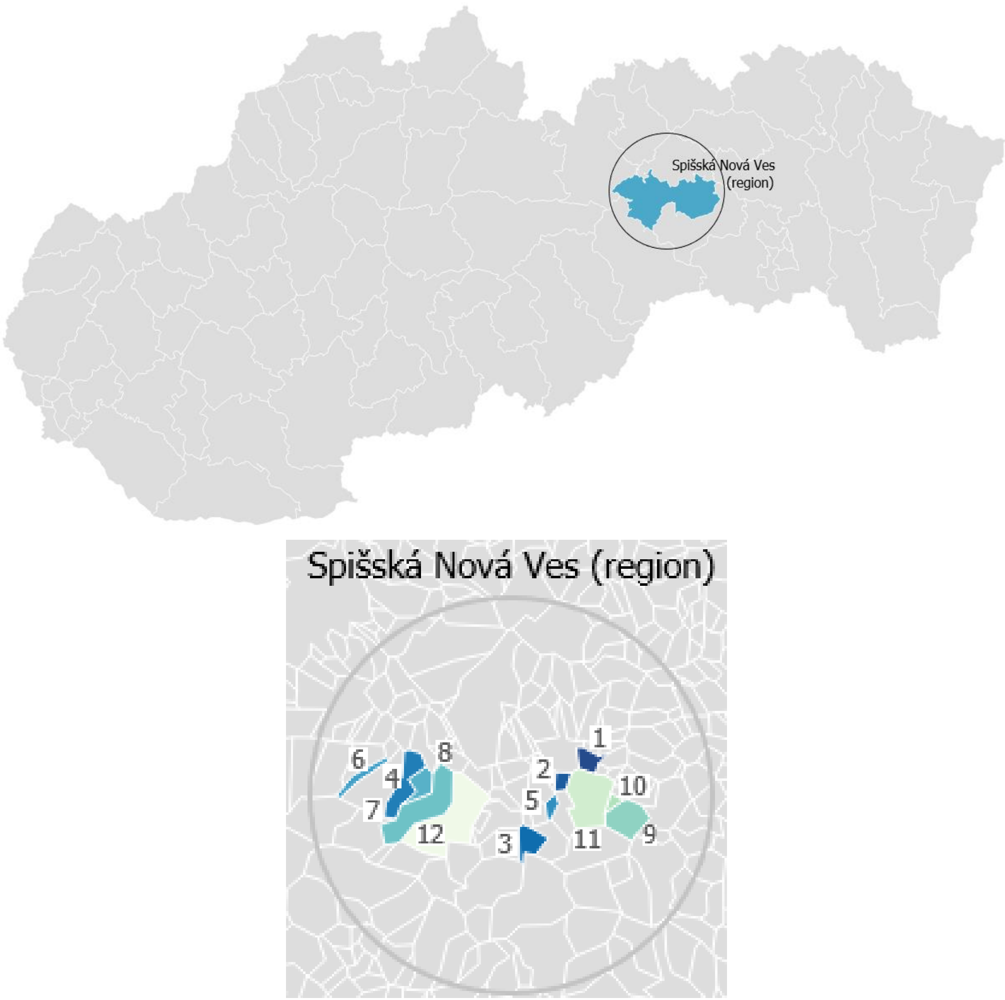

Figure 1. Overview map of surveyed municipalities: 1 Žehra; 2 Bystrany; 3 Rudňany; 4 Letanovce; 5 Vítkovce; 6 Betlanovce; 7 Spišské Tomášovce; 8 Smižany; 9 Krompachy; 10 Kolínovce; 11 Spišské Vlachy; 12 Spišská Nová Ves

METHODOLOGY

The basic means of assessing vulnerability in the studied municipalities are indicators and their weights. Using them, we can determine a quasi-SVI as a synthetic indicator that expresses municipalities' vulnerability. An important and basic prerequisite for using this method is the correct selection and quantification of indicators, and the determination of their significance/weight relative to floods. After selection, the individual indicators (variables) were standardised to a consistent scale (0,1). The normalisation of each indicator enabled the calculation of dimensionless values, allowing comparison of the state of the analysed variables across municipalities. The second step was to determine the indicator weights (their hierarchies) based on the variables' correlation matrix. The selected and used formal-statistical approach is based on the "importance" of a given variable, which is proportional to its information content in relation to the studied phenomenon. The product of the normalised variable's value and its weight is a synthetic indicator that expresses the municipalities' vulnerability level.

The formula for calculating the final vulnerability values has the following form (notation):

$$d_i = \frac{1}{k}\sum_{j=1}^{k} z_{ij} w_{j,(i=1,2,\ldots m)},$$

where w_j is the weight of the j-th sector, and z_{ij} are the values of the synthetic variable.

Indicators of social vulnerability

A wide range of SV indicators for floods have been developed internationally. Despite numerous studies on such indicators for floods and natural hazards more broadly, there is no definitive set of SV indicators or a unified approach to developing indicators (Khan, 2012). However, the same groups of variables repeatedly appear in indicator sets that can be considered key when examining SV. In the context of Slovakia, no comprehensive set of SV indicators for floods has been implemented. This study therefore sought to fill this gap by providing a set of the most significant SV indicators for floods. The scope or number of indicators is limited by the absence and unavailability of many necessary and relevant data on the Roma minority in Slovakia. These significant limitations to the availability of data on Roma – especially their demographic, social, and economic structures – thus had to be considered when selecting suitable indicators. Other criteria for selecting indicators included ensuring that indicators were from verified and relevant sources, sufficiently characterised the status and type of vulnerability, met the conditions for determining their importance to floods (weighting capability), could be interpreted easily and reliably, were informative for the assessment phase, and provided adequate spatial detail (i.e. data available at the municipal level).

The basic approach for selecting indicators was a conceptual framework that provided a logical way to consider the characteristics, importance, and interconnections of indicators and their relevance to floods. Without this conceptual framework guiding indicator selection, the selected indicators would be an eclectic mix based on data that would not make sense together. The foundation for the conceptual framework used in selecting the indicators was based on two key elements of vulnerability: susceptibility (sensitivity, helplessness, exposure) and lack of resilience. Sensitive and helpless individuals – whether due to age (childhood or old age), health status (illness or physical or mental disability), economic and social hardship (low socioeconomic status, isolation, or exclusion), or ethnic or racial affiliation (due to lack of financial or other economic and material resources, disadvantage in society, etc.) – are more vulnerable to an event (in this case, a flood) than those without these characteristics. The second key element of vulnerability, lack of resilience, has been interpreted in the SV context as an individual's inability to anticipate, manage, and recover from an event at the individual level (Faustini et al., 2010).

The selection of SV indicators used in this paper was based on a meta-analysis of nearly 80 articles focusing on SV and Roma communities. The significant differences in this ethnic group in all areas of life are largely due to their distinct history, culture, poverty, and status in society. Vulnerability to floods in this ethnic group results from a combination of multiple vulnerabilities. They experience financial vulnerability linked to poverty (lower income and greater dependency on state aid/social benefits), demographic conditions (Roma families have a larger number of children), unemployment (primarily long-term unemployment), low qualifications (due to inadequate/low education), health status (poorer health, higher morbidity, shorter life expectancy), and discrimination (Slovakia has faced several lawsuits for direct and indirect discrimination against Roma due to unsatisfactory living conditions, particularly in housing, limited access to quality education, and healthcare, which leads to lower quality of care provided). The most severe vulnerability was found among those Roma living in segregated settlements, which were often comparable, in terms of poverty and exclusion, to conditions typical in developing countries (Filadelfiová et al., 2006).

The study of the relationships between floods and the socioeconomic conditions of residents expressed by the SVI was used as the basis for the geographic analysis of SV to floods. The SVI used here consists of indicators from various dimensions, each allowing quantification of a particular attribute of vulnerability through appropriate and relevant indicators. Indicators defined at the level of flood-affected municipalities provide a relatively comprehensive view of SV among their residents. When analysing the municipalities affected by floods, our attention focused on indicators and conditions in the adverse part of the spectrum – that is, those indicating increased vulnerability. Statistical data from the latest population, housing, and dwelling census (2021) were used to analyse differing levels of SV for 12 municipalities in the Spišská Nová Ves district. Selected indicators were grouped into five categories: A – age (children and seniors); B – education (only basic education completed); C – economic activity and sector employment; D – wages/working income; and E – household size and completeness.

Category A included four characteristics/indicators (share of children up to 4 years, children aged 0–4 years, elderly aged 65–75, and over 75 years). Category B had two indicators: the proportion of residents who had completed first-level basic education and the proportion who had completed second-level basic education. Economic activity (category C) was assessed by the unemployment rate and the share of employment in the primary sector. Category D was characterised by a single indicator (working income), and category E was expressed by the share of complete households (both parents present) with three or more children and incomplete households (single parent with at least one child). Table 1 presents the selected indicators, characteristics, and SV indicators for floods in Slovakia based on relevant demographic and socioeconomic characteristics.

Table 1.

Selected Indicators, Characteristics, and SV Indicators for Floods in Slovakia

Indicator	**Characteristics of SV**	**Indicator**
Age	Older population (65 to 75 years; +75 years)	Proportion of the total population
	Children (up to 4 years; 0–14 years)	Proportion of the total population
Education	Level I Elementary School	Proportion of the total population
	Level II Elementary School	Proportion relative to the national average
Income	Low gross wage	Nominal wage
Household structure	Single-parent households	Proportion of households with only 1 parent
	Larger households	Proportion of households with 3 or more children
Employment	Unemployment	Unemployment rate
	Primary sector employment	Share of employment in the primary sector out of the total economically active population

Source: SODB 2021 (Statistical Office of the Slovak Republic 2024a), DATAcube (Statistical Office of the Slovak Republic 2024b)

Procedures of analysis

Individual variables (indicators) were transformed/standardised on a consistent scale (0,1) for statistical processing using the formula:

$$I_{xi} = (max_{xi} – xi) / (max_{xi} – min_{xi}),$$

if the favourable rating of the phenomenon increased as the value of x_i decreased, and

$$I_{xi} = (xi – min_{xi}) / (max_{xi} – min_{xi}),$$

if the favourable rating of the phenomenon increased as the value of x_i increased, where x_i is the value of the given variable, min_{xi} and max_{xi} are the minimum and maximum values, and I_{xi} is the transformed value of the given variable.

Normalising each indicator made it possible to obtain dimensionless values (Balica, 2012), which enabled comparisons of results across different periods and studied areas (Tascón-González et al., 2020). Table 2 presents the calculated normalised values for the studied municipalities. The worst values are highlighted in blue, and the best values are highlighted in yellow. At first glance, it is clear that the Žehra municipality had the worst values across seven vulnerability indicators. Two indicators showed the worst vulnerability values in Bystrany (education –

Level I basic education and single-parent households). Letanovce had the worst values for one indicator (Level II basic education), while Rudňany had the worst values for children under 4 years old. The district town of Spišská Nová Ves and Spišské Vlachy appeared to be the least vulnerable (with the lowest values for the vulnerability indicators). Both towns achieved the best values in four indicators, with the remaining three indicators showing the lowest, and thus best, values in Kolinovce, Krompachy, and Vítkovce.

Table 2.

Normalized Values by Municipality

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Betlanovce	0,38	0,85	0,2	0,03	1	0,52	0,45	0,35	0,31	0,52	0,74
Bystrany	1	0,81	0,78	0,48	0,06	0,86	0,92	0,71	0,89	1	0,61
Žehra	0,71	0,71	1	1	1	0,96	1	0,68	1	0,36	1
Kolinovce	0	0,3	0,03	0,26	0,25	0,26	0,29	0,19	0,08	0,18	0,18
Krompachy	0,14	0,25	0,23	0	0,18	0,28	0,57	0,34	0,26	0,33	0,12
Letanovce	0,16	1	0,22	0,75	0,06	0,57	0,45	0,35	0,52	0,36	0,79
Rudňany	0,25	0,78	0,42	0,26	0,06	0,76	0,70	0,99	0,9	0,39	0,54
Spiš. Tomášovce	0,22	0,56	0,34	0,45	0,25	0,55	0,72	0,36	0,39	0,13	0,30
Spišské Vlachy	0,12	0,02	0	0,17	0	0,2	0	0	0,03	0,06	0,25
Vítkovce	0,56	0,76	0,75	0,64	0,18	0,49	0,30	0,57	0,42	0	0,59
Spišská N. Ves	0,01	0	0,01	0,02	0	0	0,06	0,07	0	0,22	0
Smižany	0,13	0,37	0,15	0,18	0,12	0,45	0,57	0,19	0,15	0,20	0,27

Explanations: 1 – Level I Elementary School; **2** – Level II Elementary School; **3** – Unemployment; **4** – Primary Sector; **5** – Wage; **6** – Age 65–75; **7** – Age over 75; **8** – Age 0–4; **9** – Age 0–14; **10** – Single-parent household; **11** – Large household

Source: Calculations based on data from SODB 2021 (Statistical Office of the Slovak Republic 2024 a,b)

Determining variable weights

One of the challenges in the practical creation of an SVI is determining the weights of variables. Experience and intuition suggest that the relative weights of variables cannot be equal (Abrahamowicz and Zajac, 1986), which indicates the need to weight the variables. Other authors (e.g. Dufek and Minařík, 1984) have noted that the choice of weights should not be overestimated, although they admit that weight choice can partially affect evaluation results. Aldenderfer and Blashfield (in Krok, 2003) argued that weighting variables is essentially manipulating their values. If objects need to be analysed based on k indicators, their weights should be non-negative, with a sum equal to 1 or k. Generally, there are two approaches to variable weighting. The first is based on expert evaluations, which are primarily used when creating weights for qualitatively comparable variables and are common in economics, where direct numerical weights cannot be set, but the order or intensity of preference for variables can be determined. The second formal-statistical approach is based on the “importance” of a given variable, which is proportional to its information content relative to the phenomenon studied. Such weights can be created using either the coefficient of variation (used for weighting variables with relatively high variability) or a correlation matrix of variables (used for weighting variables with a clear character based on whether the variable positively or negatively affects the phenomenon with certainty). We used the latter approach, where the creation/determination of selected variable weights was based on the correlation matrix of variables, and weights were created using this relationship (Grabinski et al., 1993):

$$wj = \frac{\left|\sum_{i=1}^{m} \mathrm{r}ij\right|}{\left|\sum_{j=1}^{k} \sum_{i=1}^{m} \mathrm{r}ij\right|}$$

where r_{ij} is the correlation coefficient of variables X_i and X_j.

The correlation weighting system favours variables strongly correlated with other variables. High weights are assigned to central variables (marked in blue), while satellite variables (marked in yellow) have low weights. Table 3 shows the calculated weights of the selected variables using the correlation matrix. It clearly shows that age, specifically the 65–75 senior age category (weight = *0.840*), is the strongest/central variable, with a relatively high representation. The other three central variables/indicators are also associated with age; this indicates that the intensity/degree of vulnerability/SV is determined and significantly influenced by age, which plays a dominant role in the studied communities and others. All age-related variables achieved high weights/the highest indicator values (age 0–14 with weight = *0.782*; age 0–4, weight = *0.752*; and age >75, weight = *0.740*), so they can also be considered central variables. The relatively low weight of the wage variable, meanwhile, may be somewhat surprising, as this represents a satellite variable with the lowest weight. Within the broader context, however, this is not unusual because the communities studied have high unemployment (weight = *0.707*) and are thus highly dependent on social benefits, which are characterised by much lower inequality than wages (Michálek, 2007).

Table 3.

Weights of Selected Variables Using the Correlation Matrix

	Variables										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1										
2	0,58524	1									
3	0,88867	0,59958	1								
4	0,55321	0,59499	0,74789	1							
5	0,33842	0,35671	0,37515	0,25661	1						
6	0,77509	0,79941	0,82558	0,68825	0,41419	1					
7	0,65502	0,59438	0,72537	0,49544	0,38404	0,88095	1				
8	0,64909	0,71036	0,76711	0,46354	0,18905	0,83565	0,72907	1			
9	0,75603	0,73499	0,84336	0,66158	0,29466	0,94393	0,83365	0,91971	1		
10	0,64593	0,46608	0,37210	0,06463	0,15582	0,55445	0,59526	0,47658	0,58003	1	
11	0,66959	0,85189	0,70475	0,74323	0,60047	0,83210	0,56057	0,61212	0,76461	0,38951	1
	0,68182	0,67000	0,70656	0,54563	**0,43271**	**0,84033**	0,74040	0,75200	0,78167	0,69500	1

Source: Calculations based on data from SODB 2021 (Statistical Office of the Slovak Republic 2024a).

RESULTS

SVI Values in Investigated Localities

SVIs are numerical expressions that provide measurements for the level of vulnerability within a given context. They are quantitatively expressed as statistical information synthesising data provided by the analysed variables. The SVI used in this study for the analysed municipalities aggregates relevant indicators from all major dimensions corresponding to flood vulnerability. In line with recent research and existing standardised criteria, indicators are statistically expressed in percentages or proportions (older people, children, individuals with low education, unemployed). The aggregated SVI for the studied municipalities was calculated as the arithmetic mean of the transformed variables.

The weighted SVI is represented by the product of the arithmetic means of the transformed variables and calculated weights. The aggregated SVI expressed as the sum of all weighted variables, or the ranking of municipalities by calculated SVI values, is shown in Table 4. Žehra municipality stands out as the clear loser, as it achieved the highest SVI value of *6.741* and the worst values across seven SV indicators (normalised variable values). Bystrany also had a high SVI value (*6.007*) with simultaneously adverse (high) values in two variables. Žehra and Bystrany also have the highest proportion of the Roma population. According to the 2019

Table 4.

Ranking of Municipalities by Weighted SVI Values

Order	Municipality	ISV value	Share of Roma (%)
1	Žehra	**6,741**	81-90
2	Bystrany	6,007	71-80
3	Rudňany	4,575	51-60
4	Letanovce	3,888	**41-50**
5	Vítkovce	3,823	51-60
6	Betlanovce	3,796	41-50
7	Spišské Tomášovce	3,088	31-40
8	Smižany	2,068	31-40
9	Krompachy	1,971	21-30
10	Kolinovce	1,417	11-20
11	Spišské Vlachy	0,672	1-10
12	Spišská Nová Ves	0,276	1-10

Source: Calculations based on data from the 2019 Atlas of Roma Communities (Ravasz et al. 2020)

Atlas of Roma Communities (Ravasz et al., 2020), the Roma proportion in Žehra was between 81 % and 90 %, and in Bystrany, 71%–80 %. Almost the entire Roma community of approximately 2001–2100 people in Žehra lives in two settlements outside the municipality in the Dreveník and Sídlisko Dreveník areas. Rudňany also had a high SVI (*4.575*) and, like Letanovce, recorded extreme values in one variable. The higher weight of the central age variable (children 0–4 years), with a weight of 0.752, shifted Rudňany up one adverse position in the vulnerability ranking above Letanovce (which had a worse value, but in a variable with a lower weight). In Vítkovce, higher weights caused value shifts and significant deterioration in its vulnerability ranking position. All three cities and municipalities with the lowest values (below the SVI value of 3.0) performed best. The level/degree of SV in the studied municipalities is shown in Figure 2, where municipalities are grouped into one of four vulnerability levels; most municipalities have a high SV level.

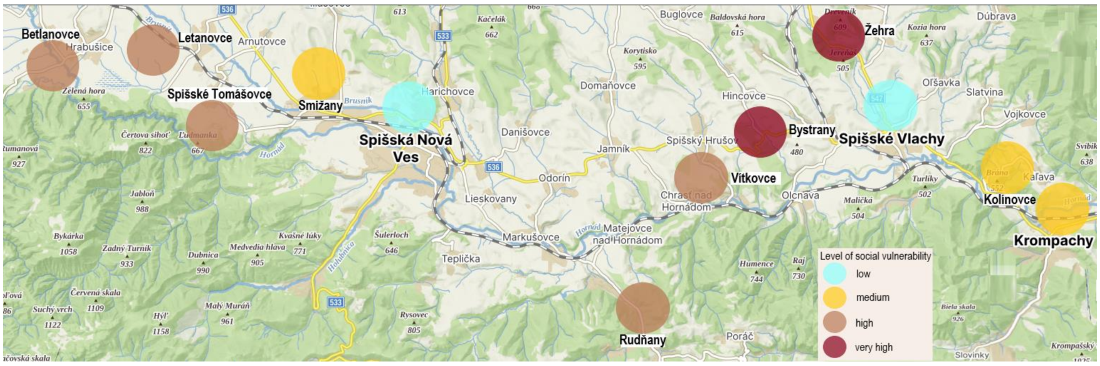

Figure 2. The level/degree of SV in the studied municipalities

Evaluation of correlation dependencies

Another fundamental and important question addressed by this paper is the extent to which SV is related to the proportion of Roma in the population of the studied municipalities. The importance of answering this question significantly affects the generalizability of results for all municipalities with MRCs affected by floods. At first glance, comparing SVI values and the proportion of Roma shows a high degree of matching. Among all municipalities, only Letanovce, which has a minority Roma population (41%–50 % of the total municipal population, an estimate from the 2019 Atlas of Roma Communities), achieved a higher SVI value than Vítkovce, where the Roma community accounts for over half of the municipality's population (51%–60 %). A slightly higher SVI (3.888) in Letanovce shifted the municipality's vulnerability ranking one place before Vítkovce, which theoretically would have occupied the fourth position based on the proportion of Roma in the municipality. This single, minimal change (the difference in SVI values between them was only 0.065) in the ranking of these two municipalities by SVI value and Roma proportion indicates that the variables are significantly correlated and closely interconnected. This critical finding was confirmed by the Pearson correlation coefficient (r), whose value of 0.9862 indicates a strong linear correlation between the level of SV and the proportion of the Roma population in the municipalities. This demonstrates a direct positive relationship between SV and the proportion of Roma in the population in the studied municipalities. This suggests a need to focus on this population when addressing SV in these municipalities. The results also indicate that attention should be focused on micro-locations of segregated Roma settlements outside municipalities and on their specific vulnerabilities, which, in addition to structural (demographic, economic, social) characteristics and disadvantages, also include a lack of basic infrastructure or limited accessibility.

Social vulnerability, sustainable development and resilience

The paper characterises social vulnerability as a combination of susceptibility and lack of resilience in marginalised Roma communities. The findings show that the sustainable development of MRCs is hampered by their "trap" in cycles of environmental instability and socio-economic disadvantage. This study uses the Social Vulnerability Index to identify social injustice and provide insights into strategies for long-term, resilient municipal planning. The paper highlights the strong correlation between ethnic marginalisation and vulnerability to floods. The paper's findings, along with other academic and institutional research frameworks, show that social vulnerability is not only a risk factor but also a primary obstacle to sustainable development. Reducing vulnerability is increasingly seen as the "flip side" of building resilience – a society cannot be considered sustainable if it lacks the adaptive capacity to protect its most vulnerable members. Modern sustainability science is moving towards a "social-environmental system" perspective, which argues that environmental health and social equity are inseparable. This is confirmed by the findings of the provided study, which show that the exclusion of specific communities directly undermines the stability and development potential of the wider region. It has been shown that high social vulnerability is not only a localised risk but also a structural barrier that threatens not only the affected communities but also the development of the regions in which these communities live. These are precisely the structural barriers that sustainable development frameworks seek to remove. The entire region where the municipalities are located, along with its wider surroundings, is among the least developed areas of the country.

The identification of "islands of vulnerability" in marginalised Roma communities in the Spišská Nová Ves district can be considered a key first step towards alignment with the global goals of sustainable settlement and reducing inequalities. Although the study focuses on vulnerability and flood risk, its results are related to the broader concept of "socially just" interventions. Linking data and the results obtained can contribute to the equitable allocation of resources. Localised social vulnerability assessments represent a significant contribution to the development of strategic sustainable development programs. The use of the Social Vulnerability Index enables a shift from reactive emergency responses to proactive investments in social safety nets and resilient infrastructure. This transformation is essential to ensure that development assistance and concessional financing reach the populations that need them most and to effectively implement the mandate and principle of "leaving no one behind" within the framework of sustainable development. The direct link between the study's findings in the Spišská Nová Ves district and localised sustainable development frameworks provides the necessary basis for fulfilling the aforementioned mandate. The paper's specific findings can be integrated into regional green transition initiatives that treat marginalised communities not only as victims of environmental risks but also as active participants in sustainable social innovations. This shift represents a transition from simple disaster management to a holistic development model that simultaneously addresses energy deprivation and environmental justice. The "vulnerability-sustainability" framework addresses the contradiction between economic growth and persistent social exclusion. The identified "pockets" of extreme social vulnerability can lead to catastrophic scenarios during environmental shocks. The study's focus on indicators such as household size and education levels of marginalised groups highlights a form of "structural vulnerability" that traditional economic metrics often overlook. By linking these data, we have shown that true sustainability requires a shift from a reactive response to the crisis to a "risk-informed" development that considers social equity as a fundamental pillar of resilience.

The results from the Hornád River Basin highlight the importance of "participatory" sustainable development strategies. The high level of social vulnerability identified in the MRC represents a significant "sustainability gap" that contributes to regional underdevelopment. Reducing social vulnerability is a prerequisite for achieving sustainability, while sustainable planning provides tools for systematically addressing vulnerability. Local knowledge informs broader efforts for global resilience and social justice. By linking local knowledge with global theories, it is possible to formulate targeted assistance to target communities. While traditional models of economic growth often mask sub-national disparities, research on vulnerability hotspots provides a detailed evidence base for more effective resource allocation. Addressing the root causes of vulnerability (such as exclusion from education, inadequate housing, etc.) is not only a humanitarian effort but also a prerequisite for protection against natural hazards in general. Results from specific municipalities serve as an important basis and source for participatory development strategies aligned with international standards. The path to a sustainable future requires the systematic removal of social barriers, institutional marginalisation and unfair distribution of resources that increase vulnerability to hazards. Targeted assistance based on the results of similar research significantly helps transform local vulnerability into community resilience. This will ultimately fulfil the global mandate to ensure that no one is left behind amid environmental change/risks. The Social Vulnerability Index serves as a bridge, enabling planners to move from reactive crisis management to a proactive model that views social justice as a pillar of environmental stability.

DISCUSSION

Examining SV in the studied municipalities revealed several limitations that must be addressed to obtain more accurate results. The first limitation of this study is the lack of precise data on the socio-demographic and socioeconomic structures and parameters of the studied MRCs or the Roma population as a whole. In Slovakia, some primary data critical for SV indicators/evaluation (i.e. that directly and significantly indicate SV levels of flood-prone populations) are not available for Roma communities or are lacking entirely. Notably, indicators of health status in MRCs are missing, although these are indispensable in most research and studies examining SV on an ethnic basis. The absence of these data at local or regional levels significantly limits vulnerability research on this community due to their poorer health status compared to the majority population. The long-term malignant influence of MRC disadvantages in multiple health determinants significantly affects (i.e. increases) their morbidity and mortality. The share of people over 64 years old in MRC environments is more than three times lower (5 % to 17 %) than in the general population (Grauzelová and Markovič, 2019). This finding aligns with previous research indicating a significantly lower average life expectancy in MRCs (68 years in MRCs compared to 76 years in the general population) (Hellebrandt et al., 2020, p. 182). The absence of health status data for MRCs does not mean that the flood vulnerability findings in this paper lack weight and relevance. The extremely low (children) or high age (over 65 or 75 years) indicators used in the study are significant proxy indicators indicating health-related vulnerability. They are primarily related to a significant decrease in mobility with ageing among seniors, but also to decreased mobility among children, which, conversely, declines with age in children. In this context, the specific age boundary for (significant) mobility reduction needs to be determined for each studied community. Another drawback of most MRC-related data is their temporal incompatibility, because most data on MRCs are derived from or are the result of various surveys related to different years or periods.

This study also has limitations related to the indicators used. Although the indicators and characteristics used in the study are the most frequently represented and analysed in most SV research and studies, they do not always reflect all aspects of the complexity of SV. Their impact on SV varies greatly depending on the type of disaster, spatial level, and context of understanding precursors, processes, and event progress. The selected and analysed indicators are thus only partial indicators of reality. While they provide a substantial part, they do not provide a complete picture of vulnerability. During an adverse event (flood), the indicators do not provide entirely accurate information about residents, their vulnerability level, or the actual degree of impact. They also indicate SV only at the individual, not at the systemic level.

Conversely, a strength of this paper is that the indicators used can be (either fully or with minor modification) transferred to another environment (e.g. other ethnic communities). Their use, however, must consider the specificities of the studied population, and indicator selection and use must be adjusted accordingly, along with the weights, which vary from place to place. The conceptual and methodological approach can also be applied to various specific communities or population groups. However, simple conceptual-methodological replication should be avoided, because the outputs relate only to a specific time period and geographic area to which the analysis applies.

The study also confirmed the generally known fact (Khan, 2012) that summarising indicators into a single index value can provide interpretive simplicity but may also conceal local specificities of vulnerability in the studied area or locality. That said, the findings provide not only conceptual and methodological contributions but also interesting empirical results on the differentiated degree/level of SV, hotspots, and the causal relationships of SV in the specific environment of the studied municipalities. At the same time, the results provide significant information on demographic and socioeconomic indicators and characteristics, which are the main drivers of flood-related SV in the studied municipalities.

CONCLUSION

Natural disasters are an increasingly popular topic not only in the natural sciences, but also prominently in the social sciences – particularly economics, sociology, and spatial studies – due to their significant impact on all major aspects of life. In the recent past, disaster risk reduction efforts have focused primarily on infrastructure and technology measures (Flanagan et al., 2011). However, for more than two decades, there has been consensus that these efforts must be accompanied by other measures related to reducing vulnerability and improving resilience in all disaster phases (i.e. preparedness, response, recovery, and mitigation). Vulnerability research appears especially important in comparing SV levels on multitemporal and multiscale levels. The results of differentiated SV levels are a valuable source of information for flood risk planning and management. Based on the calculated SVI values, highly differentiated levels of SV were identified in the studied municipalities. The ranking of municipalities in the SVI was determined by the values of individual indicators and their final sum.

This study fills a significant theoretical-methodological and empirical gap in examining SV in Slovakia in municipalities experiencing repeated floods. No comprehensive set of indicators measuring (differentiated levels of) SV to floods has yet been fully implemented in Slovakia. The indicators and calculated SVI values in the studied flood areas, as well as the ranking of municipalities by vulnerability level, provide valuable information for creating measures to reduce SV among residents of the analysed municipalities. The indicators used also point to various aspects of SV and the need for a multidisciplinary approach to reducing flood impacts and strengthening population resilience. The conceptual framework and approach for using the presented indicators are also applicable to other sudden-onset disasters, such as fires, heatwaves, earthquakes, and pandemics, such as COVID-19. The presented methodology can be implemented in various regions and locations. It is generalizable to various geographic scales, analytical frameworks, risks, and index creation methods.

The study's findings on the scope of SV, the spatial differentiation in its levels, and its various types are essential for identifying vulnerability hotspots, objectively assessing actual impacts, and preparing targeted assistance for the most vulnerable populations. The findings are also fundamental for developing measures for the effective use of all available resources to reduce vulnerability and increase population resilience. They also lead to new questions regarding flood impact mitigation options, priority setting, resource allocation, and prevention programmes targeting the studied locations. Addressing these and other related questions can provide valuable support for developing more socially just and effective flood impact reduction strategies, as well as improving systematic approaches to targeted assistance.

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