International Cartographic Association
Association Cartographique Internationale

Spatial-statistical analysis of changes in social flood vulnerability at municipal level in Slovakia

Matej Vojtek [a,*], Anna Tirpáková [b], Gabriela Repaská [a], Jana Vojteková [a]

[a] *Department of Geography, Geoinformatics and Regional Development, Faculty of Natural Sciences and Informatics, Constantine the Philosopher University in Nitra, Trieda A. Hlinku 1, 949 01 Nitra, Slovakia, mvojtek@ukf.sk, grepaska@ukf.sk, jvojtekova@ukf.sk*
[b] *Department of Mathematics, Faculty of Natural Sciences and Informatics, Constantine the Philosopher University in Nitra, Trieda A. Hlinku 1, 949 01 Nitra, Slovakia, atirpakova@ukf.sk*

* Corresponding author

Keywords: social flood vulnerability, municipalities, GIS, spatial analysis, spatial autocorrelation

Abstract:

Social vulnerability refers to demographic and other socio-economic characteristics of individuals or households, like age, health status, income, employment, education, and their sensitivity/resistance/resilience to flooding (Hinojos et al., 2023). All of these characteristics change in space and time and, therefore, may play different role in the assessment of social flood vulnerability over the time (Tang et al., 2021). The hazard independent approach was used in this study to express the susceptibility of population to flood damage, its ability to cope with floods and recover after a flood independently of the flood hazard, which was not investigated in this study (Chakraborty et al., 2020; Roldán-Valcarce et al., 2023). Such approach focuses on establishing indices that are calculated based on social vulnerability indicators (Isia et al., 2023). Finding the drivers of change in social vulnerability should be crucial for flood managers or urban planners to define the strategies and measures for reducing the vulnerability to floods (Mohanty et al., 2020). In Slovakia, the vulnerability assessment was omitted in case of the official Preliminary Flood Risk Assessment (PFRA) under the EU Directive 2007/60/EC on the assessment and management of flood risks. Therefore, we aim to propose a practical and systematic methodical approach to deal with social flood vulnerability assessment and its changes in the next revision of the PFRA in Slovakia. The research objective of this study is the assessment of spatial and temporal changes in social flood vulnerability between the years 2001, 2011, and 2021 using geographic information systems (GIS) and spatial-statistical methods, specifically the spatial autocorrelation. The place-based (municipal level) approach was used for determining the social flood vulnerability index (SFVI) in the studied years. Study area was represented by 2,927 municipalities of Slovakia. In this study, we focus on any type of flood that can happen in municipalities, especially, fluvial and pluvial floods, which reoccur the most compared to the other types of floods in Slovakia. The research questions in this study were as follows: Has the population in municipalities of Slovakia become more or less vulnerable to flooding over the studied period? Are the values of the SFVI spatially clustered or not in each studied year?

We chose eight indicators of social vulnerability, most of which are represented by population groups with higher sensitivity and lower resistance/resilience to flooding. Specifically, we used the population density indicator, share of population 65+ from total population, share of unemployed population from economically active population, share of the Roma ethnicity from total population, share of households with six and more persons from total number of households, share of incomplete households from total number of households, share of residents without education and with primary education from total population, and share of disabled from total population of municipality. These indicators are commonly used in literature, including the works mentioned in the paragraph before. In case of the Roma ethnicity indicator, it was selected due to construction of their dwellings near watercourses, which have poor quality (huts or shacks) and they are overcrowded. The source data were downloaded from the websites of the Statistical Office of the Slovak Republic and processed in GIS. All of the indicators were normalized, using the maximum method, to have them in the same scale from 0 to 1. The multicollinearity test, using the Variance Inflation Factor (VIF), as well as the Pearson correlation among indicators were calculated to determine if there are highly correlated indicators, which would be unsuitable for the calculation of SFVI due to double-counting. The SFVI for each studied year was computed in GIS as a sum of the eight normalized indicators, for which we assigned equal weights. As long as it is difficult to decide which indicators are more important and to avoid the subjective weighting of indicators, we decided for equal weighting, which was preferred to maintain more objectivity. Spatial autocorrelation was then used for the SFVI in each studied year to determine if there are statistically significant local Moran's coefficients and spatial clusters of the SFVI at municipal level.

Based on the results of multicollinearity test, all of the indicators were independent for calculating the SFVI in each year using the thresholds of <5 for the VIF and <0.7 for the Pearson correlation. The indicators, which values have increased

https://doi.org/10.5194/ica-abs-10-290-2025

throughout the studied years, were population density, population 65+, households with six and more persons, and incomplete households. On the other hand, the values of the unemployed population decreased throughout the studied years. Values of the Roma population, disabled, and population without any education or with primary education increased from 2001 to 2011, but decreased in 2021. The regions with the highest SFVI values can be found mainly in southern and eastern Slovakia in each of the studied years. The local Moran's coefficients had values of 0.416, 0.432, and 0.459 for the studied years 2001, 2011, and 2021, respectively. In 2001, 495 municipalities showed positive autocorrelation of which 258 municipalities had High-High and 237 municipalities Low-Low spatial dependence. Compared to 2001, the number of municipalities with positive autocorrelation in 2011 was higher (503 municipalities) by 0.3%. In 2011, High-High spatial dependence was recorded in 289 municipalities while Low-Low spatial dependence was in 214 municipalities. The lowest number of municipalities (436) with positive autocorrelation was in 2021. The number of municipalities with High-High and Low-Low spatial dependence decreased to 249 municipalities and 187 municipalities, respectively. The answers to the stated research questions are: The population in municipalities of Slovakia has become more vulnerable to flooding over the studied period and the values of the SFVI are spatially clustered, creating several spatial clusters with high and low values of SFVI in each studied year, as shown in Figure 1.

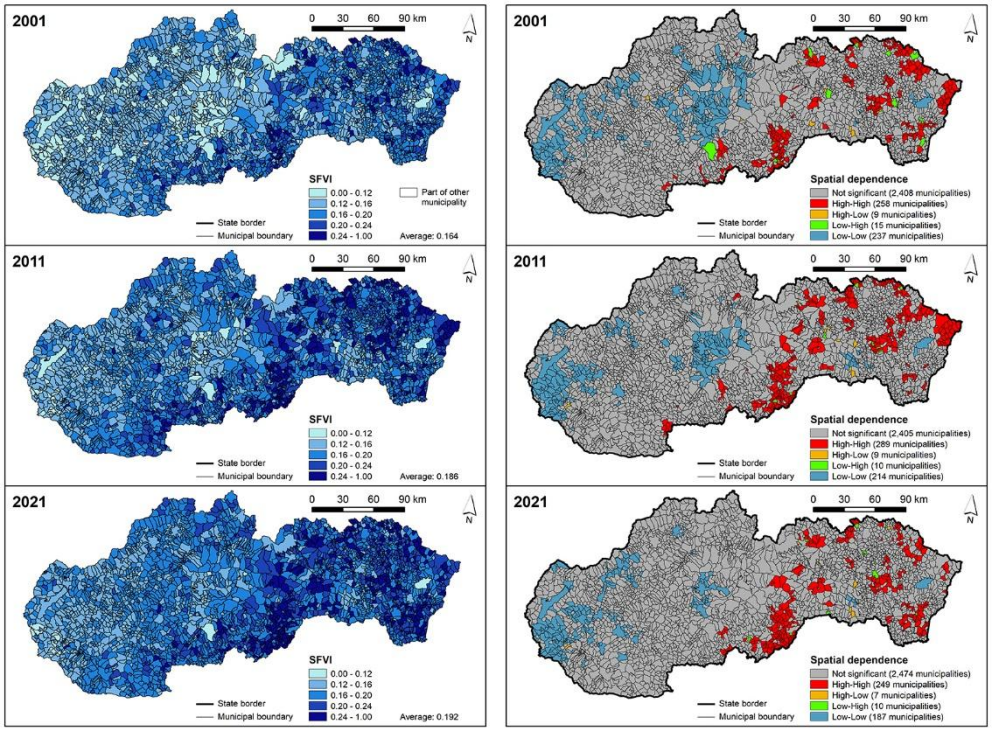

Figure 1. SFVI (left) and spatial dependence of the SFVI (right) at municipal level in Slovakia in the studied years.

Acknowledgements

Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V03-00085. This research was also supported by the VEGA agency under the grant number 1/0103/22.

References

Chakraborty, L. et al. 2020. A place-based socioeconomic status index: Measuring social vulnerability to flood hazards in the context of environmental justice. *International Journal of Disaster Risk Reduction*. 43:101394.

Hinojos, S. et al. 2023. Social and environmental vulnerability to flooding: Investigating cross-scale hypotheses. *Applied Geography*. 157:103017.

Isia, I. et al. 2023. Assessing social vulnerability to flood hazards: A case study of Sarawak's divisions. *International Journal of Disaster Risk Reduction*. 97:104052.

Mohanty, M.P. et al. 2020. A new bivariate risk classifier for flood management considering hazard and socio-economic dimensions. *Journal of Environmental Management*. 255:109733.

Roldán-Valcarce, A. et al. 2023. Vulnerability to urban flooding assessed based on spatial demographic, socio-economic and infrastructure inequalities. *International Journal of Disaster Risk Reduction*. 95:103894.

Tang, J. et al. 2021. Analyzing the spatiotemporal dynamics of flood risk and its driving factors in a coastal watershed of southeastern China. *Ecological Indicators*. 121:107134.