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The Visualisations of the Intersection between Risks and Social Vulnerability Using Interactive Dashboards

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Abstract: There is a growing importance of visual tools in risk sociology to communicate scientific concepts and data to the public and decision-makers. Here, we could observe an increasing amount of content presented by diverse tools – risk matrices, infographics, dashboards, video lessons, etc. Project Serenity aims to establish a dashboard where different risks and social vulnerability characteristics are presented for the Lithuanian case based on objective data on risk levels and population census data. In the article, we explore the differences in the urban, peri-urban and rural areas from the perspective of the spatial intersection between risks and social vulnerabilities in relation to the public perception of crisis preparedness. Urban areas face complex social and environmental challenges, while rural areas contend with resource-driven natural risks. Peri-urban zones, blending both contexts, experience heightened social vulnerabilities due to their unique dynamics. In Lithuania, where peri-urbanization is recent, these interactions are particularly dynamic, offering insights into building resilient communities.

Keywords: Social vulnerability, risk, spatial analysis, mapping, visualisation, urban, rural.

1. Introduction

Recent research highlights the importance of visual tools in risk sociology and communication. Spatial visualisation could be very insightful for exploring and presenting sociological insights, though sociology has lagged in adopting these tools in spatial analysis. However, currently, this area of research is growing fast, especially in the field of sociology of risk and uncertainty. Visual outcomes enhance risk communication and literacy. There are several visualisation tools available that focus on environmental hazards like floods, avalanches, landslides, hurricanes, etc. However, such tools challenge conventional design guidance (Nowak and Bartram 2023). The visualisations that are designed for the general population must follow a user-centred design framework and address the diversity of risk management contexts and user characteristics (Twomlow et al. 2022).

Urban and rural populations are exposed to different levels of environmental, social and economic risks. For example, air pollution has been recorded to be higher in urban areas, however, recent studies indicate that the difference in air pollution levels between urban and rural territories is decreasing, and urban populations have lower mortality rates of PM25 exposures (Molitor and White 2024). Therefore, it is important to analyse the spatial intersections between risks and social vulnerabilities in urban–rural areas to be able to identify the areas with high risks and high vulnerabilities for the targeted risk reduction measurements.

During recent decades, Lithuania has experienced significant socio-spatial changes since the collapse of the Soviet Union, characterised by rapid population decline and increasing regional disparities. Urban centres, particularly Vilnius, Kaunas, and Klaipėda, have grown while peripheral rural areas have declined (Pociūtė-Sereikienė 2019; Baranauskienė 2019). Such processes affect everything from personal choices to national development strategies, from economic development to environmental protection or technological advancements.

Such polarisation inspired our research. Here, we seek to explore how risks and risk perception, along with social vulnerability

features, are perceived on the Lithuanian map and to reveal the level of public preparedness for different types of crises in the urban-rural divide. So, the aim of this article is to analyse the spatial intersection between risk and social vulnerability using visual dashboards of urban-rural areas in Lithuania.

2. Theoretical Background

This research stems from the field of risk sociology, and it also includes several general considerations of practical applications in visualisations. It also explores the urban-rural dichotomy in the risk and social vulnerability aspects at the administrative unit LAU2 level, which is the lowest administrative level; they act as a department of the municipality.

2.1. Spatial Dimensions of Risk and Vulnerability

Over the past decade, scholars have increasingly emphasised spatial dimensions in risk and social vulnerability studies. Previously, socio-economic factors such as gender, education, and income were extensively analysed, but their spatial distribution often remained unexplored. Advancements in spatial analysis tools have shifted attention toward the geographic representation of risks and vulnerabilities.

Mapping risks, especially at national scales, presents challenges, prompting researchers to develop graded indexes. Sometimes, this scale has just three grades (small risk/no risk, average risk, and high risk) or more detailed classifications, often expressed as percentiles. These grades sometimes hold indexes expressed as percentiles. Such a diverse mosaic of risk representation hinders cross-border communications and international comparisons. A similar situation is with the expression of social vulnerability.

Social vulnerability has several calculation methods validated and applied for several different countries (i.e. SoVI). The Social Vulnerability Index (SoVI) remains a benchmark for assessing socio-economic vulnerability (Contreras, Chamorro, and Wilkinson 2020). However, these methods are not universal and require adaptation to the local context (like risk profile, cultural background, socio-economic situation, etc.). For example, some studies examined social vulnerability for groundwater abstraction (Putranto, Winarno, and Susanta 2020), climate change in Africa (Ayanlade et al. 2023), and urban peripheralisation (Gerundo, Marra, and De Salvatore 2020). These and many more studies employ diverse methodologies, including GIS, spatial multicriteria evaluation, and composite vulnerability indices (Ajtai et al. 2023; Lapietra et al. 2024). They underscore the need for more comprehensive, intersectional, and place-based vulnerability assessments to inform targeted interventions and risk reduction strategies across various spatial scales. These assessments often integrate physical and socioeconomic data, focusing on factors such as age, accessibility, and critical facilities (Contreras, Chamorro, and Wilkinson 2020).

Additionally, elaborated methodologies reflect political context and practices (Bukvic et al. 2020). The comprehensive approaches integrate multiple indicators, consider local contexts, and employ objective weighting methods (Ajtai et al. 2023). Researchers have identified key indicators such as lack of basic services, critical facilities, and demographic factors contributing to vulnerability (Goto, Suarez, and Ye 2022). Spatial analysis reveals patterns of centre-periphery opposition, with central areas showing lower vulnerability and peripheral areas with higher vulnerability (Penna and Ferreira 2014).

Last but not least, it is expected that evaluations of social vulnerability will have a temporal dimension (De Sherbinin et al. 2019). So, various projections of social vulnerability indexes are being developed and tested currently (Frigerio et al. 2019). Such expectations are very high from the policymakers. However, debates persist regarding the validity and applicability of different evaluation models, particularly in the context of specific hazard events.

2.2. Urban and Rural Context in Lithuania

This study presents the data from the Lithuanian urban-rural context. The urban population in Lithuania is 68.4 %, and the rural is 31.6 % (Official statistics 2023). During the last decade, the population has decreased in urban areas by 1.7 % and in rural areas by 8.3 % (Official statistics 2023). There is a significant territorial differentiation in urban–rural areas in Lithuania regarding average income, the gap being more

than 40 % (Okunevičiūtė- Neverauskienė and Pocius 2020). This gap is especially visible between the capital city, Vilnius, and the rest of the country in terms of economic development, foreign and national investment, the risk of deprivation, etc. For example, the ESPON report identified that quite a large population in Lithuania is at risk of poverty, and the level of this risk is 30-40 % outside the Vilnius region compared to 20-25 % in the Vilnius region (ESPON 2021). A survey of risk perception of the Lithuanian population conducted in 2020 (Balžekienė, Zolubienė, and Budžytė 2022) identified that the highest risk is attributed to social and economic risks like economic crisis, increasing prices and cost of living and health risks. The lowest risk perception was revealed in the area of environmental risks, particularly the risk of floods. Spatial analysis of environmental risk perception and objective environmental risks in Lithuania (Balžekienė, Telešienė, and Morkevičius 2022) has revealed that people in urban areas tend to underestimate environmental risks, especially air pollution and place of residence appeared to be significant moderators explaining how objective risks are reflected in public opinion.

Further research is needed to introduce social vulnerability analysis in the spatial analysis of risk in the urban-rural context. This article aims to target this need.

2.3. Sociology and Visual Tools

In sociology, the visual presentation of spatial patterns of social phenomena is quite new, yet expressing the investigation results visually by mapping techniques and spatial statistical measures is gaining more attention in sociological research and practice.

Visualisation methods require the integration of hazard assessment with social vulnerability analysis (Lapietra et al. 2024). In the last decade, several interactive dashboards have emerged as valuable tools for visualising and communicating vulnerability information (Pluto-Kossakowska et al. 2022). Additionally, research outlines the results from the interplay between vulnerability, resilience, and adaptation, highlighting the need for multidisciplinary approaches and context-specific indicators, etc. However, the majority of such investigations share some methodological limitations or lack of convincing theoretical frameworks.

Nevertheless, studies emphasise the need for designing visual analytics tools that accommodate ambiguity in risk assessment (Nowak and Bartram 2023) and developing user-centred disaster risk visualisations (Twomlow et al. 2022). That should enable risk communication and improve interaction with vulnerable communities regarding early warning measures. The best-known examples are the Social Vulnerability Index (SVI) and SoVI. Mapping techniques, ranging from univariate to multivariate visualisations, with bivariate and glyph-based methods, offer enhanced insights (Strode et al. 2020). Further, principal component analysis and integrated multihazard mapping to assess vulnerability have been applied.

3. Methodology

This research is a combination of two separate methods – spatial data analysis and a representative survey of Lithuanian inhabitants.

The first method investigates risk indexes and vulnerabilities through spatial statistics. Here, several methods are used: spatial bivariate analysis and multivariate clustering. The data used for further analysis and calculation consists of the results of the RiskSpace project and explicit census data of Lithuania (accessed through the Official Statistics Portal). RiskSpace project collected data on objective levels of risk, and risk indexes were created using normalised scales. Additionally, the urban-rural index was calculated for every LAU2 unit. This index shows the proportion between urban and rural inhabitants in the unit.

Later, local bivariate analysis between particular risk and normalised urban population was done. Its legend is provided in Fig.1. Additionally, the multivariate clustering analysis between particular risk and the urban-rural index was applied. The multivariate clustering standardises numeric attributes and applies the K-Means or K-Medians algorithm to group features based on similarity. The algorithm assigns features to the nearest cluster center using Euclidean distance, then iteratively recalculates cluster centers until assignments stabilise. If the number of clusters is not predefined, ArcGIS determines the optimal value using the Calinski-Harabasz pseudo-F statistic to balance within-

group cohesion and between-group separation. These calculations are done for environmental, social and economic risks.

Fig. 1. Legend for local bivariate analysis results

The second method is representative survey data analysis. The survey was conducted during October 10- 20, 2024. The sampling of the survey was stratified random sampling based on the address registry. The survey was conducted using face-to-face interviews, and the sample size was 1003. The survey is representative of the Lithuanian population with a margin of error of ±3.1%.

In this article, we analyse the differences among capital, big cities, small towns, and rural areas in terms of the perception of preparedness to social, economic, and environmental risks.

The wording of the question analysed in this article is as follows "*How prepared are you and your family to manage these threats?*";

Answer categories included a 5-point Likert scale from 1 – not at all prepared to 5 – very well prepared. Respondents were asked to identify the preparedness levels the (1) social, (2) economic and (3) environmental threats (these were separate questions for all three threats). The independent variable in this study is the living place. It has four categories: (1) capital city – Vilnius, (2) big cities – Kaunas, Klaipėda, Šiauliai, Panevėžys, (3) other towns, (4) rural areas.

The analysis presents the comparison of mean scores for three types of risk across four categories of living places. The significant differences of means are tested using non-parametric Kruskal-Wallis, and pairwise multiple comparisons are presented.

4. Results

This section presents particular aspects of mapping and survey outcomes. Here, we present the spatial distribution of environmental, social and economic risks in urban–rural areas and the public perception of preparedness to manage these risks in different living places.

4.1. Environmental risks

Environmental risks include impacts from a very vast range of hazards, like floods, fires, air and water pollution, etc. In the figure below, the bivariate analysis results of the environmental risk index and urban population in natural breaks (Jenks) are presented.

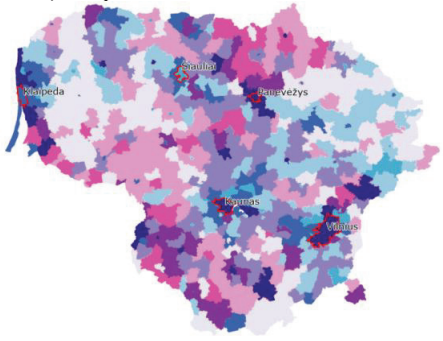

Fig. 2. The intersection of environmental risk index and urban population in Lithuania

Additionally, multivariate clustering analysis was conducted in two stages. The first stage was done to determine the amount of clusters with a significant number of values. The second stage is done by limiting calculations to a determined amount of clusters. In Fig.2, a dichotomy between rural and urban could be observed (different shades of violet lean more toward the urban population in the territory, and green colours usually represent the rural population). The different shades indicate a variation between other indicators. A lighter shade corresponds to a lower environmental risk index.

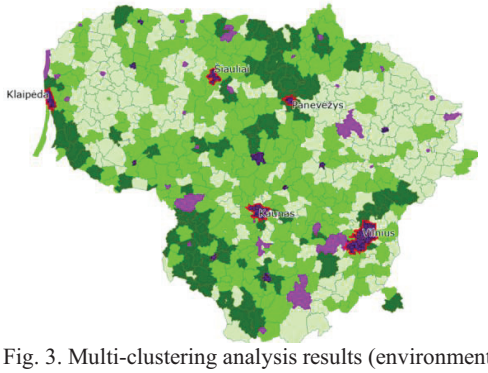

Fig. 3. Multi-clustering analysis results (environmental risk index and urban-rural index)

The perceived preparedness for environmental risks is significantly different in different types of living places (see Fig. 4) (Kruskal Wallis test, $p<0.05$).

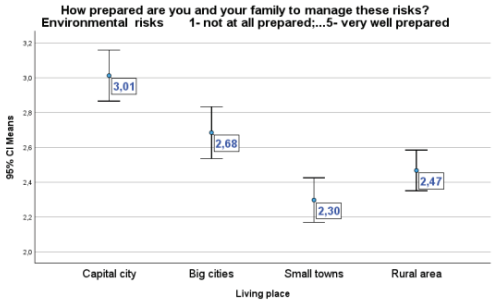

Fig. 4. Public perception of preparedness for environmental risks, means comparison, N=1003, Lithuania. 2024.

Table 1 indicates that differences are significant in most of the pairwise comparisons by the living place, excluding only small towns – rural areas and rural areas big cities.

Table 1. Multiple pairwise comparisons of preparedness for environmental risks in different types of living places.

Sample 1-Sample 2	Test Statistic	Adj. Sig.
Small towns-Rural areas	-42,635	,354
Small towns-Big cities	92,007	,001
Small towns-Capital	177,559	,000
Rural areas-Big cities	49,372	,216
Rural areas-Capital	134,924	,000
Big cities-Capital	85,552	,008

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. The significance level is 0.05.

[a] Significance values have been adjusted by the Bonferroni correction for multiple tests

People in Vilnius city feel better prepared for environmental risks compared to people from all other living place categories. There is also a significant difference between the residents of small towns and those of big cities. The average self-reported preparedness in small towns is the lowest. It is important to notice that the perceived preparedness level in rural areas is not significantly different from that in big cities. This result should be contrasted with the spatial distribution of environmental risks, which indicates "hot spots" of specific environmental risks in big cities, like air pollution. Extra attention should be dedicated to the smaller elderships, which are in darker violet (Fig.2). They represent smaller urban centres where people also indicated less preparedness.

4.2. Social risks

Social risks could be described as struggles and inequalities that society faces. The social risk index includes several indexes, such as the poverty index, crime index, health index, etc.

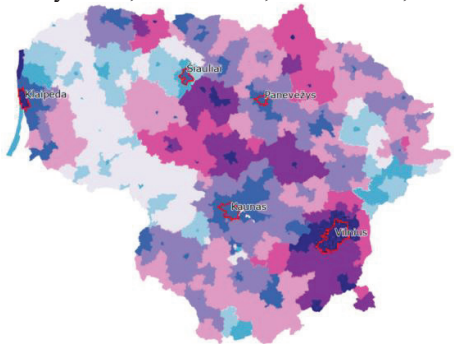

Fig. 5. The intersection of social risk index and urban population in Lithuania

Additionally, multivariate clustering analysis was carried out in the same manner as for ecological risks. Here, as well, rural and urban areas are determined.

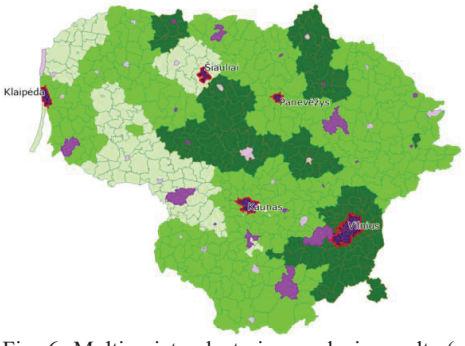

Fig. 6. Multivariate clustering analysis results (social risk index and urban-rural index)

Multivariate clustering analysis (Fig. 6) disclosed that the social risk index between rural territories expressed wide differences, yet urban territories displayed similar social risk index. The darkest green indicates territories which require significant political attention and strong financial support for their development.

The perceived preparedness for the social risks is also significantly different in different types of living places (see Fig. 7) (Kruskal Wallis test, $p<0.05$), and pairwise comparisons (Table 2) reveal the same patterns as in the case of environmental risks when all combinations of place of residence reveal significant differences, except small towns- rural areas and big cities-rural areas.

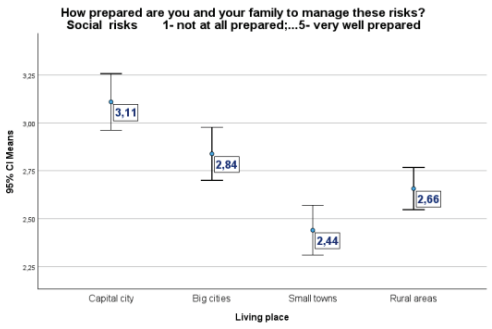

Fig. 7. Public perception of preparedness for social risks, means comparison, N=1003, Lithuania. 2024

Table 2. Multiple pairwise comparisons of preparedness for social risks in different types of living places.

Sample 1-Sample 2	Test Statistic	Adj. Sig.
Small towns-Rural areas	-54,524	,094
Small towns-Big cities	97,584	,000
Small towns-Capital	172,147	,000
Rural areas-Big cities	43,061	,405
Rural areas-Capital	117,623	,000
Big cities-Capital	74,563	,030

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Significance level is 0.05.

[a] Significance values have been adjusted by the Bonferroni correction for multiple tests

While in the case of environmental risk, these insignificant differences could account for the larger exposure of some types of environmental risks; for social risks, the exposure is higher in rural areas. Therefore, it would be important to analyse further the factors accounting for relatively lower preparedness levels in rural areas.

4.3. Economic risks

Economic risks are related to various negative financial processes and their outcomes, like high level of unemployment, real estate price fluctuations, high level of critical service (water, heating, electricity supply) prices and a negative business development environment.

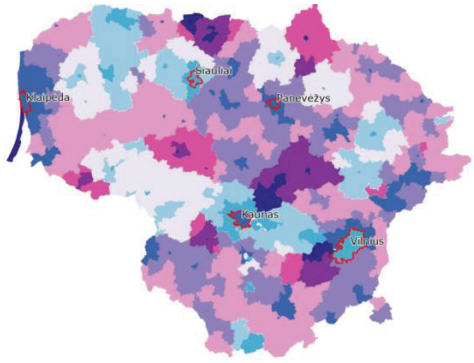

Fig. 8. The intersection of economic risk index and urban population

Multivariate clustering analysis between the economic risk index and the urban-rural index has produced distinct differences between urban and rural territories.

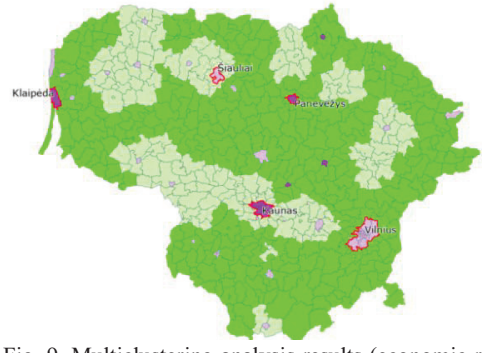

Fig. 9. Multiclustering analysis results (economic risk index and urban-rural index)

Fig. 9 exposes the shift in urban territories, here the capital city with huge economic development holds a low economic risk index. Here, we also could observe that the economic risk index is higher amongst big cities, that could be explained by limited economic growth, aging population, yet still holding an expectation of significant economic growth.

The preparedness for economic risks also reveals similar patterns, like environmental and social. The means are significantly different by the type of living place (Kruskal Wallis test, $p<0.05$) (see Fig.10).

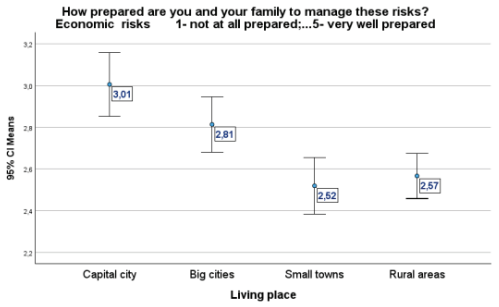

Fig. 10. Public perception of preparedness for economic risks, means comparison, N=1003, Lithuania. 2024.

Table 3. Multiple pairwise comparisons of preparedness for economic risks in different types of living places.

Sample 1-Sample 2	Test Statistic	Adj. Sig.
Small towns-Rural areas	-4,385	1,000
Small towns-Big cities	67,872	,034
Small towns-Capital	120,647	,000
Rural areas-Big cities	63,487	,045
Rural areas-Capital	116,262	,000
Big cities-Capital	52,775	,289

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. The significance level is 0.05.

[a] Significance values have been adjusted by the Bonferroni correction for multiple tests

However, pairwise comparisons (see Table 3) reveal some different patterns from previously presented data on environmental and social risk preparedness. There are no significant differences between the opinions of people in big cities and capital city (when the margin of error is estimated), and also between small towns and rural areas. So, in the case of economic risks, "two Lithuanias" can be identified, one in the biggest cities and another in the less populated areas.

4.4 Preparedness perception across different types of risks

The perceived preparedness of people from different places of residence in Lithuania shows similar patterns for environmental, social and economic risks when people in the capital report the highest preparedness and people in small towns report the lowest self-perceived preparedness levels.

It is also important to compare preparedness levels across different types of risk. The results of such analysis are presented in Fig. 11.

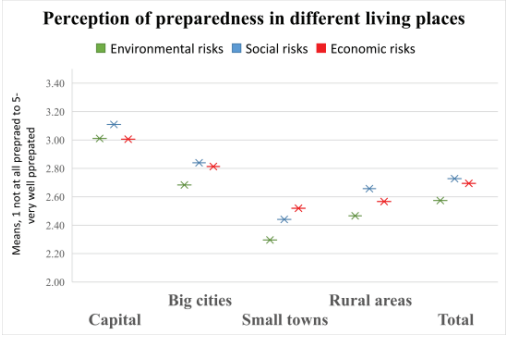

Fig. 11. Public perception of preparedness for different types of risks, means comparison, N=1003, Lithuania. 2024.

People in all types of living places feel better prepared for social and economic risks, and least prepared for environmental risks, indicating the need for understanding the features of social vulnerabilities that are characteristic of the intersection of living place and type of risks – for example, environmental risks in small towns.

5. Conclusions

Spatial analysis of the intersections between risks and social vulnerabilities indicates different spatial patterns in the distribution of environmental, social and economic risks in urban and rural areas. Environmental risks are higher in some urban areas; some complex risks are identified in the peri-urban areas, in the intersection of heavy traffic, and higher air and water pollution. The perceived preparedness for environmental risks is the lowest compared to other types of risks, yet in the big cities, risks seem to be underestimated. In big cities, the perceived preparedness is highest compared to other locations, however the objective risks are highest. Social and economic risks reveal similar spatial patterns in urban and rural areas, forming clusters of low risk in big cities and higher risks in rural areas. Yet, the perceived preparedness in rural areas is higher compared to small towns, which can indicate stronger awareness and engagement. Visual representation of spatial patterns in risk and social vulnerability distribution allows us to identify distinct clusters and to understand how to develop regional risk mitigation policies effectively.

Acknowledgement

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References

Ajtai, I., H. Ștefănie, C. Maloș, C. Botezan, A. Radovici, M. Bizău-Cârstea, and C. Baciu. 2023. "Mapping Social Vulnerability to Floods. A Comprehensive Framework Using a Vulnerability Index Approach and PCA Analysis." *Ecological Indicators* 154:110838.

Ayanlade, A., T. A. Smucker, M. Nyasimi, H. Sterly, L. F. Weldemariam, and Nicholas P Simpson. 2023. "Complex Climate Change Risk and Emerging Directions for Vulnerability Research in Africa." *Climate Risk Management* 40:100497.

Balžekienė, A., A. Telešienė, and V. Morkevičius. 2022. "Spatial Dependencies and the Relationship between Subjective Perception and Objective Environmental Risks in Lithuania." *Sustainability (Switzerland)* 14 (7).

Balžekienė, A., E. Zolubienė, and A. Budžytė. 2022. "Visuomenės Ir Ekspertų Rizikos Suvokimo Skirtumai Lietuvoje: Lokalūs Rūpesčiai Ir Globalūs Kontekstai 1." *Filosifija Sociologija.* 33 (4): 385–96.

Baranauskienė, V. 2019. "Kaimiškų Teritorijų Identifikavimo Problema: Lietuvos Seniūnijų Atvejis." *Geografijos Metrastis* 52:55–72.

Bukvic, A., G. Rohat, A. Apotsos, and A. de Sherbinin. 2020. "A Systematic Review of Coastal Vulnerability Mapping." *Sustainability* 12 (7): 2822.

Contreras, D., A. Chamorro, and Sean Wilkinson. 2020. "The Spatial Dimension in the Assessment of Urban Socio-Economic Vulnerability Related to Geohazards." *Natural Hazards and Earth System Sciences* 20 (6): 1663–87.

ESPON. 2021. "Territorial Patterns and Relations in Lithuania - Country Fiche | ESPON." 2021.

Frigerio, I., F. Zanini, M. Mattavelli, and M. D. Amicis. 2019. "Understanding the Interacting Factors That Influence Social Vulnerability: A Case Study of the 2016 Central Italy Earthquake." *Disasters* 43 (4): 867–90.

Gerundo, R., A. Marra, and V. De Salvatore. 2020. "Construction of a Composite Vulnerability Index to Map Peripheralization Risk in Urban and Metropolitan Areas." *Sustainability* 12 (11): 4641.

Goto, E. A., A M. Suarez, and H. Ye. 2022. "Spatial Analysis of Social Vulnerability in São Paulo City, Brazil." *Applied Geography* 140:102653.

Lapietra, I., R. Colacicco, D. Capolongo, M. La Salandra, A. Rinaldi, and P. Dellino. 2024. "Unveiling Social Vulnerability to Natural Hazards in the EEA and UK: A Systematic Review with Insights for Enhanced Emergency Planning and Risk Reduction." *International Journal of Disaster Risk Reduction*, 104507.

Molitor, D., and C. White. 2024. "Do Cities Mitigate or Exacerbate Environmental Damages to Health?" *Regional Science and Urban Economics* 107 (July):103973.

Nowak, S., and L. Bartram. 2023. "Designing for Ambiguity in Visual Analytics: Lessons from Risk Assessment and Prediction." *IEEE Transactions on Visualization and Computer Graphics*.

Official statistics. 2023. "Urban - Rural Population - Official Statitics Portal." 2023.

Okunevičiūtė- Neverauskienė, L. O., and A. Pocius. 2020. "Development of Regional Differentiation of Population Income in Relation to Middle Class Growth in Lithuania." *Filosofija. Sociologija* 31 (4): 306–17.

Penna, N. A., and I. B. Ferreira. 2014. "Social and Spatial Inequalities and Areas of Vulnerability in the Cities." *Mercator (Fortaleza)* 13:25–36.

Pluto-Kossakowska, J., A. Fijałkowska, M. Denis, J. Jaroszewicz, and S. Krzysztofowicz. 2022. "Dashboard as a Platform for Community Engagement in a City Development—a Review of Techniques, Tools and Methods." *Sustainability* 14 (17): 10809.

Pociūtė-Sereikienė, G. 2019. "Peripheral Regions in Lithuania: The Results of Uneven Development." *Regional Studies, Regional Science* 6 (1): 70–77.

Putranto, T. T., T. Winarno, and A. P. A. Susanta. 2020. "Risk Assessment of Groundwater Abstraction Vulnerability Using Spatial Analysis: Case Study at Salatiga Groundwater Basin, Indonesia." *Indonesian Journal on Geoscience* 7 (2): 215–24.

Sherbinin, A. D., A. Bukvic, G. Rohat, M. Gall, B. McCusker, B. Preston, A. Apotsos, C. Fish, S. Kienberger, and P. Muhonda. 2019. "Climate Vulnerability Mapping: A Systematic Review and Future Prospects." *Wiley Interdisciplinary Reviews: Climate Change* 10 (5): e600.

Strode, G., V. Mesev, S. Bleisch, K. Ziewitz, F. Reed, and J. D. Morgan. 2020. "Exploratory Bivariate and Multivariate Geovisualizations of a Social Vulnerability Index." *Cartographic Perspectives*, no. 95, 5–23.

Twomlow, A., S. Grainger, K. Cieslik, J. D. Paul, and W. Buytaert. 2022. "A User-Centred Design Framework for Disaster Risk Visualisation." *International Journal of Disaster Risk Reduction* 77 (March): 103067.