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MULTIDIMENSIONAL LOCAL RESILIENCE – ANALYSIS OF ENVIRONMENTAL, DEMOGRAPHIC AND INFRASTRUCTURAL FACTORS

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Purpose: The aim of this study is to assess the level and determinants of multidimensional local resilience in Polish municipalities between 2013 and 2023. The analysis focuses on the influence of environmental, demographic, and infrastructural factors on the adaptive capacity and socio-spatial cohesion of territorial units.
Design/methodology/approach: The study is based on secondary data obtained from Statistics Poland (GUS), encompassing environmental, demographic, and infrastructural variables. A synthetic local resilience index was constructed using the CRITIC–TOPSIS method, and the results were analyzed with descriptive statistics, regression tests, ANOVA, and Spearman's rank correlation.
Findings: Local resilience in Poland depends primarily on environmental and infrastructural components, while demographic factors play a supporting role. Urban municipalities demonstrate the highest levels of resilience, with rural and urban–rural units showing intermediate values. The results indicate a synergistic interaction between environmental quality, infrastructure, and demographic stability, with a limited negative impact of intensive industrial activity.
Research limitations/implications: The limitations concern insufficient data availability and challenges in capturing dynamic interactions. Future research should include cultural and institutional components, as well as predictive models for infrastructure, demographic, and environmental policy development scenarios.
Practical implications: The findings highlight the need to monitor migration, mitigate the negative effects of industrial activity, and invest in green areas and urban ecosystems. Integrated spatial and investment planning that takes into account infrastructure, environmental protection, and demographic support enhances the adaptive capacity and cohesion of local communities.
Originality/value: The innovative approach applies synthetic indicators covering three dimensions of local resilience—environmental, demographic, and infrastructural—in an analysis spanning 2013-2023 for all Polish municipalities. The study enables an assessment of trends, spatial disparities, and changes in the structure of interdependencies among components, demonstrating the growing importance of environmental quality and the significant role of infrastructure in shaping local resilience.

Keywords: multidimensional local resilience, Polish municipalities, environmental factors, infrastructure, demography.
Category of the paper: Research paper.

1. Introduction

Local resilience in its multidimensional aspect constitutes the foundation of the capacity of local government units (LGUs) to maintain the continuity of development processes despite the occurrence of destabilizing factors. This concept aligns with the paradigm of sustainable local development, which—as emphasized by M. Güngör and Z. Elburz (2024)—should be understood as a process that balances environmental, social, economic, and infrastructural aspects, requiring the creation of mechanisms resistant to diverse disruptions. Similarly, S. Arzo and M. Hong (2024) define resilience as an evolutionary and adaptive process encompassing environmental, infrastructural, economic, social, human, and institutional dimensions. This process enables the absorption of disturbances, the restoration of functionality, and the establishment of lasting preventive mechanisms. According to G. Bristow and A. Healy (2014), the limits of resilience become apparent when the accumulation of crises exceeds the adaptive capacity of local authorities, exposing deficits in territorial, economic, and social cohesion. Consequently, this leads to developmental imbalance and the deepening of local disparities.

Adaptive capacity, as one of the principal components of local resilience, defines the potential of LGUs to survive and develop under conditions of uncertainty, manifested through flexible responses to change and the adjustment of local policies. As A. Busłowska and J. Marcinkiewicz (2023) indicate, the limits of this capacity emerge when there is a shortage of financial, technological, or competency-related resources, which constrains the effectiveness of adaptive actions. A. Choryński, I. Pińskwar, D. Graczyk, and M. Krzyżaniak (2022) highlight territorial cohesion as a key factor determining adaptive capacity, noting that the uneven development of central and peripheral regions negatively affects local resilience levels. According to J. Zaucha and T. Komornicki (2019), social, economic, and territorial cohesion constitute essential conditions for the effectiveness of adaptive actions, enabling the mobilization of social capital, stakeholder cooperation, and the building of trust between residents and local authorities. Deficits in these areas lead to weakened implementation capacity of LGUs and reduced legitimacy of their actions.

As Y. Lv and M.N. Islam Sarker (2024) emphasize, the effectiveness of local adaptive strategies largely depends on the integration of green infrastructure, stability of local policies, technological innovation, and the development of social competences. P. Chamusca (2023) notes that a fragmentary analysis focused on a single dimension of resilience proves less effective than an integrated approach encompassing physical, social, and institutional aspects simultaneously. In this context, S.J. Birchall, S. Kehler, and S. Weissenberger (2025) stress that urban and regional planning integrating infrastructure, spatial development, and public services constitutes a key instrument for supporting adaptation and strengthening the resilience of local communities—particularly in the face of the growing risks associated with climate change.

The aim of the study is to assess the level and determinants of multidimensional local resilience in Polish municipalities between 2013 and 2023. Particular attention is given to the influence of environmental, demographic, and infrastructural factors on the adaptive capacity and socio-spatial cohesion of territorial units in the context of increasing socio-economic and environmental uncertainty. The study focuses on three main research questions. First, what are the spatial and temporal differences in the level of multidimensional local resilience among urban, rural, and urban–rural municipalities in Poland between 2013 and 2023? Second, which factors—environmental, demographic, or infrastructural—most strongly determine the level of local resilience, and how has their significance evolved over the analyzed period? Third, how does the differentiation of local resilience affect the balance between adaptability and socio-spatial cohesion of municipalities, and what are the implications for regional development policy and local resource management?

The innovative aspect of this study lies in the application of synthetic indicators of local resilience encompassing three complementary dimensions—environmental, demographic, and infrastructural—for all Polish municipalities in an analysis covering the years 2013-2023. This approach enables a comprehensive assessment of trends, determinants, and spatial variations in resilience, accounting for the type of municipality (urban, rural, or urban–rural) and the "resilience–cohesion trade-off" effect. Empirical findings indicate an increasing significance of the environmental component, alongside the sustained role of infrastructure, which carries important implications for spatial planning, environmental policy, and adaptive strategies under conditions of growing uncertainty.

2. Literature review

R. Martin (2012) emphasizes that the concept of resilience is inherently multidimensional, encompassing, among other aspects, the ability of economic systems to regain equilibrium following the occurrence of shocks. M. Boston, D. Bernie et al. (2024) observe that resilience, originally defined as the capacity of systems to absorb disturbances and maintain core functions, has evolved across disciplines—from disaster management and urban planning to socio-ecological research—adopting definitions and approaches tailored to the specific contexts of each field.

In the environmental and infrastructural dimensions, local resilience varies according to the degree of exposure to extreme weather events such as floods, droughts, or heatwaves. As N. Kapucu, Y. Ge, E. Rott, and H. Isgandar (2024) note, municipalities more severely affected by such phenomena tend to develop recovery resilience, whereas less exposed communities cultivate creative resilience, oriented toward the implementation of innovative adaptive measures. The long-term maintenance of ecosystem functions requires the preservation of biodiversity, which supports adaptation to climate change. T.H. Oliver, M.S. Heard et al. (2015) emphasize that environmental resilience reflects the capacity of ecosystems to regenerate after disturbances and to maintain key functions under increasing climatic pressures. In the social dimension, according to Y. Liu, L. Cao, D. Yang, and B.C. Anderson (2022), social capital, trust, and community ties play a pivotal role in fostering resilience by enabling collective action and cooperative adaptation in response to crises.

L. Briguglio, G. Cordina, N. Farrugia, and S. Vella (2009) define economic resilience as an economy's capacity—shaped by public policy—to counteract and recover from the effects of shocks. B. Eichengreen, D. Park, and K. Shin (2024) point out that factors such as flexible exchange rates, trade openness, stable current account balances, and high foreign reserves strengthen economic resilience, whereas excessive financial liberalization or rapid private credit growth during expansionary periods may weaken it.

Social resilience refers to the ability of communities to adapt and restore functionality after disruptions, grounded in social capital, trust, and community cohesion. It is strengthened by education, risk awareness, civic participation, and stakeholder integration. However, as S. Carrasco, Ch. Ochiai, and L.M. Tang (2024) observe, excessively strong intra-group ties may constrain external cooperation and foster exclusion. Social resilience tends to increase in response to disasters, though significant spatial disparities persist—higher in central areas and lower in peripheral regions. Its determinants include economic and demographic factors, access to public services, and the frequency of extreme events, the effects of which are nonlinear.

Multidimensional resilience encompasses the interactions between social, economic, environmental, infrastructural, institutional, and technological dimensions. As S.B. Tan (2021) highlights, the interdependence between resilience dimensions and public health determinants suggests that highly resilient communities possess integrated social, economic, and environmental resources, enabling effective prevention and mitigation of disaster impacts. J.E. Cinner and M.L. Barnes (2021) argue that a holistic approach must account for the feedbacks among these dimensions, allowing systems to respond flexibly to changes and disturbances. According to P. Sánchez-Zamora and R. Gallardo-Cobos (2020), the resilience of socio-ecological systems depends on assets, flexibility, social organization, learning capacity, and agency—all of which condition responses to environmental change and the effects of climate variability. At the same time, feedback loops between social and environmental factors may generate socio-ecological traps, perpetuating undesirable system states.

In the urban and regional context, A. Naderi and K. Khoshnevis (2025) observe that resilience integrates social, economic, and infrastructural dimensions, enabling the absorption of shocks, maintenance of core functions, and adaptation or transformation amid long-term change. Urban and regional resilience is therefore multidimensional, encompassing social, economic, ecological, infrastructural, institutional, and human components. Under conditions of accelerated urbanization and increasing risks such as climate change or resource depletion, effective resilience building requires interdisciplinary integration, cross-sectoral collaboration, and innovative governance strategies. N. Kapucu, Y. Ge, E. Rott, and H. Isgandar (2024) emphasize that such an approach necessitates identifying key challenges within each dimension, analyzing their interactions, and enhancing adaptive and recovery capacities while striving for long-term stability and sustainable development.

Natural resources function within complex socio-ecological systems that are vulnerable to change and unforeseen disruptions, posing significant governance challenges and underscoring the importance of systemic resilience. As S. Dressel, M. Johansson, G. Ericsson, and C. Sandström (2020) stress, adaptive resource management requires cooperation between public and private institutions, balanced power distribution, continuous learning processes, and adjustment to local conditions—all of which enhance a system's responsiveness to threats and strengthen its resilience.

F.E. Córdova, T. Krause et al. (2024) argue that the development of adaptive capacities and socio-ecological resilience requires systematic measurement that accounts for social capital, agency, knowledge transfer, and power relations—factors that enhance a community's ability to absorb, adapt, and transform in the face of hazards. X. Gong, W.-K. Wong, Y. Peng et al. (2023) note that sustainable economic development demands the integration of economic growth with ecological resilience, environmental protection, and social well-being. Diverse and stable ecosystems support survival and regeneration after disturbances, fostering long-term development, whereas environmental degradation constrains growth potential.

According to Z. Assarkhaniki, A. Rajabifard, and S. Sabri (2020), the Sustainable Development Goals (SDGs) insufficiently address resilience as the capacity to prepare for, absorb, recover from, and adapt to extreme events. J. Salomon, J. Behrensdorf, N. Winnewisser, M. Broggi, and M. Beer (2022) emphasize that improving the resilience of complex systems requires a rational analysis of available resources and intervention costs, as the potential for increasing resilience is inherently limited.

As P. Sánchez-Zamora and R. Gallardo-Cobos (2019) observe, adaptability and cohesion constitute two complementary dimensions of municipal resilience. Adaptability, understood as system flexibility, reflects the ability to modify functions in response to threats, while cohesion refers to social capital and the strength of community bonds. A municipality's resilience results from the synergy of these two dimensions, reinforced by institutional and organizational capacities that enable effective response, recovery, and long-term system transformation.

According to T. Gu, H. Zhao et al. (2025), traditional methods of resilience assessment—based on assumptions of homogeneity or simple linear relationships—fail to capture the complexity of adaptive processes and may lead to erroneous conclusions. The use of synthetic measure models or machine learning techniques allows for the identification of nonlinearity, heterogeneity, and local threshold effects, thereby improving the accuracy of assessments and supporting evidence-based decision-making in adaptive disaster management and urban planning.

The level of multidimensional local resilience in Polish municipalities varies by type, with urban municipalities exhibiting higher resilience than rural and urban–rural ones, due to more advanced infrastructural development and concentration of resources (H1). Environmental, demographic, and infrastructural factors significantly influence the level of local resilience; over the analyzed period (2013–2023), the importance of the environmental component increased, while that of the demographic component relatively declined (H2). Higher levels of environmental and infrastructural resilience strengthen the balance between adaptability and socio-spatial cohesion in local communities, whereas declining demographic resilience reduces adaptive capacity and may lead to potential destabilization of local systems (H3).

3. Materials and Methods

The subject of the study was multidimensional local resilience in Polish municipalities, encompassing environmental, demographic, and infrastructural components and their interrelationships in the context of municipal types (urban, rural, and urban–rural). Particular attention was devoted to the influence of these dimensions on the balance between adaptability and the socio-spatial cohesion of local systems. The analysis covered the period 2013-2023, which enabled the identification of changes in the level and structure of local resilience, the assessment of developmental trends, and the comparison of their significance across different types of municipalities. Furthermore, it facilitated the formulation of policy directions and practices that support sustainable and durable territorial resilience, thereby enhancing understanding of the evolution of the studied phenomenon.

Local system resilience is analyzed across several dimensions: economic (sectoral structure, financial liquidity, labor market stability, diversification of activities), demographic (human capital, migration, social capital, labor force participation), infrastructural (investment capacity, transportation, technology, energy security), and environmental. Strengthening resilience requires economic diversification, support for innovation, the development of human capital, targeted instruments for enterprises, and systematic monitoring of key economic and social indicators.

Multidimensional local resilience refers to the capacity of territorial units—such as municipalities or cities—to adapt to environmental, economic, and demographic changes and threats, to maintain socio-economic cohesion, and to effectively recover from crises. Its assessment is based on an integrated set of indicators encompassing economic, social, institutional, infrastructural, environmental, and demographic dimensions.

The study of local resilience provides insight into diverse spatial and social determinants, allowing the identification of factors that strengthen or constrain the capacity to respond to crises and the formulation of development and spatial planning strategies that promote long-term socio-spatial cohesion. Figure 1 illustrates the procedure for constructing the synthetic multivariate resilience index, which constitutes the methodological framework for the quantitative analysis. The process begins with a comprehensive literature review that defines the purpose and scope of the research.

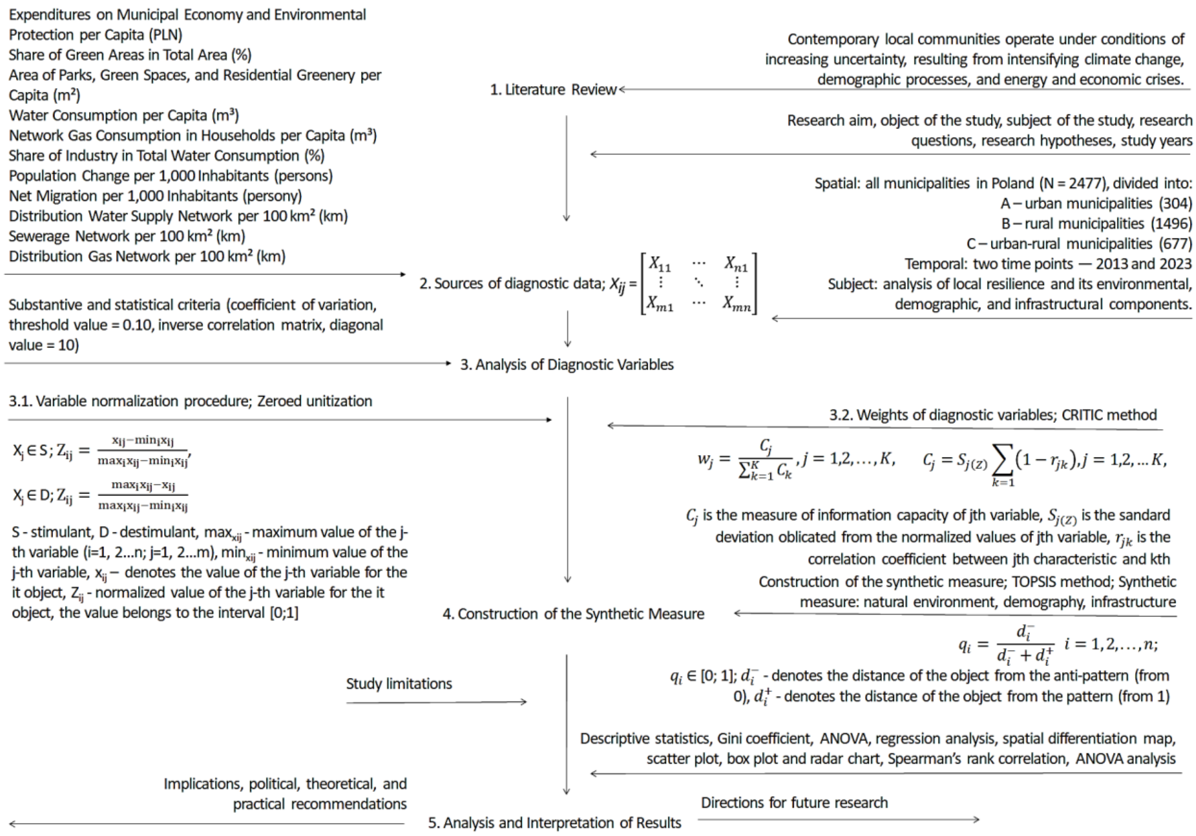

Figure 1. Methodology for Constructing a Synthetic Local Resilience Index for Polish Municipalities (TOPSIS–CRITIC).

Source: opracowanie wlasne na podstawie: Malina, Zieliaś, 1996, pp. 85-89; Poplawski, Glova, Dziekański, 2025, pp. 25-48; Hassan, Alhamrouni, Azhan, 2023, p. 4245; Kukuła, Bogocz, 2014; pp. 5-13; Yin, Wang, Wang, Wang, Chang, 2023; Grzelak, Popławski, Dziekański, 2024.

The resilience assessment process involves the identification and selection of diagnostic variables based on substantive and statistical criteria, including the coefficient of variation and the inverse correlation matrix analysis, ensuring their adequacy and informational independence. Each variable is subsequently normalized using the zero unitarization method, while its weights are objectively determined through the CRITIC method, which accounts for both the dispersion of characteristics and the correlations among them. The synthetic indicator is then aggregated using the TOPSIS method, which determines the distance of each object from the ideal and anti-ideal solutions, allowing for their comprehensive ranking and comparative evaluation. The final stage comprises the analysis of results employing descriptive statistics, rankings, and advanced analytical tools such as the Gini coefficient, forming the basis for the formulation of theoretical, practical, and policy conclusions, as well as for defining directions of further research.

4. Results

Between 2013 and 2023, an increase in environmental resilience has been observed, resulting from pro-ecological initiatives and investments in sustainable resource management. At the same time, a decline in demographic resilience has occurred in rural and urban–rural municipalities, reflecting processes of depopulation and the outflow of human capital. Infrastructural resilience has remained relatively stable but at a consistently low level, indicating persistent disparities in access to technical and digital services (Table 1). The results confirm that the growth of environmental resilience enhances adaptive capacity, yet it does not compensate for the demographic regression and infrastructural stagnation, leading to the erosion of cohesion within local communities. This phenomenon aligns with the theory of uneven development, according to which urban centers exhibit greater systemic stability than peripheral areas. These findings underscore the necessity of an integrated policy approach encompassing environmental, demographic, and infrastructural dimensions to support sustainable and enduring territorial resilience.

Table 1.
Spatial and temporal differentiation of local resilience components in Polish municipalities by type (2013-2023)

Synthetic measure			Number of units	Mean	Minimum	Maximum	Range	Interquartile Range	Variance	Standard Deviation	Skewness	Kurtosis
Natural env.	2013	All units	2477	0.59	0.33	0.82	0.49	0.02	0.00	0.04	-2.29	7.95
Demography			2477	0.71	0.00	0.94	0.94	0.08	0.01	0.09	-2.06	8.53
Infrastructure			2477	0.12	0.00	0.86	0.86	0.07	0.01	0.12	2.53	7.06
Local resilience			2477	0.51	0.33	0.69	0.36	0.02	0.00	0.03	-0.16	4.76
Natural env.		A	304	0.58	0.37	0.82	0.45	0.07	0.01	0.08	-0.81	0.88
Demography			304	0.75	0.37	0.93	0.57	0.05	0.00	0.06	-2.17	10.66
Infrastructure			304	0.35	0.02	0.86	0.85	0.23	0.03	0.17	0.21	-0.22
Local resilience			304	0.54	0.38	0.69	0.31	0.07	0.00	0.06	-0.33	0.09
Natural env.		B	1496	0.59	0.34	0.69	0.34	0.01	0.00	0.03	-3.32	13.86
Demography			1496	0.70	0.00	0.94	0.94	0.09	0.01	0.10	-1.89	7.42
Infrastructure			1496	0.09	0.00	0.44	0.44	0.05	0.00	0.06	2.10	6.99
Local resilience			1496	0.51	0.33	0.56	0.23	0.02	0.00	0.03	-2.28	7.33
Natural env.		C	677	0.58	0.33	0.66	0.33	0.03	0.00	0.05	-2.60	7.46
Demography			677	0.72	0.19	0.87	0.68	0.06	0.01	0.07	-2.20	9.50
Infrastructure			677	0.08	0.01	0.49	0.48	0.06	0.00	0.06	2.41	9.31
Local resilience			677	0.50	0.35	0.59	0.24	0.03	0.00	0.03	-1.99	5.11
Natural env.	2023	All units	2477	0.62	0.35	1.00	0.65	0.03	0.00	0.05	-2.29	9.25
Demography			2477	0.50	0.00	0.73	0.73	0.07	0.01	0.08	-1.92	5.82
Infrastructure			2477	0.11	0.00	1.00	1.00	0.06	0.01	0.12	2.59	7.58
Local resilience			2477	0.49	0.32	0.64	0.32	0.02	0.00	0.04	-0.85	4.15
Natural env.		A	304	0.61	0.39	1.00	0.60	0.08	0.01	0.08	-0.61	2.10
Demography			304	0.54	0.28	0.68	0.39	0.05	0.00	0.05	-1.16	3.71
Infrastructure			304	0.33	0.01	1.00	0.99	0.22	0.03	0.16	0.39	0.40
Local resilience			304	0.52	0.34	0.64	0.30	0.06	0.00	0.06	-0.64	0.18
Natural env.		B	1496	0.63	0.36	0.71	0.35	0.02	0.00	0.04	-3.44	14.89
Demography			1496	0.49	0.00	0.73	0.73	0.09	0.01	0.09	-1.67	4.44
Infrastructure			1496	0.07	0.00	0.46	0.46	0.04	0.00	0.06	2.68	10.03
Local resilience			1496	0.49	0.33	0.54	0.21	0.02	0.00	0.03	-2.38	7.19
Natural env.		C	677	0.61	0.35	0.68	0.33	0.03	0.00	0.05	-2.63	7.87
Demography			677	0.51	0.17	0.66	0.49	0.06	0.00	0.07	-2.31	7.75
Infrastructure			677	0.07	0.01	0.43	0.42	0.04	0.00	0.06	2.67	9.55
Local resilience			677	0.48	0.32	0.54	0.21	0.03	0.00	0.03	-2.00	4.52

A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The analysis of relationships in 2013 between the level of local resilience and its key dimensions—environmental, infrastructural, and demographic—reveals a clear spatial differentiation depending on the type of municipality. Across all types, the environmental dimension emerges as the strongest determinant of resilience, underscoring the enduring importance of natural capital quality for the stability and adaptive capacity of local systems. In urban municipalities, technical infrastructure plays a significant role, exhibiting a moderately strong correlation with resilience, which enhances the developmental potential and functional cohesion of urban centers. In contrast, within rural areas, demography constitutes the key factor—particularly population stability and reproductive capacity—while the impact of infrastructure remains marginal and statistically insignificant. Urban–rural municipalities occupy an intermediate position, characterized by a strong dependence on environmental factors and weaker associations with demography, alongside a marginal contribution of infrastructure (Figure 2).

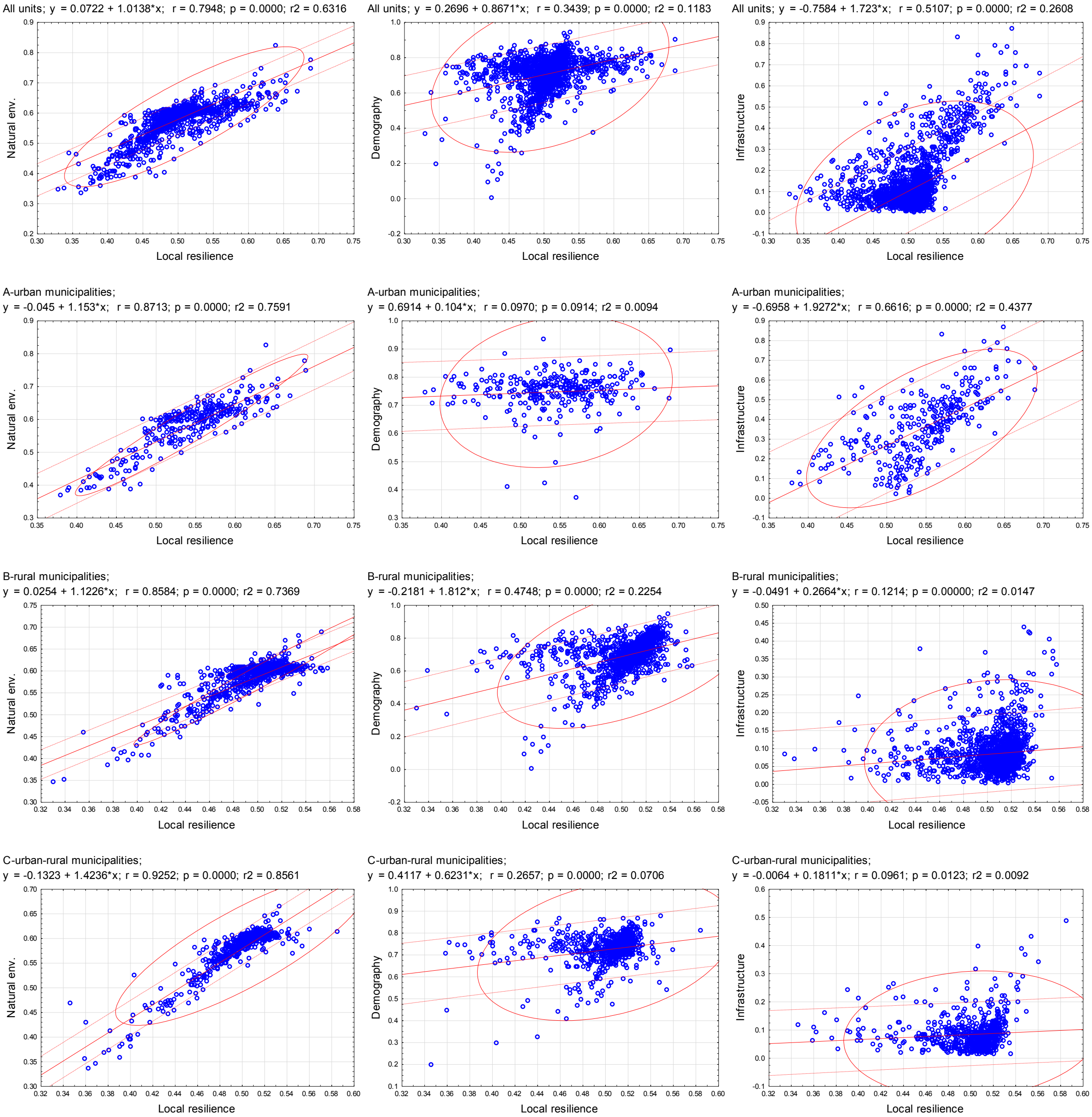

Figure 2. Variation in the relationships between environmental, demographic, infrastructural, and overall resilience in urban, rural, and urban-rural municipalities (Types of municipalities according to 2023; A – urban municipalities, B – rural municipalities, C – urban-rural municipalities).

Source: own elaboration based on BDL GUS data (2013-2023).

In 2023, the environmental dimension remains the strongest determinant of resilience across all municipalities, emphasizing the importance of natural capital. In urban municipalities, infrastructure plays a significant role, enhancing developmental potential. In contrast, in rural areas, demography is the key factor, while the role of infrastructure is marginal and statistically insignificant. Urban–rural municipalities occupy an intermediate position, characterized by a strong dependence on the environment, weaker links to demography, and a marginal contribution of infrastructure (Figure 3).

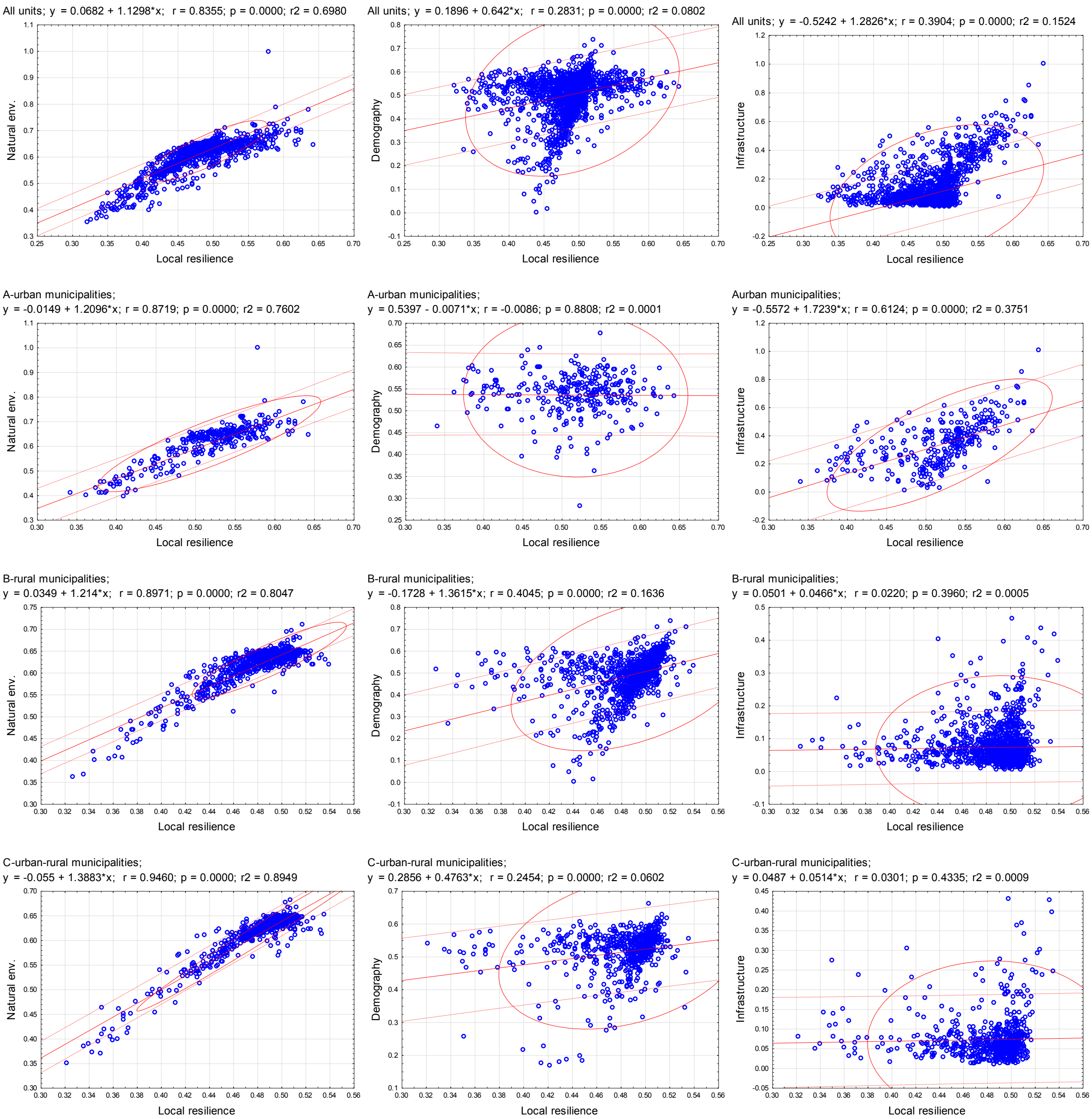

Figure 3. Variation in the relationships between environmental, demographic, infrastructural, and overall resilience in urban, rural, and urban-rural municipalities (Types of municipalities according to 2023; A – urban municipalities, B – rural municipalities, C – urban-rural municipalities).

Source: own elaboration based on BDL GUS data (2013-2023).

The correlation analysis between local resilience factors from 2013 to 2023 indicates a significant transformation in the structure of dependencies determining the stability of territorial systems (Table 2). The environmental dimension exerts the strongest influence on overall resilience, highlighting the importance of natural resources and spatial quality for the sustainability of local socio-economic systems, while demographic and infrastructural factors maintain a moderate, stable supportive role. The lack of significant correlations between public expenditures and resilience indicators suggests limited effectiveness of financial instruments, whereas the growing importance of institutional and social dimensions emphasizes the role of management quality and local cooperation. Spatial differentiation of correlations reveals that in urban areas, resilience primarily results from the synergy between environmental and infrastructural factors, whereas in rural areas it stems from the interaction between natural and demographic capital. The findings are consistent with theories of sustainable development, the new institutional economics, and the "resilience–cohesion trade-off" model, indicating that long-term local resilience depends chiefly on the integration of environmental, social, and infrastructural dimensions, rather than on the mere scale of financial investments. In the local resilience analysis, expenditures on municipal economy and environmental protection were included as they reflect the capacity of local governments to maintain infrastructure and environmental quality during crises. The level of these expenditures thus constitutes an important indicator of the preparedness and responsiveness of local units, and consequently, their resilience.

Table 2.
Spearman's Rank Correlation Coefficient Matrix between Expenditures on Municipal Economy and Environmental Protection and Environmental, Demographic, Infrastructural Indicators, and Local Resilience (2013, 2023)

variable / synthetic measure	**group**	**Expenditures on Municipal Economy and Environmental Protection**	**Natural env.**	**Demography**	**Infrastructure**	**Local resilience**	**Expenditures on Municipal Economy and Environmental Protection**	**Natural env.**	**Demography**	**Infrastructure**	**Local resilience**
		2013					**2023**				
Expenditures on Municipal Economy and Environmental Protection	All units	1.00	-0.14	-0.06	0.10	-0.07	1.00	-0.06	-0.03	0.06	-0.01
Natural env.		-0.14	1.00	0.15	-0.06	0.65	-0.06	1.00	0.16	-0.19	0.69
Demography		-0.06	0.15	1.00	-0.17	0.44	-0.03	0.16	1.00	-0.22	0.43
Infrastructure		0.10	-0.06	-0.17	1.00	0.32	0.06	-0.19	-0.22	1.00	0.18
Local resilience		-0.07	0.65	0.44	0.32	1.00	-0.01	0.69	0.43	0.18	1.00
Expenditures on Municipal Economy and Environmental Protection	A	1.00	-0.06	-0.13	-0.21	-0.15	1.00	-0.01	-0.13	-0.21	-0.08
Natural env.		-0.06	1.00	0.09	0.28	0.83	-0.01	1.00	-0.04	0.25	0.82
Demography		-0.13	0.09	1.00	-0.04	0.11	-0.13	-0.04	1.00	-0.08	0.01
Infrastructure		-0.21	0.28	-0.04	1.00	0.69	-0.21	0.25	-0.08	1.00	0.66
Local resilience		-0.15	0.83	0.11	0.69	1.00	-0.08	0.82	0.01	0.66	1.00

Cont. table 2.

Expenditures on Municipal Economy and Environmental Protection	B	1.00	-0.15	-0.17	0.03	-0.17	1.00	-0.03	-0.12	0.05	-0.05
Natural env.		-0.15	1.00	0.22	-0.16	0.56	-0.03	1.00	0.28	-0.32	0.63
Demography		-0.17	0.22	1.00	-0.35	0.57	-0.12	0.28	1.00	-0.39	0.60
Infrastructure		0.03	-0.16	-0.35	1.00	0.19	0.05	-0.32	-0.39	1.00	-0.01
Local resilience		-0.17	0.56	0.57	0.19	1.00	-0.05	0.63	0.60	-0.01	1.00
Expenditures on Municipal Economy and Environmental Protection	C	1.00	-0.09	-0.08	0.04	-0.05	1.00	-0.02	0.07	-0.07	0.03
Natural env.		-0.09	1.00	0.13	-0.12	0.81	-0.02	1.00	0.15	-0.18	0.83
Demography		-0.08	0.13	1.00	-0.33	0.28	0.07	0.15	1.00	-0.35	0.29
Infrastructure		0.04	-0.12	-0.33	1.00	0.18	-0.07	-0.18	-0.35	1.00	0.09
Local resilience		-0.05	0.81	0.28	0.18	1.00	0.03	0.83	0.29	0.09	1.00

Correlation coefficients marked are significant at $p < .05000$. A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The analysis of the Kruskal–Wallis test results confirms statistically significant differences between types of municipalities in Poland across all dimensions of local resilience (Table 3). Urban municipalities exhibit the highest levels of infrastructural, demographic, and overall resilience metrics, reflecting their stronger economic potential, resource concentration, and greater adaptive capacity. Rural municipalities, despite infrastructural deficits, show a systematic increase in the environmental component and overall resilience, indicating a growing adaptive capacity in response to socio-economic and climatic changes. The observed partial convergence in environmental and demographic components suggests a gradual equalization of potentials between urban and non-urban units. The results reaffirm the established spatial hierarchy of local resilience alongside the intensification of adaptive trends in peripheral municipalities, emphasizing the role of institutional quality and governance mechanisms as factors strengthening long-term resilience within the frameworks of sustainable development theory, growth poles, and adaptive management.

Table 3.

Results of the Kruskal–Wallis ANOVA test comparing groups A, B, and C in terms of expenditures on municipal economy and environmental protection, as well as environmental, demographic, infrastructural indicators, and local resilience (2013 and 2023)

2013					**2023**				
Dependent variable: Expenditures on Municipal Economy and Environmental Protection	H (2, N= 2477) =184.5626 p =0.000				Dependent variable: Expenditures on Municipal Economy and Environmental Protection	H (2, N= 2477) =103.8762 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	486172	1599.25	A	1	304	443679	1459.47
C	2	C	956469	1412.81	C	2	677	947974	1400.26
B	3	B	1626362	1087.14	B	3	1496	1677350	1121.22

Cont. table 3.

Dependent variable: Natural env.	H (2, N= 2477) =68.81815 p =.0000				Dependent variable: Natural env.	H (2, N= 2477) =121.4166 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	404721	1331.32	A	1	304	379292	1247.67
C	2	C	707464	1045.00	C	2	677	667883	986.53
B	3	B	1956819	1308.03	B	3	1496	2021828	1351.49
Dependent variable: Demography	H (2, N= 2477) =142.5309 p =0.000				Dependent variable: Demography	H (2, N= 2477) =101.5145 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	491704	1617.45	A	1	304	472457	1554.13
C	2	C	907111	1339.90	C	2	677	899297	1328.36
B	3	B	1670188	1116.44	B	3	1496	1697249	1134.52
Dependent variable: Infrastructure	H (2, N= 2477) =626.2617 p =0.000				Dependent variable: Infrastructure	H (2, N= 2477) =642.5819 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	668722	2199.74	A	1	304	672723	2212.90
C	2	C	732899	1082.57	C	2	677	747376	1103.95
B	3	B	1667382	1114.56	B	3	1496	1648904	1102.21
Dependent variable: Local resilience	H (2, N= 2477) =233.9829 p =0.000				Dependent variable: Local resilience	H (2, N= 2477) =206.3725 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	550994	1812.48	A	1	304	530326	1744.49
C	2	C	732873	1082.53	C	2	677	701879	1036.75
B	3	B	1785136	1193.27	B	3	1496	1836798	1227.81

A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The linear regression analysis using synthetic indicators for all municipalities in Poland in 2013 and 2023 demonstrated high model accuracy (R^2 values of 0.983 and 0.971, respectively) and statistical significance of all variables ($p < 0.001$), confirming the stability and reliability of the results (Table 4). In both periods, the dominant determinant of local resilience remains the environmental component, whose importance increased in 2023. The technical infrastructure—comprising water supply, sewage, and gas networks—retains a significant positive impact, although slightly diminished compared to 2013, which may reflect the stabilization of its role within local systems. The demographic component maintains a positive but relatively lower influence, suggesting that adaptive management mechanisms and population structure stabilization reduce resilience sensitivity to demographic changes. The findings corroborate the theoretical assumptions of sustainable development and the socio-ecological resilience concept, indicating that municipal resilience arises from the synergy of natural environment quality, infrastructure development, and demographic stability. Systematic monitoring and management of these factors constitute the foundation for effective public policy, spatial planning, and adaptive strategies in environmental protection and human resource management.

Table 4.
Multiple regression results for models including environmental, demographic, and infrastructural factors (2013, 2023)

2013						
	R= .99124859 R^2= .98257376 Adjusted. R^2= .98255262 F(3,2473)=46480. p<0.0000 Standard error of estimate: .00462 d Durbin-Watson statistic1.760774					
N=2477	b*	Standard Error (z b*)	b	Standard Error (z b)	t(2473)	p
intercept			0.046	0.001	32.881	0.000
Natural env.	0.765	0.003	0.600	0.002	287.629	0.000
Demography	0.326	0.003	0.129	0.001	122.347	0.000
Infrastructure	0.514	0.003	0.152	0.001	193.242	0.000
2023						
	R= .98514236 R^2= .97050546 Adjusted. R^2= .97046968 F(3,2473)=27124. p<0.0000 Standard error of estimate: .00603 d Durbin-Watson statistic1.798738					
N=2477	b*	Standard Error (z b*)	b	Standard Error (z b)	t(2473)	p
intercept			0.023	0.002	13.240	0.000
Natural env.	0.852	0.003	0.630	0.003	245.810	0.000
Demography	0.271	0.003	0.120	0.002	78.286	0.000
Infrastructure	0.466	0.003	0.142	0.001	134.401	0.000

Dependent variable: synthetic measure of Local resilience.

Source: own elaboration based on BDL GUS data (2013-2023).

The primary determinants remain environmental and infrastructural factors, whose significance evolves over time. The increasing importance of the environmental component highlights the growing role of ecological policy, while the stable influence of technical infrastructure—including water supply, sewage, and gas networks—confirms its crucial role in the functionality of local systems. Simultaneously, a gradual weakening of the impact of demographic factors is observed, which may reflect the adaptive mechanisms of municipalities in response to population changes. The results indicate the need to strengthen green infrastructure, further develop technical networks, monitor migration processes, and reduce industrial pressure to enhance local resilience. The identified trends corroborate the premises of sustainable development and socio-ecological resilience concepts, emphasizing the complementary role of environmental quality, infrastructure, and demographic stability in shaping the adaptability of local systems. Moreover, this dynamic interplay aligns with the theory of complex adaptive systems, highlighting how local resilience emerges from the continuous interactions and feedback loops among environmental, infrastructural, and demographic components, enabling local systems to adapt and transform in response to changing external and internal conditions (Bristow, Healy, 2014; Nel, Taeihagh, 2024).

5. Discussion

Local resilience of Polish municipalities is primarily determined by environmental factors, which exert the strongest positive influence—particularly in urban and urban–rural municipalities. The impact of technical infrastructure and demographic factors remains moderate, showing a trend toward the stabilization of the infrastructural role and a slight decline in the significance of demography between 2013 and 2023. Expenditures on municipal management exert a weak yet locally significant effect, while intensive industrial activity, high gas consumption, and fluctuations in population and migration systematically constrain the adaptive capacity of territorial units.

An analysis of differences between types of municipalities using the Kruskal–Wallis test revealed statistically significant variation in resilience levels: urban municipalities exhibit the highest environmental, demographic, infrastructural, and overall resilience indices; rural municipalities display the lowest values; and urban–rural municipalities occupy an intermediate and relatively stable position over time. The results of synthetic regression analysis confirm the hierarchy of resilience determinants (MEnvironment > MInfrastructure > MDemography), indicating that environmental policy, technical infrastructure development, and demographic stabilization constitute key directions for strengthening adaptive capacities. At the same time, intensive industrial activity and population fluctuations necessitate targeted regulation and spatially oriented planning.

The findings substantiate the theoretical premises of sustainable development and social–ecological resilience, emphasizing the synergistic interplay between environmental, infrastructural, and socio-demographic factors as fundamental to the durability of local systems. The resilience of local governments should be analyzed in the context of their vulnerability to specific risks—some units, despite greater exposure, may exhibit higher resilience owing to stronger financial, infrastructural, and human capital resources. As Ziarko (2025) notes, examples from large cities such as Warsaw and Gdańsk demonstrate that in crisis situations, wealthier municipalities are capable of responding effectively despite higher levels of systemic risk. Importantly, resilience often manifests only under crisis conditions, revealing social and institutional characteristics that are difficult to predict ex ante. Case studies from Poland and Ukraine indicate that local communities can respond actively and collectively in unforeseen circumstances, confirming the importance of social capital and institutional competencies in shaping local resilience.

Resilience can be enhanced through the development of infrastructure, financial stability, competent leadership, and active citizen engagement. However, as noted in Local Governments Facing Contemporary Threats..., the effectiveness of these measures depends on the specific characteristics of each territorial unit. According to Malik, Szewczuk-Stępień, and Bębenek (2025a), the developed model for identifying smart economic specializations, supplemented with resilience-strengthening criteria, addresses contemporary external challenges such as armed conflicts, climate change, mass migration, and pandemics. The authors present a model that establishes a framework for a policy of identifying smart specializations, supporting both short-term economic resilience and long-term sustainable development. As further emphasized by Malik, Szewczuk-Stępień, and Bębenek (2025b), sustainable development policy in this context facilitates the integration of long-term strategies with operational plans, thereby enhancing the capacity of regions to respond effectively to contemporary threats.

As Strzelecki (2013) argues, demographic structures play a crucial role in shaping resilience and sustainable development at both local and regional scales. Demographic processes in Poland reveal significant spatial disparities—positive in diversified metropolitan areas and negative in monocultural regions with low endogenous potential—thus constraining the resilience of those territories. Peripheral regions often display symptoms of unsustainable development, while urban areas accumulate factors conducive to regional resilience. Demography, as Strzelecki emphasizes, does not directly determine sustainable development but interacts with other systemic components, modulating the resilience and adaptive capacity of regions. Incorporating demographic structure into regional policy planning is therefore essential for strengthening socio-economic resilience and preventing the marginalization of areas with low development potential.

Masik (2022) highlights that regional resilience focuses primarily on economic dimensions, whereas urban resilience encompasses social and infrastructural systems. The author presents the evolution of research perspectives—from engineering-based interpretations toward systemic approaches—in which transformative capacities are recognized as a key dimension of social–ecological resilience. The integration of systemic and equilibrium methods with path-dependence analysis and long-term perspectives enables the identification of post-disruption equilibrium points and decision-making processes that shape relationships among the natural environment, infrastructure, society, economy, and institutions—thereby reinforcing both regional and urban resilience.

According to Rynio (2024), implementing the concept of "short-distance cities" in areas with diverse economic status supports the development of multidimensional resilience by integrating physical, environmental, and social systems. The decentralization of services and spatial organization enabling access to essential activities within a 15-minute walking or cycling distance improve quality of life, social resilience, and safety, while simultaneously reducing transportation pressure and enhancing environmental conditions.

As Ziarko (2025) further observes, the growing importance of community preparedness for responding to threats and mitigating their effects is evident. Critical factors include local action capacities, effective use of material and immaterial resources, availability of social support, preventive measures, and cultural values and norms that foster trust and reduce conflict. Research in this field enables a comprehensive assessment of local resilience, identification of its weaknesses, and the design of adaptive interventions. In addition, we examine the economic and political factors related to country risk. Our assessment is based on the country's economic and financial challenges, as well as the investment climate it faces (Glova, Bernatik, Tulai 2020).

The research findings have significant policy, practical, and theoretical implications. At the policy level, they highlight the need for integrated spatial and investment planning that incorporates the development of technical infrastructure, environmental protection, and demographic stabilization, particularly in rural and urban–rural municipalities. At the practical level, they emphasize the importance of migration monitoring, reducing industrial pressure, and investing in green areas and urban ecosystems to enhance local resilience. At the theoretical level, they reaffirm the relevance of the social–ecological resilience framework, sustainable development theory, and the resilience–cohesion trade-off model, underscoring the interdependence of environmental, demographic, and infrastructural components depending on the level of urbanization and spatial context.

The limitations of this study stem from the restricted availability of administrative and statistical data, the lack of comprehensive indicators for social and cultural capital quality, and the difficulty of capturing dynamic institutional and economic interactions. Future research should incorporate analyses of institutional and cultural dimensions, social capital quality, and the long-term effects of adaptive policies, as well as employ predictive modeling to assess the impact of alternative scenarios for infrastructure, demographic, and environmental policy development on local resilience.

6. Conclusions

The analysis of multidimensional local resilience in Polish municipalities during the period 2013-2023 demonstrated that its level is primarily determined by environmental and infrastructural factors, while demographic factors play a complementary role. The type of municipality significantly modifies both the level of resilience and the relative influence of individual determinants—urban municipalities exhibit the highest resilience levels, whereas rural and urban–rural municipalities show intermediate values. The results of synthetic regression analysis, Spearman's rank correlations, and Kruskal–Wallis tests are consistent, confirming the hierarchy of determinants as well as the spatial differentiation of local resilience.

The environmental component proved to be a universal and dominant factor enhancing resilience throughout the entire study period, reflecting the effectiveness of pro-environmental policies and the increasing importance of environmental actions. Technical infrastructure plays a crucial role particularly in urban municipalities, while in rural and urban–rural units it serves a supporting function. The demographic component exerts a weaker influence, reflecting depopulation processes and the outflow of the working-age population, which negatively affect social cohesion and the adaptive capacity of local systems. Regression analyses and statistical tests indicate that local resilience results from the synergistic interaction between environmental quality, infrastructural development, and demographic stability, with a moderate positive effect of public expenditures on municipal management and environmental protection, and a negative impact of intensive industrial activity and high resource consumption.

The spatial differentiation of relationships among components depending on the level of urbanization underscores the necessity of incorporating local context into development policy planning. The results clearly demonstrate that the balance between adaptability and cohesion within local systems depends primarily on the interaction of environmental and infrastructural components, while limited demographic resilience reduces adaptive potential.

Strengthening multidimensional local resilience requires integrated actions encompassing spatial, environmental, and demographic policies, tailored to the specific characteristics and spatial diversity of different types of municipalities. This approach aligns with the principles of sustainable development theory, the resilience thinking framework, and the "resilience–cohesion trade-off" model.

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References

1. Arzo, S., Hong, M. (2024). Resilient green infrastructure: Navigating environmental resistance for sustainable development, social mobility in climate change policy. *Heliyon*, *Vol. 10, Iss. 13*, e33524, https://doi.org/10.1016/j.heliyon.2024.e33524
2. Assarkhaniki, Z, Rajabifard, A., Sabri, S. (2020). The conceptualisation of resilience dimensions and comprehensive quantification of the associated indicators: A systematic approach. *International Journal of Disaster Risk Reduction*, *Vol. 51,* 101840, https://doi.org/10.1016/j.ijdrr.2020.101840
3. Birchall, S.J., Kehler, S., Weissenberger, S. (2025). Sometimes, I just want to scream: Institutional barriers limiting adaptive capacity and resilience to extreme events. *Global Environmental Change*, *Vol. 91,* 102967, https://doi.org/10.1016/j.gloenvcha.2025.102967

4. Boston, M., Bernie, D. et al. (2024). Community resilience: A multidisciplinary exploration for inclusive strategies and scalable solutions. *Resilient Cities and Structures*, *Vol. 3, Iss. 1,* 114-130, https://doi.org/10.1016/j.rcns.2024.03.005
5. Briguglio, L., Cordina, G., Farrugia, N., Vella, S. (2009). Economic Vulnerability and Resilience: Concepts and Measurements. *Oxford Development Studies, 37(3),* 229-247. https://doi.org/10.1080/13600810903089893
6. Bristow, G., Healy, A. (2014). Building Resilient Regions: Complex Adaptive Systems and the Role of Policy Intervention. *Raumforschung und Raumordnung, Spatial Research and Planning, 72*, 93-102 https://doi.org/10.1007/s13147-014-0280-0
7. Busłowska, A., Marcinkiewicz, J. (2023). Social Cohesion of Functional Urban Areas (Example of Eastern Poland). *Soc. Indic. Res., 167*, 451-473, https://doi.org/10.1007/s11205-023-03119-4
8. Carrasco, S., Ochiai, Ch., Tang, L.M. (2024). Social Capital and Community Resilience in the wake of disasters, conflicts and displacements. *International Journal of Disaster Risk Reduction*, *Vol. 115*, 105049, https://doi.org/10.1016/j.ijdrr.2024.105049
9. Chamusca, P. (2023). Public Policies for Territorial Cohesion and Sustainability in Europe: An Overview. *Sustainability*, *15*, 6890. https://doi.org/10.3390/su15086890
10. Choryński, A., Pińskwar, I., Graczyk, D., Krzyżaniak, M. (2022).The Emergence of Different Local Resilience Arrangements Regarding Extreme Weather Events in Small Municipalities—A Case Study from the Wielkopolska Region, Poland. *Sustainability, 14*, 2052. https://doi.org/10.3390/su14042052
11. Cinner, J.E., Barnes, M.L. (2019) Social Dimensions of Resilience in Social-Ecological Systems, *One Earth*, *Vol. 1, Iss. 1,* 51-56, https://doi.org/10.1016/j.oneear.2019.08.003
12. Córdova, F.E., Krause, T. (2024) et al. Framing adaptive capacity of coastal communities: A review of the role of scientific framing in indicator-based adaptive capacity assessments in coastal social-ecological systems. *Ocean & Coastal Management*, *Vol. 259,* 107455, https://doi.org/10.1016/j.ocecoaman.2024.107455
13. Dressel, S., Johansson, M., Ericsson, G., Sandström, C. (2020). Perceived adaptive capacity within a multi-level governance setting: The role of bonding, bridging, and linking social capital. *Environmental Science & Policy*, *Vol. 104,* 88-97, https://doi.org/10.1016/j.envsci.2019.11.011
14. Eichengreen, B., Park, D., Shin, K. (2024). Economic resilience: Why some countries recover more robustly than others from shocks. *Economic Modelling*, *Vol. 136,* 106748, https://doi.org/10.1016/j.econmod.2024.106748
15. Glova, J., Bernatik, W., Tulai, O. (2020). Determinant Effects of Political and Economic Factors on Country Risk: An Evidence from the EU Countries. *Montenegrin Journal of Economics*, 16(1), 37-53. DOI: 10.14254/1800-5845/2020.16-1.3
16. Gong, X., Wong, W.-K., Peng, Y. et al. (2023), Exploring an interdisciplinary approach to sustainable economic development in resource-rich regions: An investigation of resource

productivity, technological innovation, and ecosystem resilience. *Resources Policy*, *Vol. 87, Part A,* 104294, https://doi.org/10.1016/j.resourpol.2023.104294
17. Gu, T., Zhao, H. et al. (2025), Attribution analysis of urban social resilience differences under rainstorm disaster impact: Insights from interpretable spatial machine learning framework. *Sustainable Cities and Society*, *Vol. 118,* 106029, https://doi.org/10.1016/j.scs.2024.106029
18. Güngör, M., Elburz, Z. (2024). Beyond boundaries: What makes a community resilient? A Systematic Review. *International Journal of Disaster Risk Reduction*, *Vol. 108,* 104552, https://doi.org/10.1016/j.ijdrr.2024.104552
19. Kapucu, N., Ge, Y., Rott, E., Isgandar, H. (2024). Urban resilience: Multidimensional perspectives, challenges and prospects for future research. *Urban Governance*, *Vol. 4, Iss. 3,* 162-179, https://doi.org/10.1016/j.ugj.2024.09.003
20. Liu, Y., Cao, L., Yang, D., Anderson, B.C. (2022). How social capital influences community resilience management development. *Environmental Science & Policy*, *Vol. 136,* 642-651, https://doi.org/10.1016/j.envsci.2022.07.028
21. Lv, Y., Islam Sarker, M.N. (2024). Integrative approaches to urban resilience: Evaluating the efficacy of resilience strategies in mitigating climate change vulnerabilities. *Heliyon*, *Vol. 10, Iss. 6,* e28191, https://doi.org/10.1016/j.heliyon.2024.e28191
22. Malik, K., Szewczuk-Stępień, M., Bębenek, P. (2025a). Smart specializing as key driver of sustainability and resilience of regional economy. *Economics and Environment*, *93(2),* 979. https://doi.org/10.34659/eis.2025.93.2.979
23. Malik, K., Szewczuk-Stępień, M., Bębenek, P. (2025b). Rethinking sustainable development (policy) towards integrated resilience (action plan): regional level. *Economics and Environment*, *91(4),* 959. https://doi.org/10.34659/eis.2024.91.4.959
24. Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography, Vol. 12, Iss. 1,* 1-32, https://doi.org/10.1093/jeg/lbr019
25. Masik, G. (2022). Koncepcja odporności: definicje, interpretacje, podejścia badawcze oraz szkoły myśli. *Przegląd Geograficzny*, *3*, 1-28. doi: 10.7163/przg.2022.3.1
26. Naderi, A., Khoshnevis, K. (2025). The sustainable future of cities under uncertainty: identifying key factors of adaptive urban resilience in Yazd, Iran. *Ain Shams Engineering Journal, Vol. 16, Iss. 11*, 103732, https://doi.org/10.1016/j.asej.2025.103732
27. Nel, D., Taeihagh, A. (2024). The soft underbelly of complexity science adoption in policymaking: towards addressing frequently overlooked non-technical challenges. *Policy Sci., 57*, 403-436 https://doi.org/10.1007/s11077-024-09531-y
28. Oliver, T.H., Heard, M.S. et al. (2015), Biodiversity and Resilience of Ecosystem Functions, *Trends in Ecology & Evolution*, *Vol. 30, Iss. 11,* 673-684, https://doi.org/10.1016/j.tree.2015.08.009

29. Rynio, D. (2024). Wdrażanie koncepcji miast krótkich odległości jako element budowy odporności współczesnych ośrodków osadniczych. *Regional Development and Regional Policy*, *70*, 45-61. doi: 10.14746/rrpr.2024.70s.05
30. Salomon, J., Behrensdorf, J., Winnewisser, N., Broggi, M., Beer, M. (2022). Multidimensional resilience decision-making for complex and substructured systems. *Resilient Cities and Structures*, *Vol. 1, Iss. 3,* 61-78, https://doi.org/10.1016/j.rcns.2022.10.005.
31. *Samorządy wobec współczesnych zagrożeń, Odporność polskich gmin i miast.* Departament Badań i Analiz BGK (Czerwiec 2025). https://www.bgk.pl/files/public/user_upload/Raport_BGK_odporność_samorządów.pdf?utm_source=chatgpt.com (12.11.2025).
32. Sánchez-Zamora, P., Gallardo-Cobos, R. (2019). Diversity, Disparity and Territorial Resilience in the Context of the Economic Crisis: An Analysis of Rural Areas in Southern Spain. *Sustainability*, *11*, 1743. https://doi.org/10.3390/su11061743
33. Sánchez-Zamora, P., Gallardo-Cobos, R. (2020). Territorial Cohesion in Rural Areas: An Analysis of Determinants in the Post-Economic Crisis Context. *Sustainability*, *12*, 3816. https://doi.org/10.3390/su12093816
34. Strzelecki, Z. (2013). Demograficzne uwarunkowania rozwoju zrównoważonego w skali regionalnej i lokalnej. *Studia Komitetu Przestrzennego Zagospodarowania Kraju PAN*, *152*, 39-55.
35. Zaucha, J., Komornicki, T. (2019). Territorial Cohesion: The Economy and Welfare of Cities. In: E. Medeiros (ed.), *Territorial Cohesion*. The Urban Book Series. Cham: Springer, https://doi.org/10.1007/978-3-030-03386-6_3
36. Ziarko, J. (2025). Odporność społeczności lokalnej na zagrożenia kryzysowe – ku holistycznym ramom odporności. *Bezpieczeństwo. Teoria i Praktyka*, *1,* 145-160.