Analysis of community resilience in Hungary – An adaptation of the basic resilience indicators for communities (BRIC), 2020

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Currently, resilience studies are at the forefront of urban and regional research. However, community resilience is generally less investigated than economic or climate resilience. Community resilience, defined as the ability of different regional levels to adjust their socioeconomic systems to cope with adverse effects of external factors and to be able to provide adaptive responses, plays a crucial role in sustainable regional development patterns. This paper addresses this scientific gap in the general lack of community resilience studies in Hungary and the understudied regional focus. The study has two aims: 1) to collect statistical variables for assessing community resilience based on the basic resilience indicators for communities (BRIC) framework and 2) to conduct statistical and regional analyses at the Hungarian subregional level (former LAU level 1). The subregional level provides an extensive amount of spatial units that enabled the authors to apply context-specific indicators and reveal regional patterns. The authors conducted several statistical analyses, proving the independence of the selected variables and the effectiveness of the elaborated community resilience index. Regarding regional characteristics, the authors mapped and analyzed the spatial pattern of each community resilience dimension and the overall index. Furthermore, this paper evaluated spatial autocorrelation aspects to identify those areas where similar subregions can be found. The applied statistical analyses regarding the elaborated set of indicators prove the relatively high independence of variables. Although the Pearson correlation was found to be significant in some cases, there were no professional connections. Regarding the multicollinearity analysis, the authors found that the variance inflation factor (VIF) values of the dimensions do not exceed the benchmark value of 5. The regional analyses showed high heterogeneity concerning the evaluated resilience category. In the cases of infrastructure, community, and environmental dimensions, rapidly urbanized subregions and their agglomerations had lower values. The economic and social aspects proved the east–west axis within the country, and the below-average values well followed the average size of municipalities within the subregions. Finally, the Central-Northern subregions are spatially correlated, defining a regional hotspot with below-average performances by paying attention to the calculated Moran's I values.

Keywords:
community resilience,
spatial autocorrelation,
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regional pattern

Introduction

The frequency and severity of natural catastrophes have been on the rise during the last few decades. The loss of life and property as a result of natural hazards brought on by extreme weather events is already at an all-time high (Sung–Liaw 2020). In addition to the damage caused by the overexploitation of resources (Champagne–Aktas 2016) or induced by climate change (Kais–Islam, 2016), the occurrence of unexpected global shocks such as the COVID-19 pandemic has led to further severe socioeconomic losses (South et al. 2020, Xie et al. 2022, Yip et al. 2021). In light of recent events, the concept of resilience is receiving increasing attention both in academia and in practice (Mayer 2019, Roostaie et al. 2019). The conceptual origins of resilience – apart from the fields of physics and ecology – are in disaster management science (Davidson 2010). Resilience took root in the social sciences in the early 2000s, and since the 2010s, studies have focused on practical research. Resilience building plays a vital role in handling the rising potential of catastrophic disasters (Cutter et al. 2014). Managing emergencies involves several important considerations, including the community's and the individual's ability to operate under such circumstances (Cohen et al. 2013). Building on society's strengths can increase the capacity of the impacted areas to better plan for, respond to, and recover from the negative consequences (Scherzer et al. 2019). The key aspects of social/community resilience are recovery from stress and access to critical resources (Xu et al. 2015) by building local capacities to adapt to changing and uncertain environments, which also serve to avoid disasters (Mayer 2019).

Generally, resilience is recognized as a positive attribute since it is associated with fewer losses and more rapid recovery in the face of catastrophes (Scherzer et al. 2019). Accurate resilience assessments can aid in locating potential issues within communities where resilience has diminished or where adaptation is urgently required (Singh-Peterson et al. 2014). Many scholars criticize the concept of resilience for being ambiguous (Roostaie et al. 2019), casting doubt on its capacity to be measured (Brand–Jax 2007, Folke 2016) and the reliability of existing indicator systems (Cai et al. 2018, Sharifi 2016). However, an increasing number of academics and professionals advocate for the value of resilience measures in catastrophe risk reduction (Burton 2015, Scherzer et al. 2019, Sharifi 2016). Community resilience assessment tools make resilience a more tangible, understandable, and quantifiable term by examining several aspects of a community connected to resilience (Asadzadeh et al. 2017). The goal of community resilience assessment is to put the idea into practice. When planning and making decisions, policymakers may give more attention to the identified shortcomings in those communities that lack resources, assets, or capacities (Javadpoor et al. 2021).

The international literature provides a large number of case studies and indicator systems for evaluating community resilience, applying risk-specific (e.g., flood (Jacinto et al. 2020, Lwin et al. 2020, Qasim et al. 2016), earthquake (Song et al. 2022, Vona et al. 2018), climate change (Kim et al. 2018, Yazar et al. 2022), epidemic)Fernández-Prados et al. 2020, Kucsera 2021, Stevenson et al. 2021) or comprehensive (e.g., (Bixler et al. 2021, Cutter et al. 2014, Fraser 2021, Leykin et al. 2013, Sherrieb et al. 2012, Sung–Liaw 2020) approaches. Despite the many existing indicator systems to measure resilience, there are presently no widely accepted approaches that operate across all situations (Javadpoor et al. 2021). According to recent studies, a composite community resilience assessment that includes elements of human health, well-being, and social, economic, and ecological resilience is favorable (Saravanan–Garren 2021). Physical elements such as infrastructure, economic resources, disaster readiness, and the accessibility of different services are all included in community resilience. Moreover, the individual's perception of the community is also considered, including their prior encounters with various challenging circumstances, social networks, and social capital (Cohen et al. 2013). Even though most models and indicators overlook them, spatial differences and spatial patterns are influential considerations. Age, income, and employment are three examples of human attributes that can vary significantly in space and affect how resilient people are to natural hazards (Sung–

Liaw 2021). As a result, many researchers favor small-scale, local data since it enables the consideration of specific characteristics and disturbances (Saravanan–Garren 2021). Along this line, we are joining the extension of the BRIC framework and trying to customize it to Hungary's local characteristics as well as available data.

BRIC is a pivotal framework for evaluating community disaster resilience. The indicators were designed based on the disaster resilience of place (DROP) model, a theoretical framework focusing on inherent resilience (Cutter et al. 2010). According to the DROP framework, resilience is a bouncing-forward cycle (Sung–Liaw 2020) relying on previous conditions such as existing networks, infrastructure, and society's responding and recovery ability (Singh-Peterson et al. 2014). The BRIC framework covers all the vital themes suggested in community resilience studies (Singh-Peterson et al. 2014) and is recognized for its various dimensions and better coverage in terms of disaster resilience attributes (Asadzadeh et al. 2017, Sharifi 2016). Moreover, Cutter et al.'s (2014) resilience tool has a solid reputation and credibility (Asadzadeh et al. 2017).

In contrast to the international scholarly discussion, Hungarian publications do not specifically discuss the concept of community resilience or its analysis emphasis. However, some connected papers are present that either address resilience in a more general sense or apply a completely different resilience focus. On the one hand, studies address the theoretical interpretation of settlements' resilience (Pirisi 2019, Sikos T.–Szendi 2022) and the elaboration of a complex urban resilience index (Szép et al. 2021). On the other hand, domestic papers concentrate on other areas of resilience. Economic resilience illustrates this point clearly, where papers examine the evolution and targets of the Hungarian budget in the event of external shocks (Pulay et al. 2020) or the resilience and performance of the Hungarian labor market (Fekete-Fábián–Jánosi 2022) or businesses (Nyikos et al. 2021) during the pandemic. At the same time, resilience studies that fundamentally build on social capital/impacts are present in the domestic literature, focusing on education-health (Berkes 2021, Bordás 2020, Czinderi et al. 2018, Kovács–Vántus 2022, Pál et al. 2021, Papp–Neumann 2021, Uzzoli et al. 2019, 2021), psychology (Bandi et al. 2019, Dobokai 2020), and the urban environment (Nagy et al. 2021, Sebestyénné Szép et al. 2020). Overall, to the best of our knowledge, there is no study on community resilience and its measurement in the Hungarian academic environment.

Currently, resilience studies are at the forefront of urban and regional research (Cariolet et al. 2019). However, community resilience is generally less investigated than economic (Evenhuis 2020) or climate resilience (Wardekker 2021). This paper addresses this scientific gap, namely, the general lack of community resilience studies and the understudied regional focus. In Hungary, research on resilience is still in its infancy. At present, data about resilience are limited. To the best of the authors' knowledge, no study or measurement framework has yet been conducted on community resilience in Hungary. This study focuses on developing a baseline resilience index to evaluate each subregion's strengths and weaknesses. We attempt to adopt an already existing framework with several international applications. We present 36 indicators divided into five dimensions (social, economic, community, infrastructure, and environmental) inspired by the BRIC framework and embedded in the local context. As introduced above, indicators measuring community resilience can provide information on society's ability to carry on or adapt in case of disasters. The findings should make a meaningful contribution to decision-makers by identifying shortcomings.

This paper begins with the proper statistical and methodological foundation of the indicators. It supports the validation and the professional basis of the indicator systems in the context of Hungarian resilience studies. The remaining part of the article presents a case study on resilience in the Hungarian subregions. The results reveal the consequences of rapid urbanization and disclose regional patterns of community resilience. The findings also indicate clear guidance for local/regional resilience strategic planning by determining priorities for improvement.

Methodology

The study aims to develop a set of indicators suitable for measuring the community resilience of Hungarian subregions. This paper considers the relationship between indicators to validate the indicator set. Finally, a case study helps to explore the regional patterns in Hungary's community resilience. The studies have quite varied interpretations of the community on which they are founded. According to Kais–Islam (2016), there are two main approaches between the household and the national level: 1) spatial unit (municipality, administrative unit) or 2) group (individuals who identify with each other and are in daily interaction based on shared values, culture, and activities). In our research, we take the former interpretation as a basis and use data from Hungarian subregions to examine the variables measuring community resilience using statistical methods.

Construction of the BRIC

The set of variables used to describe the resilience of communities was developed based on the BRICs (Cutter et al. 2010), taking into account the previous adaptations (Cutter et al. 2014, Javadpoor et al. 2021, Opach et al. 2020, Scherzer et al. 2019, Singh-Peterson et al. 2014) and their implications.

The choice of indicators was guided by the original BRIC framework (Cutter et al. 2010, 2014) and existing BRIC adaptations (Javadpoor et al. 2021, Saravanan–Garren 2021, Scherzer et al. 2019, Singh-Peterson et al. 2014) and was largely based on the work of Scherzer et al. (2019), who studied the resilience of Norwegian municipalities. In the final indicator set, all 36 variables were selected from the Hungarian Central

Statistical Office (KSH) and the National Regional Development and Spatial Planning Information System (TeIR). We used publicly available data at the subregional level that fit the Hungarian context.

The environmental dimension was not included in the original BRIC framework (Cutter et al. 2010), but several studies (Sharifi 2016, Singh-Peterson et al. 2014) highlight the importance of this element, and we have therefore decided to incorporate it. Finally, similar to Javadpoor et al. (2021), we did not define a separate institutional dimension but decided to integrate it into the other dimensions, thus reducing the number of dimensions. The key components associated with the institutions have a strong logical link with the other dimensions; the physical or social infrastructures are included in the community or infrastructure indicators, while municipal management is inextricably linked to the economic dimension (da Silva et al. 2021). The selected indicators by dimension are shown in Table 1, where we have also indicated whether the increase in the variables is considered beneficial or detrimental. The indicators were selected and collected from the spatial statistical data available in the databases of the KSH [1] and the TeIR [2] at the subregional level, using 2020 as the reference year where possible.

The category of social resilience encapsulates the general demographic characteristics of the population as well as indicators that can be used to infer the resilience of individuals (Scherzer et al. 2019). This dimension refers to the physical and mental well-being of the population, which underpins communication, cognitive understanding, and mobility in the event of disasters, both from the perspective of avoidance, preparedness, response, and recovery (Cutter et al. 2010). For example, a higher proportion of working-age people is considered advantageous, as they are assumed to be better able to help themselves and others than minors, especially young children or elderly individuals. Migration balance, natural growth and marriage rate together indicate the self-sustainability of the population, which is a key factor for long-term adaptability. In addition, having sufficient access to basic health care improves the neighborhood's general health; therefore, healthier individuals make the community more resilient as a whole (Scherzer et al. 2019). Similarly, having adequate access to transport or communications infrastructure can be critical in times of crisis. Hence, the number of cars is an important indicator of evacuation capacity and increased individual mobility, and its increase (although it works against the state of the environment) can be seen as positive (Lu et al. 2020), while the number of internet subscriptions is essential for maintaining communication; for example, internet subscriptions greatly increased resilience in the case of the COVID-19 pandemic (but also indicates greater economic development) (Figueiredo et al. 2018).

Table 1

Indicators of community resilience for Hungary, 2020

Indicators	Effects on resilience	Source
Social		
S1 – Working age (proportion of population aged 15–64 years)	+	KSH
S2 – Migration balance per 1000 capita	+	KSH
S3 – Natural growth rate	+	KSH
S4 – Number of marriages per 1000 capita	+	KSH
S5 – Number of residents per GPs and pediatricians	–	KSH
S6 – Cars per 1000 capita	+	KSH
S7 – internet subscriptions per apartment	+	KSH
Economic		
Ec1 – Registered jobseekers per 1000 persons aged 15–64 years	–	KSH
Ec2 – Proportion of microenterprises in active enterprises[a)]	–	KSH
Ec3 – Enterprises having at least 50 employees per 1000 capita	+	KSH
Ec4 – Total budget revenues of local government (HUF per capita)	+	KSH
Ec5 – Number of branch banks per 1000 capita	+	KSH
Ec6 – Personal income taxable income (1000 HUF) per taxpayer	+	TeIR
Ec7 – Number of civic organizations per 1000 capita	+	KSH
Community		
C1 – Places in infant nurseries (per 1000 persons aged 0–2 years)	+	KSH
C2 – Schools (per 1000 capita)	+	KSH
C3 – Number of family and child welfare services (per 100 000 capita)	+	KSH
C4 – Total number of persons employed in basic social services and day care (per 1000 capita)	+	KSH
C5 – Proportion of settlements providing day care for the aged	+	KSH
C6 – Area of playgrounds, athletic grounds and resting places (m^2 per capita)	+	KSH
C7 – Number of cultural events and performances of theatres per 1000 capita	+	KSH
Infrastructure		
I1 – Number of dwellings ceased due to obsolescence or natural disasters per 1000 apartment	–	KSH
I2 – Proportion of dwellings connected to public water conduit network	+	KSH
I3 – Proportion of dwellings connected to public sewerage network	+	KSH
I4 – Length of public roads (km per 1000 capita)	+	KSH
I5 – Number of railway stations (per 1000 capita)	+	KSH
I6 – Time to reach the nearest city of at least 100,000 inhabitants by the fastest road (min)[a)]	–	TeIR
I7 – Number of pharmacies (per 1000 capita)	+	KSH
I8 – Number of fire protection units (per 1000 capita)[a)]	+	TeIR
Environmental		
En1 – Local government owned green areas, total (m^2 per capita)	+	KSH
En2 – Agricultural holdings (per 1000 capita)	+	KSH
En3 – Number of livestock (per 1000 capita)	+	KSH
En4 – Water consumption (m^3 per capita)	–	KSH
En5 – Energy consumption (kWh per capita)	–	KSH
En6 – Proportion of built-up areas (Corine 11, 12, 13)[b)]	–	TeIR
En7 – Proportion of natural areas (Corine 31, 32, 41, 42, 51)[b)]	+	TeIR

a) 2019.
b) 2018.

Economic resilience focuses on the vitality of the local economy. It emphasizes not the resilience of individual businesses but the benefits to the community of a well-functioning, prosperous economy (Opach et al. 2020). Employment rates, the number of nongovernmental organizations (NGOs), and entrepreneurial activity are all indicators of the health of the local economy (Cai et al. 2018). Other key elements of a functioning economy are access to financial resources and higher personal income (Burton 2015). It should be further noted that in a crisis, larger companies have a higher capacity to adapt and are often better at managing and recovering from recessions caused by unexpected events (Scherzer et al. 2019). They are also better able to tap into resources from outside the community through their business networks. The capital strength of local government is a key determinant of both regional development and preparedness opportunities and can also provide a basis for supporting residents and businesses in times of emergency (Huck et al. 2021).

The community dimension is linked to the social dimension, but its distinction is justified, as it emphasizes the capacities responsible for strengthening society as a whole and underpins the support provided in emergencies (Cutter et al. 2014). For example, active community life - approached through cultural events and community spaces for active leisure - results in the formation of social networks acting as informal safety nets which offer assistance during difficult times and throughout recovery (Scherzer et al. 2019). The other important subarea offers information on formal safety nets and social services in the community. The role of institutionalized safety nets is essential in shaping the adaptive capacities of more vulnerable populations (poorer financial status, poorer health, more vulnerable) and in providing a better basis for relying on established networks when needed (Ómarsdóttir et al. 2022). Along this logic, we considered the higher number or rate of social services and social workers as positive, even if it can represent a higher number of people in need.

For the infrastructure dimension, the underlying studies have taken a different approach. In the case of early BRIC studies (Cutter et al. 2010, 2014, Singh-Peterson et al. 2014), the focus was on the quality of housing, evacuation and shelter facilities and the provision of emergency services. In contrast, Scherzer et al. (2019) emphasized crisis response and resilience provision, analyzing the proximity to a hospital, fire or police station and the availability of transport infrastructure to describe resilience. In this study, we wanted to combine these two approaches. Thus, the quality of housing is represented by the rate of apartments ceased due to obsolescence or natural disasters and the connection to public water and sewage networks, which indicates reduced health and pollution risks and improves the quality of the environment. Indicators I5-8 - imply the availability of transportation and ways to escape or for supply, together with the existence of assistance in case of disasters.

Following the logic of Cutter et al. (2014), the indicators of the environmental subdomain are composed of two main parts, the first of which (composed of En4 and En5) examines communities' consumption, i.e., the use of natural resources. This is mainly relevant in the long term in the case of slow-onset crises and long-term stresses, while the second set of indicators provides the basis for short-term responses. En1, En6, and En7 represent the absorptive capacity of nature in the case of extreme weather events, such as heat waves, drought, or flash floods (Saravanan–Garren 2021). The capacity to manufacture food can be crucial during times of crisis, particularly if supply routes are disrupted; therefore, two variables referring to agricultural production are included (Scherzer et al. 2019).

Statistical and spatial analysis of data

The district-level data for the selected 36 indicators were then analyzed from several perspectives. First, statistical tests were carried out to validate the indicator set. Based on the results of the analyses, the indicators were reconsidered several times until the system presented above was developed. We then calculated the aggregate resilience values of the subregions and analyzed their spatial distribution. Overall, the following objectives were investigated:

1. correlations between the variables within each dimension,
2. multicollinearity using the VIF value,
3. the possibilities of reducing the number of variables by principal component analysis (PCA) of the indicators,
4. emerging regional patterns for each dimension and for the overall resilience indicator,
5. spatial autocorrelation to identify hot spots.

First, Pearson's correlation of the variables in each dimension was determined; it was considered strongly correlated above 0.7 (Burton 2015, Scherzer et al. 2019). The aim of the analysis is to filter out redundant variables, thus decreasing the number of variables as well as ensuring that the variables are reasonably independent concerning linear relationships. Replacing redundant indicators with other variables helps to provide a more comprehensive description of communities' adaptability and preparedness. All correlations above 0.5 were investigated to see what kind of professional relationship could be found between the indicators, and in each case, a decision was made whether to omit or keep one or both.

For the analysis of multicollinearity, we considered the VIF value, which basically tries to link multicollinearity to individual variables in a set of multiple regression variables (Kovács 2008). In studies, a VIF value below 5 is generally accepted as appropriate; therefore, similar to several researchers (Idris et al. 2019, Oladele et al. 2022), we considered this threshold as a guideline.

Subsequently, PCA is used to explore the possibilities of reducing the number of variables per dimension. In PCA, variables are compressed into index variables by adopting a linear combination. For the analysis, varimax rotation was used, and the number of components was set such that they accounted for at least two-thirds of the variance. To ensure the adequacy of the analysis, we also applied the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity.

In addition to the statistical-oriented analyses, we aimed to reveal regional patterns regarding the community resilience level of the Hungarian subregions. For this purpose, we first performed a min-max transformation to ensure that the indicators take a value between 0 and 1 while maintaining their original distribution. The average values of each subdomain, namely, Community, Economic, Environmental, Infrastructural, and Social, were inserted into QGIS 3.22 by applying quintiles to distinguish low- and high-performance spatial units clearly. Then, overall community resilience scores were calculated by summarizing the dimensional values, and the results were analyzed with the same illustration technique. Finally, the regional analysis includes spatial autocorrelation calculation by applying the nearest neighbor's method with three neighboring units, representing Moran's I values. In this case, 5-5 categories were determined to depict low and high values of spatial autocorrelation to define regional similarities and differences in the overall community resilience score across the subregions.

Results and discussion

Statistical analysis

We applied a correlation analysis to measure relationships among the variables. The study resulted in revising the indicator set several times to develop an indicator set that reflects the resilience of the system yet has adequate statistical grounding. For correlations above 0.5, we investigated the reasons for the comovement of the indicators. For values above 0.7, we have examined the possibility of replacing the variable with another indicator covering the original intention but avoiding comovement with other indicators. We choose not to present all considered variables, only the final set. Examining the social indicators, Table 2 indicates that only S2 and S6 show a moderately strong correlation. In this case, we can find a professional relationship between the indicators, given that the direction of migration in 2020 is mainly sub- and deurbanization, reinforcing the reliance on already individual modes of transport in destination settlements.

Table 2

Pearson correlation of social resilience indicators, 2020

Indicator	S2	S3	S4	S5	S6	S7
S1	–0.233*	0.444*	0.251*	0.226*	–0.068	0.045
	0.002	< 0.001	< 0.001	0.003	0.377	0.552
S2		–0.028	–0.293*	0.187	**0.550***	0.458*
		0.711	< 0.001	0.013	< 0.001	< 0.001
S3			0.219*	0.382*	–0.116	0.285*
			0.004	< 0.001	0.128	< 0.001
S4				0.004	–0.261*	–0.101
				0.955	< 0.001	0.183
S5					–0.068	0.164
					0.374	0.030
S6						0.480*
						< 0.001

* Correlation is significant at the 0.01 level (2-tailed).

In the economic dimension (Table 3), the Pearson correlation coefficient was above 0.5 in 3 cases, one of which showed a strong negative correlation between Ec1 and Ec6. Both variables describe the prosperity and well-functioning of the economy, which goes hand in hand with higher income and lower unemployment. Nevertheless, there is a professional justification for the presence of both indicators, as the number of jobseekers is a proxy for the availability of jobs and for the most economically vulnerable, while Ec6 indicates the financial position enabling more expensive adaptation options. Additionally, omitting either or both Ec1 and Ec6, the KMO value drops significantly. The authors tried several slightly different indicators, none of which could address both aspects. There is also a moderate correlation between Ec2 and Ec3 since a higher rate of microenterprises means fewer large companies. The correlation between indicators Ec3 and Ec6 reflects that larger companies generate more revenue and employ more people.

Table 3

Pearson correlation of economic resilience indicators, 2020

Indicator	Ec2	Ec3	Ec4	Ec5	Ec6	Ec7
Ec1	0.092	–0.458*	0.407*	0.195*	**–0.704***	–0.081
	0.227	< 0.001	< 0.001	0.01	< 0.001	0.284
Ec2 a)		**–0.515***	–0.02	–0.06	–0.139	0.029
		< 0.001	0.794	0.428	0.067	0.708
Ec3			–0.055	–0.137	**0.533***	0.127
			0.473	0.07	< 0.001	0.09
Ec4				0.089	–0.276*	0.322*
				0.24	< 0.001	< 0.001
Ec5					–0.415	0.034
						0.658
Ec6						0.083
						0.275

a) 2019. * Correlation is significant at the 0.01 level (2-tailed).

On the dimension of community resilience (Table 4), we find a moderately strong negative correlation between C1 and C2, indicating that relatively fewer childcare establishments are available at higher school capacities. This is a result of limited budgets in local governments, especially smaller ones, where the survival of schools is considered crucial and therefore there are limited opportunities to establish nurseries. In these settlements, decision-makers may pay more attention to maintaining a higher number of schools within a subregion to enhance population retention ability. Consequently, a limited local budget entails reduced community resilience through reduced institutional capacity.

Table 4

Pearson correlation of community resilience indicators, 2020

Indicator	C2	C3	C4	C5	C6	C7
C1	**–0.578***	–0.36*	–0.89	0.041	0.095	0.138
	< 0.001	< 0.001	0.242	0.588	0.213	0.068
C2		0.47*	0.321	–0.08	–0.123	–0.111
		< 0.001	< 0.001	0.293	0.103	0.143
C3			0.272*	0.102	–0.038	–0.021
			< 0.001	0.179	0.618	0.779
C4				0.102	–0.073	–0.008
				0.177	0.337	0.912
C5					0.049	–0.016
					0.523	0.833
C6						–0.073
						0.337

* Correlation is significant at the 0.01 level (2-tailed).

Concerning the indicators describing infrastructure (Table 5), I3 and I4 and I4 and I5 show moderate or moderately strong correlation coefficients. In the former case, we cannot find any negative relationship between the sewage system and the length of roads. However, the correlation between I4 and I5 suggests better connectivity and a link between the extent of different transport infrastructures.

Table 5

Pearson correlation of infrastructure resilience indicators, 2020

Indicator	I2	I3	I4	I5	I6	I7
I1	0.159	0.064	–0.088	–0.024	–0.067	–0.108
	0.035	0.4	0.247	0.753	0.379	0.155
I2		0.476*	–0.14	–0.03	0.19	–0.171
		< 0.001	0.065	0.69	0.012	0.024
I3			**–0.565***	–0.384*	–0.107	–0.381*
			< 0.001	< 0.001	0.16	< 0.001
I4				**0.518***	0.454*	0.461*
				< 0.001	< 0.001	< 0.001
I5					0.217*	0.13
					0.004	0.086
I6 [a)]						0.08
						0.296

a) 2019. * Correlation is significant at the 0.01 level (2-tailed).

Concerning the environmental dimension (Table 6), there is a moderate correlation between indicators En2 and En3, both describing agriculture, while the negative relationship between En2 and En6 is rooted in the rural–urban contrast.

Table 6

Pearson correlation of environmental resilience indicators, 2020

Indicator	En2	En3	En4	En5	En6	En7
En1	–0.043	–0.046	–0.019	0.114	–0.032	0.098
	0.573	0.542	0.804	0.133	0.673	0.197
En2		0.487*	–0.402*	–0.251*	–0.444*	–0.184
		< 0.001	< 0.001	< 0.001	< 0.001	0.015
En3			–0.201*	–0.068	–0.33*	–0.306*
			0.008	0.375	< 0.001	< 0.001
En4				0.285*	0.358*	0.039
				< 0.001	< 0.001	0.612
En5					0.1	–0.027
					0.188	0.723
En6 a)						–0.131
						0.084

a) 2018. * Correlation is significant at the 0.01 level (2-tailed).

Table 7

VIF and KMO values of the indicators for community resilience, 2020

Indicator	S1	S2	S3	S4	S5	S6	S7	
VIF	1.416	1.853	1.628	1.187	1.305	1.818	1.658	
KMO	0.609							
Indicator	Ec1	Ec2	Ec3	Ec4	Ec5	Ec6	Ec7	
VIF	2.39	1.462	2.072	1.444	1.266	2.676	1.204	
KMO	0.603							
Indicator	C1	C2	C3	C4	C5	C6	C7	
VIF	1.574	1.891	1.37	1.182	1.049	1.029	1.033	
KMO	0.632							
Indicator	I1	I2	I3	I4	I5	I6	I7	I8
VIF	1.049	1.492	2.05	2.559	1.458	1.445	1.382	1.109
KMO	0.639							
Indicator	En1	En2	En3	En4	En5	En6	En7	
VIF	1.028	1.698	1.475	1.321	1.147	1.1466	1.223	
KMO	0.647							

Next, we tested the multicollinearity with the aid of the variance inflation factor for each variable (Table 7). This test enabled us to filter out indicators that have a strong relationship with the others, which are responsible for the comovements. We found that the VIF values of the dimensions do not exceed the benchmark value of 5. However, Ec6 and Ec1 are relatively outstanding for the economic dimension, so an attempt was made to exclude either or both indicators, but this led to a further decrease in the KMO; therefore, none of them were omitted. Among the infrastructure variables, a slightly higher VIF value was observed for I4, but similar to Ec1 and Ec6, its removal was considered detrimental due to the decrease in KMO. In conclusion, there is no multicollinearity between the variables, i.e., the variables can be considered relatively independent, which is beneficial for the analysis.

PCA was conducted by dimensions to reduce the number of variables to a more manageable set of indicators (see Table 8). The number of components per dimension was determined to account for at least 2/3 of the variance. A preliminary KMO test was applied to assess whether the variables were suitable for PCA, and KMO values above 0.6 were considered appropriate. Bartlett's sphericity tests showed that PCA is applicable in each dimension, and the data reduction technique can compress the data in a meaningful way. The PCA of the seven variables of the social dimension yielded three components, which accounted for 71,25% of the variance. The first component is composed of indicators S2, S6, and S7, all of which indicate the prosperity of the subregions. The second component reflects the structure and internal reproduction of the population since the increased presence of a reproductive population combined with a secure family structure (marriage) implies the birth of more children. The third component shows the burden on the basic health care system through indicator S5. Of the three components that emerge for the economic dimension, the first one includes indicators describing the private sector. The second component provides information on the business structure, while the third component deals with the municipal and nonprofit segments of the economy. The community dimension is described by four components, the first factor covering human infrastructure services for children and the second covering social infrastructure. The third component describes cultural activities, while the fourth describes outdoor recreational opportunities. There are four factors describing the infrastructure resilience indicators. The first, comprising three indicators, shows the extent of physical transport infrastructure. The second component relates to public health, mainly through access to utility infrastructure. The third factor describes the emergency infrastructure, while the fourth refers to the state of the housing stock. The first component of the environmental dimension, somewhat surprisingly, describes the extent to which a given subregion is considered urban or rural. The second component is a cluster of indicators describing the consumption habits of the inhabitants. The third factor refers to the extent of natural areas, while the fourth refers to the extent of urban green spaces. While the PCA revealed logical connections between the indicators, its additional value raises some doubts. The number of indicators could not be reduced significantly. Since we conducted PCA by dimensions, the analysis only halved the number of components compared to the original 36 variables. Moreover, multiple components consist of only 1 or 2 main determining variables signaling the lack of increased benefits. Subsequently, the community resilience index was calculated without using the results of the PCA.

Table 8

Principal component analysis, 2020

Number of factor / Number of indicator	Factor			
	1	2	3	
	Social			
1		0.73		
2	0.74			
3		0.61	0.57	
4		0.72		
5			0.92	
6	0.85			
7	0.82			
8				
Eigenvalues, %	31.2	26.8	13.2	
p value of Bartlett's test of sphericity	<0.001			
Total variance explained, %	71.25			
	Economic			
1	0.80			
2		–0.90		
3	–0.45	0.77		
4			0.77	
5	0.64			
6	–0.87			
7			0.84	
8				
Eigenvalues, %	35.9	19.9	16.8	
p value of Bartlett's test of sphericity	<0.001			
Total variance explained, %	72.65			
	Community			
1	–0.76			
2	0.87			
3	0.73			
4	0.43	0.52		
5		0.87		
6				0.99
7			0.95	
8				
Eigenvalues, %	30.5	16.1	15.6	12.7
p value of Bartlett's test of sphericity	<0.001			
Total variance explained, %	74.83			

(Table continues ont he next page.)

(Continued.)

Number of indicator \ Number of factor	Factor			
	1	2	3	
	Infrastructure			
1				0.96
2		0.82		
3	–0.48	0.72		
4	0.76			
5	0.84			
6	0.60			
7		–0.54	0.52	
8			0.84	
Eigenvalues, %	32.0	18.6	12.5	11.6
p value of Bartlett's test of sphericity	<0.001			
Total variance explained, %	74.70			
	Environmental			
1				0.98
2	0.73			
3	0.69		0.47	
4	–0.46	0.60		
5		0.90		
6	–0.83			
7			–0.93	
8				
Eigenvalues, %	32.3	17.9	15.5	12.3
p value of Bartlett's test of sphericity	<0.001			
Total variance explained, %	78.01			

Regional analysis

Since this study aims to analyze regional patterns of the established community resilience index and its components, in the following pages, related figures and explanations can be found about the spatial characteristics of the assessed aspects. First, Figure 1 depicts the community resilience components and their regional patterns. At first glance, it can be stated that these components show truly heterogeneous spatial characteristics, proving the selection of indicators regarding the overall index. However, several similar features can be revealed in the cases of community and environmental dimensions; the agglomeration of Budapest and Northwestern subregions performed worse, not independently of the fast urbanization processes that can be observed in these regions. Sticking to the community and environmental dimensions, it can be seen how the subregions of the agglomeration ring around Budapest show a very different pattern for the two dimensions; in terms of community resilience, the southeastern districts show below-average performance, while the northwestern districts show lower scores for the environmental component.

However, several spatially concentrated hot spots can be detected in addition to the previously mentioned regions: the southeastern part of the Budapest agglomeration and some mosaic-like orange and red colored subregions can be found in the western part of the country as well, proving spatial heterogeneity of the reduced socioeconomic welfare in Hungary. Finally, the infrastructural component represents a thought-provoking spatial pattern with regard to the worst-performer districts. Almost every subregion around Budapest, Kecskemét, Szeged, and Debrecen has orange or red colors; however, these regions are some of the most dynamically developing and already developed regions. Their below-average performance highlights the rapid and consequently unsustainable development path observed in these areas.

The overall community resilience score (Figure 2) is based on the average of each indicator; consequently, every single weakness or strength can be balanced, providing useful outputs and regional characteristics of such a specific resilience. Basically, it seems to be clear that western regions and districts performed much better than eastern companions. Not surprisingly, Northern Hungarian districts and the northern part of the Danube–Tisza Interfluve were colored red alongside some districts from Northern and Southern Great Plain NUTS-2 regions. Interestingly, several subregions from Fejér County have below-average performances, although one of the most industrialized and developed Hungarian county seats, Székesfehérvár, is in their neighborhood. In summary, an easily detected west–east axis regarding community resilience in Hungary has been revealed, with some exceptions from Transdanubia; however, the calculated scores show a more homogenous regional pattern than average wellbeing or welfare performances could be across the country.

Table 9 shows the best and worst performing subregions with their overall scores and NUTS-2 regions. From a regional perspective, the abovementioned east–west axis can easily be proven by paying attention to the geographical positions of the below-listed spatial units. The bottom 10 subregions are from the northeastern and middle-eastern parts of the country, all without exception. The lowest value has gone to Ózdi járás, which is one of the most endangered rust zones in Hungary with multiple socioeconomic challenges and continuously deteriorating environmental conditions. This subregion was in the last quintile in three categories (Economic, Infrastructural, and Social); its best value was associated with the Environmental component, ranking 73/175. The list of the top 10 subregions consists of mainly western units from Baranya, Somogy, Zala, and Vas counties; however, in the 9th overall position, we found the Tokaji járás from the Northeastern Hungary NUTS-2 region. The relatively good performance is based on its high position in the economic (16/175) and infrastructural (7/175) dimensions; these values may reflect the fact that this subregion is a well-known wine-producer area with higher added value export products. Surprisingly, the Hegyháti járás achieved the highest overall score among all Hungarian subregions, although it is situated in Baranya county, near one of Hungary's largest university cities, Pécs. This subregion has been ranked in the first quintile in the case of economic, infrastructural, environmental, and community resilience, making the ground for its top overall position. Although this part of the country is underdeveloped, Hegyháti járás revealed the difference between the general well-being score and the hereby elaborated resilience value.

Figure 1

Community resilience components at the subregional level, 2020

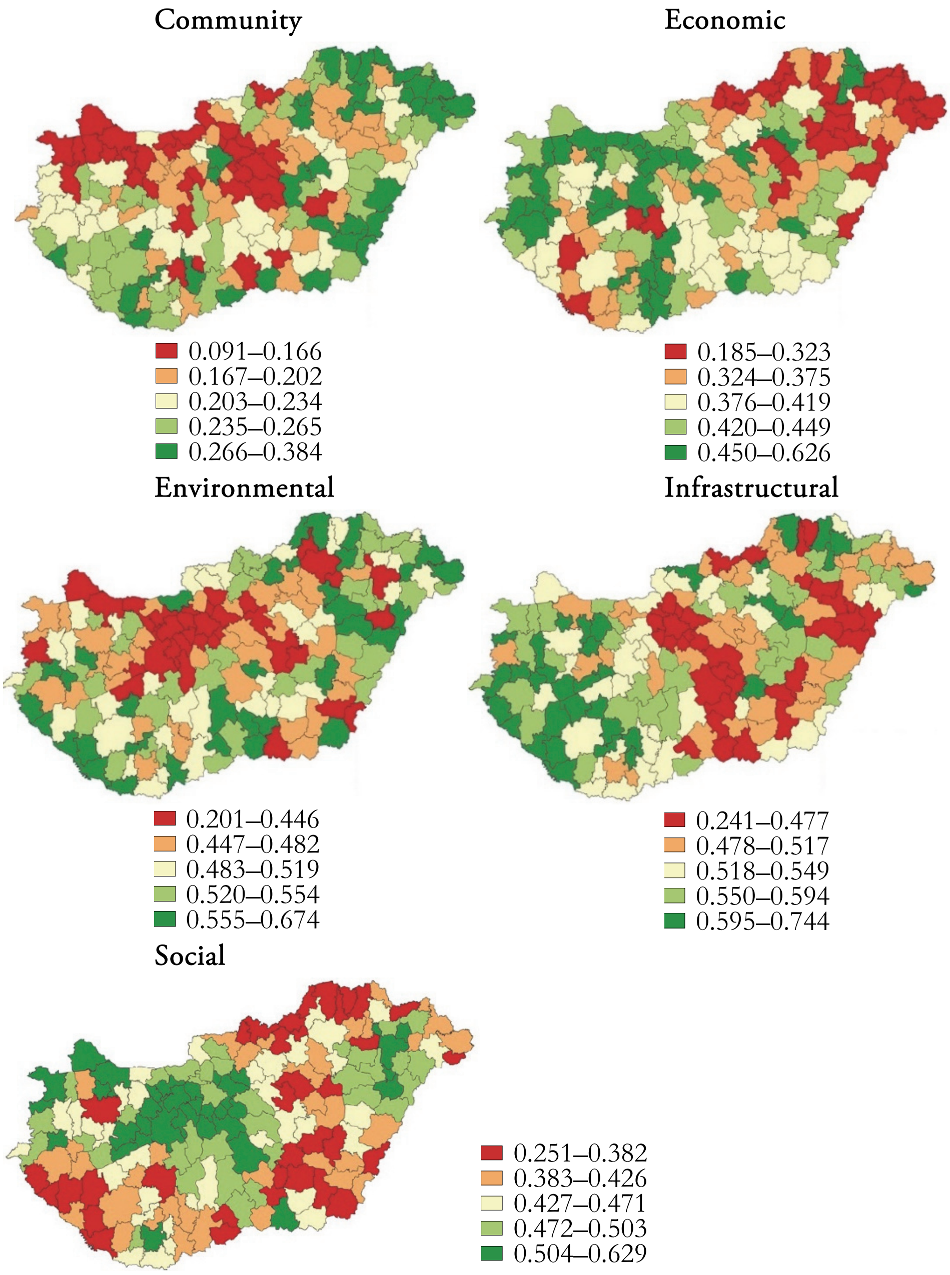

Figure 2

Overall values of the community resilience index, 2020

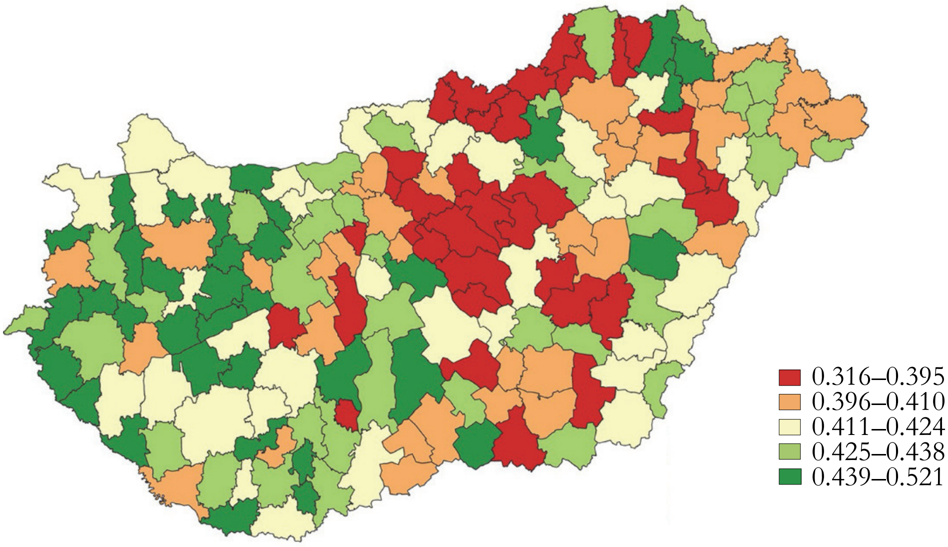

Figure 3

Spatial autocorrelation map, 2020

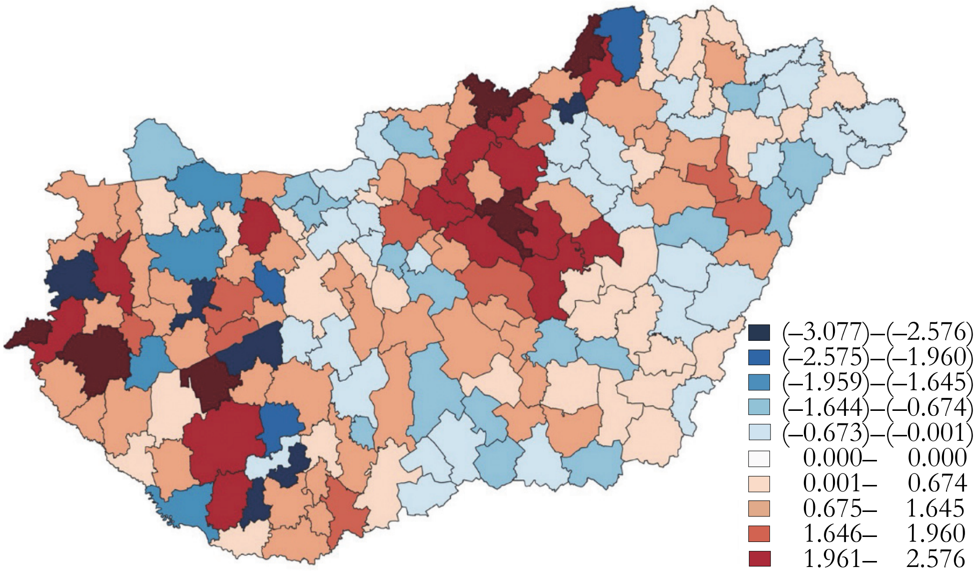

Table 9

Worst and best-performing subregions regarding their overall resilience score, 2020

Bottom 10 subregions		TOP 10 subregions	
Name (official Hungarian)	Overall score	Name (official Hungarian)	Overall score
Ózdi járás	0.316	Hegyháti járás	0.521
Hajdúhadházi járás	0.355	Balatonfüredi járás	0.500
Jászapáti járás	0.357	Pécsváradi járás	0.491
Hevesi járás	0.364	Tabi járás	0.484
Salgótarjáni járás	0.365	Dabasi járás	0.483
Kiskunfélegyházi járás	0.367	Vasvári járás	0.478
Kazincbarcikai járás	0.372	Paksi járás	0.474
Szikszói járás	0.373	Sellyei járás	0.472
Putnoki járás	0.373	Tokaji járás	0.470
Hajdúböszörményi járás	0.374	Lenti járás	0.469

Finally, spatial autocorrelation was calculated by using QGIS 3.22 and applying the nearest neighbors method with three neighboring units, representing Moran's I values in Figure 3. By paying attention to the outputs, mainly the Central-Northern subregions are spatially correlated with each other, defining a regional hotspot with below-average performances. In addition, subregions along the Slovakian border from Eastern Hungary represent another cluster with similar weaknesses regarding community resilience; however, the Edelény subregion breaks this spatial homogeneity with a surprisingly high level of resilience. Two spatial clusters with a high level of autocorrelation can be found in Transdanubia – the first one is from Lake Balaton toward the Croatian border, with average resilience performances in the subregions; the second one can be seen around Zalaegerszeg with above-average resilience scores in the Pre-Alps region.

Conclusion

Based on the BRIC framework, developed by Cutter et al. (2014), and its various applications (Javadpoor et al. 2021, Saravanan–Garren 2021, Scherzer et al. 2019, Singh-Peterson et al. 2014), we created the first community resilience indicator in Hungary. We determined 36 variables across five dimensions (social, economic, community, infrastructure, and environment), from which we calculated the total resilience score to evaluate the Hungarian subregions' community resilience. To the best of the authors' knowledge, the literature does not contain such an analysis; therefore, the first added value of the paper is to fill this scientific gap.

Our findings show that the selected variables are independent of each other, and multicollinearity does not occur between them. By analyzing spatial patterns, it is striking that the dimensions present a rather divergent pattern, meaning that the subregions having relatively high resilience values in the social and economic dimensions have below-average performances in the environmental and community subdomains. This is particularly true for the larger cities of Hungary and their close surroundings. However, the community resilience scores calculated from the dimensions hide these differences and show a much more homogeneous picture. The scores clearly show the better preparedness of subregions in Western Hungary and the worse performances of those in Eastern Hungary, which also applies in the case of the metropolitan agglomeration. More precisely, the top 10 subregions are located in less developed counties instead of well-known developed cities and regions; Vas, Zala, and Somogy counties are overrepresented in the top performer subregions. Regarding the components of our overall index, the environmental and community dimensions, as well as the infrastructural and social aspects, show the same regional patterns. One of the most important new findings of this study is related to the spatial heterogeneity and the differences between subregional-level performances regarding the different resilience categories. In summary, rapid urbanization processes around the largest Hungarian cities contributed significantly to the decrease in community resilience. Finally, spatial autocorrelation was calculated, resulting in four clusters: two clusters composed of subregions having poor resilience performances (one near the Slovakian border, the other in Central-Northern Hungary); one average resilience cluster from Lake Balaton to the Croatian border; and one cluster with a high resilience value around Zalaegerszeg.

The results of the study (see in the internet appendix) can be used to support regional resilience planning across Hungary by revealing the different spatial patterns of traditionally applied well-being dimensions and the hereby elaborated community resilience. Moreover, our index can contribute to defining subcategories within the overall index; therefore, more effective and targeted development strategies can be developed based on the results of our index. Consequently, policymakers can adopt our methodology by developing a county- or even region-scale strategy to better position subregional-scale differences. The overall and dimensional community resilience scores show where more support/intervention is needed. Our method therefore provides guidance for decision-makers to consider more resilience aspects and advocates that the evolution of resilience should be measurable, for which a periodical revision is recommended.

However, we are aware of certain limitations concerning our results. Indices, from their very nature, simplify complex phenomena, but whether a framework is the best possible reflection of reality will always be a source of debate. Moreover, since our focus was on the subregional level, the single values regarding almost every indicator were built by aggregating municipality-level data; consequently, the internal spatial heterogeneity within subregions is hidden in this case. Although a statistical analysis and some international examples support our indicator system, it is not yet proven that this framework is reliable to predestinate how real catastrophes or crises affect the Hungarian subregions. The practical validation of the index is still a matter of future research.

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