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Assessing the Adequacy of Territorial Indicators for Rural Sustainability: A Typological Approach in Romania

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Abstract

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This study examines the adequacy of territorial indicators in assessing rural sustainability at the local level, addressing the limitations of standardised monitoring frameworks in capturing spatial and functional diversity. Recognising the heterogeneity of rural areas, the research adopts a typological approach based on three rural contexts (peri-urban, intermediate, and deep rural). A set of demographic, social, and infrastructural indicators is applied to three case studies in Southern Romania, each representing a distinct spatial configuration. The analysis moves beyond measuring development outcomes by evaluating how effectively indicators reflect context-specific dynamics. The results reveal significant variations in indicator adequacy across rural typologies. While certain indicators perform well in peri-urban areas, their explanatory value decreases in more remote contexts, where structural constraints and informal dynamics are not adequately captured. These findings highlight the need for a context-sensitive, territorially grounded approach to sustainability assessment and contribute to improving indicator-based monitoring frameworks.

Keywords: Sustainability indicators; Indicator adequacy; Rural typologies; Territorial indicators; Place-based approach.

1. Introduction

1.1 Sustainability Indicators in Rural Development Assessment

Sustainability indicators are widely used as operational tools for assessing and monitoring development processes, providing a structured way to translate complex socio-economic, environmental, and territorial dynamics into measurable variables (Gebara et al., 2024). They play a central role in sustainability assessment across multiple spatial scales, including the rural context, thereby supporting evidence-based decision-making. However, their adequacy in capturing context-specific dynamics remains subject to ongoing debate (Nešković et al., 2026).

Over the past decades, sustainability monitoring has been strongly influenced by global frameworks such as the United Nations 2030 Agenda for Sustainable Development, which includes a comprehensive set of indicators designed to track progress towards the Sustainable Development Goals (SDGs). While these indicators provide important benchmarks at national and global levels, their application at finer territorial scales remains challenging, particularly in heterogeneous contexts such as rural areas (Gebara et al., 2024; Liu et al., 2024; Olmedo et al., 2026). Recent research has also shown that standardised indicator frameworks often fail to capture local specificities and may reproduce structural limitations when applied at subnational levels (Peters & Liedloff, 2025).

Previous work highlights the need to localise the SDGs and adopt place-based approaches that better capture territorial diversity and spatial disparities in sustainable development (Barca et al., 2012; Olmedo et al., 2026). This perspective is further reinforced by studies emphasising the importance of site-specific and context-sensitive approaches in rural development, particularly in relation to the limitations of top-down planning models (Boyacıoğlu et al., 2023), which also have implications for how sustainability indicators are selected and interpreted across different territorial contexts.

Existing literature emphasises that sustainability indicators are not neutral measurement instruments, but context-dependent constructs whose performance varies across territorial settings (Nešković et al., 2026). The transferability of indicator sets across spatial scales has therefore been increasingly questioned, as frameworks developed at national and global levels often fail to reflect local realities.

These challenges are especially relevant in rural areas, which are often treated as homogeneous despite their significant internal diversity (Liu et al., 2024; Stanny et al., 2021). Differences in accessibility, functional roles, and socio-economic structures lead to distinct development trajectories across rural areas (Jurjević et al., 2023), a consideration that is particularly relevant when comparing peri-urban, intermediate, and deep rural contexts.

1.2 Research Gap and Study Objective

Despite the widespread use of sustainability indicators in rural development assessment (Hajjaliani et al., 2025), limited attention has been paid to how their performance varies across rural typologies. Most approaches focus on measuring development outcomes rather than evaluating how indicators reflect context-specific dynamics. Previous reviews have highlighted substantial variation in how rural sustainability is conceptualised and operationalised (Nelson et al., 2023). This gap is particularly relevant in territories characterised by strong spatial disparities, where uniform application of indicators may lead to misleading interpretations. Recent research on SDG localisation has highlighted the challenges of applying standardised monitoring frameworks across diverse territorial contexts, suggesting that indicator relevance and interpretation may vary depending on local conditions (Ciambra et al., 2023; Sato, 2025). Moreover, few studies explicitly examine how the adequacy of sustainability indicators varies across different rural typologies or assess their ability to capture distinct patterns of rural development associated with territorial context and functional diversity.

In this context, the concept of indicator adequacy becomes central. Rather than assuming universal applicability, indicator adequacy refers to the extent to which an indicator reflects specific characteristics, processes and development dynamics of a given territorial context. This view is consistent with previous research showing that the relevance and interpretation of sustainability indicators are influenced not only by methodological robustness but also by the assessment framework and local context in which they are applied (Packer & Zanasi, 2023). This perspective extends recent place-based and context-sensitive approaches to territorial development by explicitly linking indicator performance to local territorial conditions (Olmedo et al., 2026).

This paper addresses this gap by applying a typological and indicator-based approach to assess the adequacy of sustainability indicators across different rural contexts. The analysis is based on three rural case studies in Southern Romania, representing peri-urban, intermediate, and deep rural contexts, defined by varying degrees of urban proximity and functional integration. The study aims to evaluate how commonly used indicators capture context-specific development dynamics across different rural typologies and assess their adequacy in reflecting spatial differences. In doing so, it contributes to the development of more territorially grounded monitoring frameworks.

2. Materials and Methods

This study adopts a comparative analytical approach to assess how sustainability indicators perform across different rural contexts. Rather than assuming that a single set of indicators can be applied uniformly, the research is based on the premise that indicator adequacy depends on territorial specificities.

The methodological framework consists of several sequential steps, illustrated in Figure 1: (i) defining the conceptual framework for assessing indicator adequacy; (ii) selecting a set of sustainability indicators based on data availability, comparability, and relevance for the analysis; (iii) identifying case studies representing different rural typologies; (iv) collecting and processing data at the local level; and (v) conducting a comparative analysis to examine variations in indicator performance across contexts.

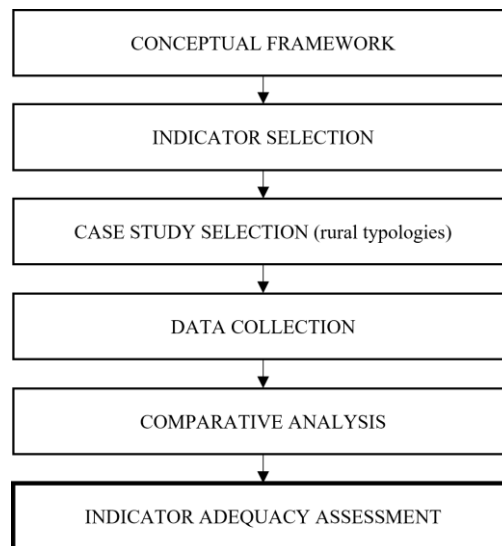


Figure 1. Methodological framework for assessing indicator adequacy across rural typologies (created by the authors).

2.1 Conceptual Framework

The study is grounded in the concept of sustainable development, understood as an integrated process that brings together economic, social, and environmental dimensions. Within this framework, sustainability indicators are approached as analytical tools for capturing and interpreting territorial dynamics.

Indicators are generally understood as quantitative or qualitative tools used to monitor and assess progress toward specific development objectives, supporting evidence-based decision-making. In the context of sustainable development, indicators play a central role in structuring evaluation frameworks and tracking progress towards policy targets. At the same time, recent research emphasises that indicators are not neutral measurement instruments, but performative tools that influence how development processes are interpreted and implemented (Kim, 2023).

Recent studies suggest that standardised indicator frameworks may not fully capture local development processes, particularly in heterogeneous rural contexts. Differences in development trajectories and uneven indicator performance across territories demonstrate that universal assessment may fail to capture context-specific dynamics (Ma et al., 2025). In response, tailored measurement approaches, including composite indicator systems, have been proposed to improve the sensitivity of sustainability assessment to local conditions (López-Penabad et al., 2022).

At the same time, the literature emphasises that indicator systems often rely on simplified socio-economic metrics, while underrepresenting spatial, environmental, and functional dimensions essential for understanding rural development processes (Memo & Pieńkowski, 2023; Olmedo et al., 2026). In parallel, recent work highlights the role of structured, quantitative indicator systems in improving the consistency and comparability of sustainability assessment (Okay et al., 2024). However, their application remains limited in capturing context-specific dynamics, particularly in heterogeneous rural settings. This limitation is particularly relevant in rural areas, where development patterns are shaped by complex interactions between demographic trends, economic structures, and spatial relationships.

Rural areas exhibit significant internal diversity, reflecting variations in accessibility, functional integration, and socio-economic conditions (Jurjević et al., 2023; Stanny et al., 2021). The heterogeneity challenges the use of uniform analytical frameworks and reinforces the need for context-sensitive approaches to sustainability assessment.

A place-based perspective informs the study's analytical framework, emphasising the need to adapt analytical tools to local conditions and spatial relations (Barca et al., 2012). From this perspective, rural areas can be understood as differentiated spaces shaped by their proximity to urban centres and their level of functional integration.

Based on this perspective, the study distinguishes among three types of rural areas: peri-urban, intermediate, and deep rural. This typology is defined by differences in accessibility and functional relationships with urban centres, which generate distinct territorial conditions. This tripartite classification provides the basis for analysing variations in development patterns across rural contexts.

Within this framework, indicator adequacy provides the basis for analysing how indicators perform across different rural typologies and for identifying their limitations in capturing local realities.

As illustrated in Figure 1, the methodological framework links indicator performance to territorial characteristics. This approach moves beyond a statistical assessment and provides a critical evaluation of how indicators align with the structural characteristics of rural areas in Romania.

2.2 Methodological Approach to Indicator Selection

The selection of sustainability indicators followed a contextualised approach, rather than the direct adoption of standardised frameworks such as the global SDG indicator set. This reflects the need to adapt sustainability assessment tools to the specific characteristics of rural territories. Recent studies have shown that countries follow diverse sustainable development trajectories and perform differently across indicators, highlighting the limitations of universal assessment frameworks (Ma et al., 2025).

The selection was structured around key dimensions of sustainable development relevant to rural areas, including demographic dynamics, human capital, economic structure, and living conditions. These dimensions provide a conceptual basis for indicator selection by linking them to core aspects of rural development and ensuring a balanced representation of socio-economic processes. At the same time, the selection of these dimensions reflects the broader challenge of defining consistent sustainability assessment frameworks, as no consensus exists on standardised approaches across territorial contexts (Packer & Zanasi, 2023).

A pool of potential indicators was initially defined based on the availability of statistical data at the level of local administrative units (LAU). From this pool, indicators were selected through a filtering process based on three main criteria: (i) data availability and comparability across all case studies; (ii) relevance for capturing key dimensions of sustainable rural development; and (iii) sensitivity to territorial differences between rural typologies (peri-urban, intermediate, and deep rural).

In addition, the selection process considered the discriminatory capacity of indicators, defined as their ability to exhibit meaningful variation across territorial contexts. Indicators with higher variability across the rural-urban continuum are more suitable for distinguishing between integrated, intermediate, and peripheral rural areas (Perpiña Castillo et al., 2023). Indicator selection represents a well-recognised methodological challenge in sustainability assessment, particularly at local scales where data constraints and contextual variability are significant (Gebara et al., 2024; Karami & Madlener, 2023; López-Penabad et al., 2022). This study conceptualises indicator adequacy as context-dependent, assessing how effectively selected indicators capture diverse rural development patterns.

To facilitate a focused comparative analysis while ensuring consistency across case studies, the number of indicators was deliberately limited. This approach allows for clearer interpretation of results without introducing unnecessary methodological complexity. The final set of indicators and their analytical relevance are summarised in **Table 1**.

Table 1: Selected indicators and their analytical relevance.

Indicator (Unit)	Dimension	Data source	Analytical relevance
Population change (%)	Demographic	NIS, Population and Housing Census (2011, 2021)	Reflects demographic dynamics, long-term population trends; captures the contrast between peri-urban growth and deep rural decline
Ageing index (ratio)	Social	NIS, Population and Housing Census (2021)	Evaluates generational imbalance; critical for evaluating sustainability
Share of population with tertiary education (%)	Social/Human capital	NIS, Population and Housing Census (2021)	Indicates human capital and access to education, reflecting the socio-economic development potential

Indicator (Unit)	Dimension	Data source	Analytical relevance
Housing comfort, derived from Average living space (m ² /person)	Social/Quality of life	NIS, Population and Housing Census (2021)	Reflects living standards and housing quality
Employment rate (%)	Economic	NIS, Population and Housing Census (2021); Tempo database	Reflects labour market participation and economic activity
Share of employment in agriculture (%)	Economic	NIS, Population and Housing Census (2021); Tempo database	Highlights the degree of economic diversification and dependence on primary activities
Access to basic utilities (water, sewage) (%)	Infrastructural	NIS, Population and Housing Census (2021); Tempo database	Indicates the quality of living conditions and the level of infrastructural development
Accessibility to urban centres (min)	Functional/Territorial	Own Spatial Analysis/Google Maps API	Measures spatial connectivity and functional integration with urban systems

2.3 Case Studies Selection: The Romanian Context

The selection of case studies was guided by the objective of evaluating how the adequacy of territorial indicators varies across different rural contexts. The selected settlements were not intended to be statistically representative, but analytically relevant for capturing territorial diversity.

Three rural settlements in Southern Romania were selected to represent distinct spatial typologies: Mogoșoaia, a peri-urban area characterised by strong functional integration with Bucharest; Băleni, an intermediate rural area with mixed development; and Chiojdu, a deep rural area characterised by relative spatial isolation and limited accessibility.

The selection reflects variation in proximity to urban centres and levels of functional connectivity, which are key factors influencing rural development patterns (Perpiña Castillo et al., 2023). Although the case studies are located in different counties, this choice allows the analysis to capture a broader range of territorial conditions, while maintaining a focus on typological differentiation rather than administrative boundaries.

The spatial distribution of the selected case studies and their classification according to rural typology are illustrated in Figure 2. This spatial representation provides the necessary geographical context for the comparative analysis of the indicator adequacy.

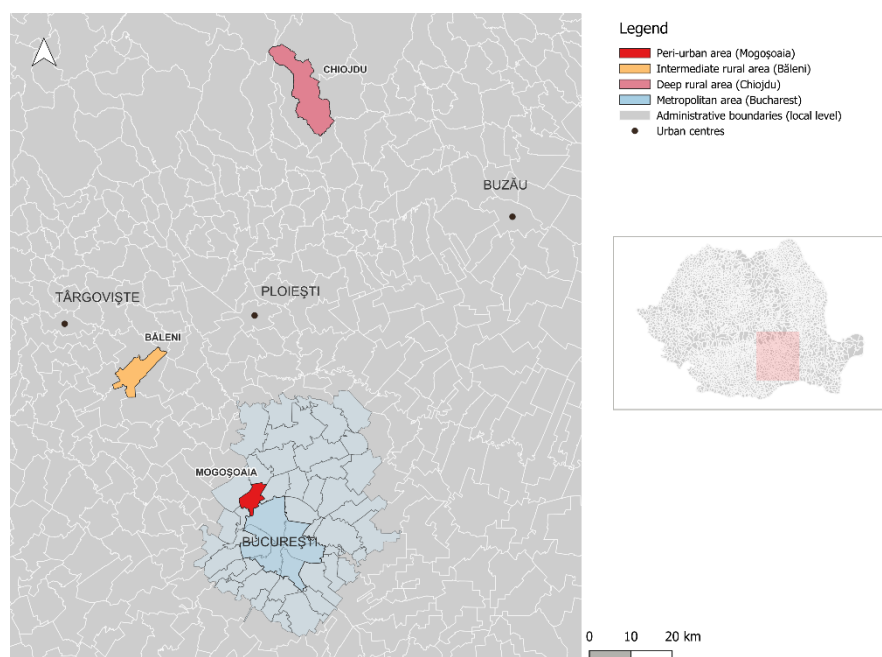


Figure 2. Location of the selected rural case studies in Southern Romania and their typological classification.

2.4 Data Sources and Analytical Approach

The data collected for the three rural typologies defined in Section 2.3 were analysed using descriptive statistics and the spatial comparison technique. The analysis was based on quantitative data obtained from national statistical sources, primarily the Population and Housing Census (2021), complemented by additional data from national statistical databases (INS/TEMPO).

The selected indicators were computed at the level of local administrative units (LAU) for each case study. To enable comparison across indicators measured in different units, all variables were normalised using a min-max transformation, rescaling values to 0-100. Indicators generally interpreted as unfavourable, such as the ageing index and accessibility measured in travel time, were inverted before normalisation so that higher normalised values consistently reflect more favourable outcomes.

The analysis used a comparative approach, focusing on identifying differences in indicator performance across rural typologies. Rather than interpreting indicators in isolation, the study examined their variation in relation to territorial context.

This approach supports the assessment of indicator adequacy, understood as the capacity of indicators to reflect the specific characteristics and development patterns of each rural area.

3. Results

3.1 Comparative Analysis as a Basis for Adequacy Assessment

The comparative analysis of demographic, social and economic indicators across the three study areas highlights clear differences in development patterns.

The comparative patterns identified in **Table 2** are further illustrated through a visual representation of normalised indicator values (Figure 3). The radar chart highlights the distinct development profiles associated with each rural typology.

Table 2: Comparative indicators across differentiated rural typologies.

Indicator	Peri-urban (Mogoșoaia)	Intermediate (Băleni)	Deep Rural (Chiojdu)
Population Growth (%) *	22.35	-8.2	-18.95
Ageing Index (Ratio)	70.56	81.73	175.00
Higher education (%)	31.82	5.72	5.69
Average living space (m ² /person)	34.89	20.63	27.51
Employment rate (%)	74.42	54.53	46.41
Agriculture share (%)	1.11	59.19	38.53
Access to water/sewage (%)	94.2	68.5	32.4
Effective Accessibility (min)	45**	35	85

(*) Population growth (%) represents the percentage change in population between 2011 and 2021.

(**) Effective Accessibility is measured in minutes to the nearest urban centre. The value for Mogoșoaia (45min) specifically accounts for real-time traffic congestion during peak hours to reflect commuting patterns, rather than theoretical proximity to the urban core.

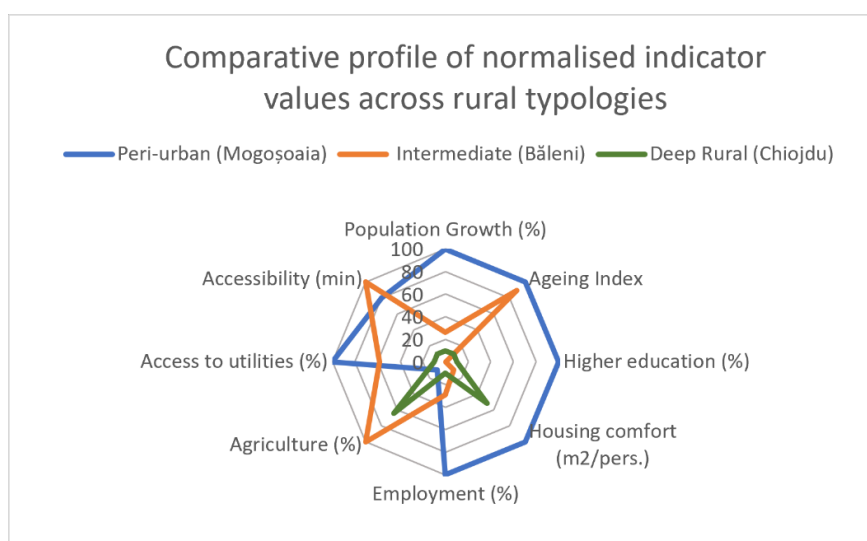


Figure 3. Comparative profile of normalised indicator values across rural typologies.

While these differences may suggest varying levels of development, they do not necessarily reflect the actual complexity of local conditions. The same indicator may capture different underlying processes across territorial contexts, limiting its interpretative value.

3.2 Demographic and social indicators

The analysis of demographic and social indicators highlighted differences in their capacity to reflect development patterns across selected rural typologies. In the peri-urban commune of Mogoșoaia, demographic indicators effectively capture local development dynamics. The significant population growth (22.35%) and high share of individuals with tertiary education (31.82%, referred to as “higher education” in **Table 2**) reflect strong functional integration with Bucharest metropolitan area. In this context, indicators related to population change and educational attainment exhibited high adequacy, accurately reflecting ongoing socio-economic development and urban-to-rural migration.

In contrast, the deep rural commune of Chiojdu presented a markedly different profile, characterised by population decline (-18.95%) and a high Ageing Index (175.00). In this case, the Ageing Index proves a relevant indicator, capturing structural demographic imbalances. However, the higher education indicator (5.69%) shows limited adequacy for assessing current local potential, as it reflects out-migration of educated individuals rather than locally retained human capital. This pattern is consistent with broader rural trends, where population decline and migration to urban areas

contribute to the loss of local human resources (Memo & Pieńkowski, 2023; Wang et al., 2025). In this sense, this statistical value may be better interpreted as a sign of rural depopulation than a failure of the local educational system. Băleni, representing an intermediate rural context, displayed a mixed demographic profile, with a moderate Ageing Index (81.73) and low levels of higher education (5.72%). While some indicators suggest relative stability compared with deep rural areas, the low share of tertiary education suggests emerging constraints in terms of long-term development capacity. In this context, the adequacy of demographic indicators remains partial, requiring careful interpretation in relation to local socio-economic conditions, including agricultural traditions and limited access to regional educational hubs. Overall, the results indicate that demographic and social indicators do not perform uniformly across rural typologies. While they are highly effective in peri-urban areas, their adequacy decreases in remote settlements, where demographic imbalances and reduced human capital influence the observed values.

3.3 Economic specialisation and functional isolation

The analysis of economic indicators further highlights the differentiated performance of sustainability indicators across rural contexts, particularly in relation to local economic structures. In the peri-urban commune of Mogoşoaia, the employment rate (74.42%) was a strong indicator of labour market integration and a diversified economic base. Proximity to Bucharest facilitates access to non-agricultural employment, making this indicator particularly adequate for capturing local development dynamics. In contrast, the share of employment in agriculture (1.11%) had low explanatory value in this context, as it did not reflect the dominant metropolitan economic activities.

In the case of Chiojdu, the deep rural context revealed important limitations in the use of standard monitoring. While the share of employment in agriculture (38.53%) remained highly relevant for capturing dependence on primary activities, the low employment rate (46.41%) exhibited limited adequacy as a measure of local economic potential. This was partially due to the presence of informal or subsistence-based economic activities (e.g., subsistence agriculture and small-scale forestry), which are not fully captured by official statistics, leading to an underestimation of actual economic engagement. Similarly, in Băleni, the high share of employment in agriculture (59.19%) reflected a specialised, yet vulnerable economic structure. Although this indicator accurately captured the dominant economic profile, it provided limited insights into diversification potential and long-term sustainable development capacity. In this case, economic indicators were only partially adequate, as they do not fully reflect the ongoing transition from traditional agricultural activities to more diversified economic structures.

3.4 Living Conditions and Infrastructure

The analysis of indicators related to living conditions and infrastructure provided additional insights into the differentiated performance of sustainability indicators across rural contexts, particularly regarding access to basic services and territorial connectivity.

In the peri-urban commune of Mogoşoaia, access to basic utilities (94.2%) indicated a high level of infrastructural development. However, the Effective Accessibility (45 min) showed limited adequacy. Although it reflected travel time to the urban centre, it did not fully capture the variability in daily mobility conditions associated with metropolitan dynamics (peak-hour congestion and infrastructure pressure from metropolitan expansion).

In the case of Chiojdu, the deep rural context highlighted the limited adequacy of standard indicators for both infrastructure and connectivity. While the Effective Accessibility (85 minutes to the county capital Buzău) and the low level of access to utilities (32.4%) indicated reduced accessibility and limited infrastructure provision, these metrics provided only a partial view, as they did not fully reflect the constraints on transport options, service accessibility, and quality in sparsely populated areas.

Băleni presented an intermediate situation, in which indicators for utilities and housing conditions indicated moderate adequacy. While the Effective Accessibility (35 min) and the utility coverage suggest gradual improvements, they remained limited in their explanatory capacity. These indicators captured the presence of basic infrastructure but did not fully reflect the structural limitations affecting local connectivity and public transport service provision.

3.5 Assessment of Indicator Adequacy

The differences observed across the three rural typologies provided an empirical basis for assessing the adequacy of the selected indicators, as summarised in **Table 3**. The analysis highlights that standard monitoring indicators vary significantly in their adequacy depending on the territorial context.

Table 3: Critical evaluation of sustainable development indicators across different rural functional typologies.

Indicator	Peri-urban (Mogoşoaia)	Intermediate (Băleni)	Deep Rural (Chiojdu)	Interpretation
Population Growth	+	±	-	High adequacy in peri-urban areas; limited adequacy in intermediate and deep rural contexts, where official data may not fully reflect migration dynamics.
Ageing Index	+	+	+	High adequacy across all typologies; accurately reflects the demographic structure and ageing patterns.
Higher Education	+	±	-	High adequacy in peri-urban; limited adequacy in deep rural areas, as it reflects out-migration of educated individuals rather than locally retained human capital.
Housing Comfort	+	±	-	High adequacy in peri-urban areas; limited adequacy in intermediate and deep rural contexts, where higher values

Indicator	Peri-urban (Mogoşoia)	Intermediate (Băleni)	Deep Rural (Chiojdu)	Interpretation
				may not reflect actual living conditions or access to basic services.
Employment	±	±	-	Limited adequacy outside peri-urban areas; does not fully capture informal or subsistence-based economic activities, leading to underestimation of actual economic engagement.
Agriculture	-	+	±	Highly adequate in intermediate areas; low adequacy in peri-urban contexts; partially adequate in deep rural areas, as it fails to distinguish between subsistence and market-oriented activities.
Utilities Access	+	±	-	High adequacy in peri-urban areas; limited adequacy in deep rural contexts, where the presence of infrastructure does not fully reflect service quality or effective access.
Accessibility	-	±	-	Limited adequacy across all typologies; it reflects general connectivity, but does not capture variability in mobility conditions or transport availability.

Legend:

(+) Adequate: the indicator accurately reflects the territorial conditions.

(±) Partially adequate: the indicator captures general trends, but misses important local nuances (e.g., quality of service, traffic, or informal labour).

(-) Limited adequacy: the indicator is misleading or irrelevant as it fails to account for the specific socio-economic characteristics of the area.

4. Discussion

4.1 Interpretation of Findings

The results demonstrate that the performance of sustainability indicators is strongly conditioned by territorial context. Rather than functioning as neutral measurement tools, indicators exhibit varying levels of adequacy depending on spatial characteristics, accessibility, and functional integration, as emphasised in place-based approaches to territorial development (Barca et al., 2012; Olmedo et al., 2026).

In peri-urban areas, most indicators show high adequacy, as they effectively capture dynamic socio-economic processes driven by proximity to urban centres. Indicators such as population growth, employment, and access to services accurately reflect development patterns in these contexts, where formal economic structures and infrastructural integration are well established.

In contrast, deep rural areas reveal significant limitations in the performance of several commonly used indicators. While demographic indicators such as the Ageing Index remain robust, other indicators, particularly those related to education and employment, show reduced adequacy. This is largely due to processes associated with the out-migration of younger and more educated populations, often described in the literature as “brain drain”, which leads to the erosion of local human capital and weakens the relevance of education-based indicators for assessing local development potential (Wang et al., 2025).

Similarly, economic indicators in deep rural areas tend to underestimate actual economic activity. The employment rate, for instance, does not fully capture informal or subsistence-based activities that play a significant role in local livelihoods. Such patterns reflect a structural disconnect between local economic practices and formal labour market statistics, limiting the interpretative value of standard indicators. These findings are consistent with a broader interpretation of peripheral regions as “territorial disconnects” where limited integration into high-value economic circuits affects both development trajectories and the performance of conventional indicators (Rodríguez-Pose & Bartalucci, 2024).

Intermediate rural areas exhibit mixed patterns, with indicators providing only partial insights into development processes. In these contexts, the coexistence of agricultural activities and emerging non-agricultural functions suggests a transitional stage, in which standard indicators capture general trends but fail to reflect underlying structural transformation. This situation may be associated with conditions described in the literature as a “development trap”, where limited diversification and structural constraints hinder long-term progress (Diemer et al., 2022).

Overall, the findings confirm that the interpretative value of sustainability indicators is not intrinsic but shaped by territorial specificity. Indicators that perform well in peri-urban areas tend to lose explanatory power in more remote and structurally constrained contexts, highlighting the need for a more context-sensitive approach to rural sustainability assessment.

4.2 Limitations of Indicators-Based Assessment and Data Constraints

The findings of this study are consistent with a growing body of literature highlighting the limitations of standardised sustainability indicator frameworks in capturing local development dynamics. Previous research has shown that such frameworks often lack sensitivity to territorial diversity, particularly in rural areas characterised by structural constraints, informal economic practices, and data limitations (Ciambra et al., 2023; Olmedo et al., 2026; Peters & Liedloff, 2025).

While the findings are based on a limited number of case studies and are not intended for statistical generalisation, they provide analytical insights into how indicator adequacy varies across rural typologies. The case-based approach allows for a detailed examination of territorial differences, offering a context-sensitive understanding of indicator adequacy.

A second limitation concerns data availability and comparability at the local administrative unit (LAU) level. Many sustainability indicators are not consistently available at fine spatial scales, limiting their applicability in analyses aimed

at capturing intra-rural diversity. This limitation affects the ability to conduct consistent comparisons across heterogeneous rural territories.

An additional limitation concerns the exclusion of environmental indicators from empirical analysis. Although environmental dimensions represent a core component of sustainable development, their integration at the local level remains constrained by data availability and spatial coverage. Many environmental indicators, such as air quality or pollution-related metrics, are collected through monitoring systems that are unevenly distributed and often absent in rural areas. As a result, these indicators cannot be consistently applied across local administrative units (LAU), limiting their suitability for comparative analyses. This reflects a broader challenge identified in the literature, namely, the difficulty of operationalising environmental sustainability at fine territorial scales due to data fragmentation and measurement inconsistencies (Memo & Pieńkowski, 2023).

Finally, methodological aspects also influence the interpretation of results. The normalisation process, while necessary for enabling comparison across indicators, introduces an additional layer of interpretation that may affect the overall assessment of indicator adequacy. This limitation reflects a broader methodological concern identified by Qi et al. (2024), namely that aggregate sustainability assessments may conceal important variations among individual indicators and dimensions of sustainable development.

Overall, these limitations support the argument that sustainability monitoring in rural areas requires more flexible, context-sensitive approaches that reflect territorial diversity and local development dynamics.

4.3 Contribution to Indicator-Based Rural Assessment

The study contributes to existing research by operationalising the concept of indicator adequacy in the assessment of rural sustainability across rural typologies. Rather than assessing indicators solely in terms of availability or standardisation, the analysis demonstrates the importance of considering their capacity to reflect territory-specific conditions.

By linking indicator adequacy to rural typologies, this study provides a structural framework for interpreting how the same indicator may have different meanings across spatial contexts. This perspective enables a more nuanced understanding of indicator behaviour and supports the development of more flexible, territorially grounded assessment frameworks.

In this sense, the findings suggest that sustainability monitoring should incorporate not only standard metrics, but also context-based evaluation criteria capable of capturing the diversity of rural development patterns.

5. Conclusions

The study examined how territorial indicators perform across different rural contexts using a typological approach. The results highlight significant differences in indicator adequacy between peri-urban, intermediate, and deep rural areas, reflecting distinct territorial conditions. These findings confirm that commonly used indicators cannot be interpreted independently of spatial context, as their capacity to capture development dynamics varies across different rural typologies.

The results demonstrate that indicator adequacy represents an important dimension of rural sustainability assessment. Linking indicators to territorial typologies provides a more fine-tuned understanding of development processes and improves the interpretation of standard monitoring frameworks.

The study also emphasises the limitations of applying uniform indicator sets in heterogeneous rural contexts. Without accounting for territorial diversity, such approaches may yield partial or misleading assessments, particularly at the local level.

Future research should focus on improving the availability and comparability of local-level data, including environmental indicators, to support more comprehensive sustainability assessments. Expanding the empirical scope and refining the methodological approach would further support the development of more adaptable and context-responsive monitoring frameworks.

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Conflicts of Interest

The author(s) report no conflicts of interest.

Data Availability Statement

The data used in this study are publicly available from official statistical sources. Processed data supporting the findings of this study are available from the corresponding author upon reasonable request.

Institutional Review Board Statement

This study did not involve human participants or animals and therefore did not require ethical approval.

CRedit Author Statement

Conceptualisation, Methodology, Formal analysis, Writing – original draft: Simona-Rodica Șoldan. Supervision, Writing – review & editing: Alexandru-Ionuț Petrișor. All authors have read and approved the final manuscript.

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