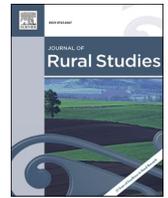




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# Revitalizing rural areas: A review of vivacity indicators and the potential of generative AI in rural development analysis

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## ABSTRACT

Over the past several decades, rural areas in Spain and the European Union have experienced progressive population decline that has fostered negative discourse and generated a loss of interest among the population, exacerbating these issues. Therefore, it is essential to promote a new and optimistic narrative that highlights the potential of rural areas and its present and future development possibilities to provide a positive image of rural territories. This concept, which we have termed 'vivacity', reflects the level of opportunities for inhabitants to achieve a sustainable future that encourages their settlement in rural areas and the development of their lives without location-related difficulties. This study aims to identify the most suitable rural development indicators for measuring the vivacity of rural territories. Therefore, a qualitative analysis of the literature on rural development indicators was conducted, and the potential of a generative artificial intelligence tool (ChatGPT 4) is examined to assist researchers in conducting such analysis. The study's findings indicate that economic and social wellbeing indicators are relevant to the dynamism or vivacity of rural territories. Furthermore, ChatGPT currently does not meet the standards of human analysts although it can facilitate directed analysis with close scrutiny of the results.

## 1. Introduction

In the predominantly rural regions of the European Union, population loss combined with aging is a serious issue that has recently become increasingly prominent. Some of these areas are experiencing significant annual population declines, often starting from already low population density figures (Collantes, 2019). This loss is primarily concentrated in younger demographics, resulting in an aging rural population (Burillo Cuadrado et al., 2019).

The remoteness of major population centers, the lack of employment opportunities, and residual economic activity (Abreu, 2014; Alamá-Sabater et al., 2021; Herráiz Hernansanz and Serrano Gil, 2013), along with issues related to the provision of essential public services (Escalona and Díez, 2005), infrastructure endowment (Herranz Loncán, 2002), land management (Fernández García et al., 2007), and the mobility and accessibility of individuals (Delgado and Martínez, 2016), have imposed significant restrictions on rural development.

These data have fostered discourse around rural areas with negative connotations. Numerous studies have focused on the vulnerability of rural territories, linking the current state of rurality with these negative

aspects, thereby creating a feedback loop that discourages public interest in these areas and serves to exacerbate existing problems (Sánchez-Zamora and Gallardo-Cobos, 2019). Therefore, without neglecting the identification of problems faced by rural areas, it is critical that a new and optimistic discourse be promoted that emphasises rural potential and the possibilities for present and future development. To this end this study introduces the term 'vivacity', defined as the level of opportunity that enables rural inhabitants to have a sustainable future that supports their settlement and the development of their lives without difficulties arising from their location. This approach aims to provide a positive image of rural territories as places of opportunity for stakeholders, thereby raising general awareness on the need to enhance their development (Tambovceva and Tereshina, 2021).

Various studies have focused on analysing the potential of rural territories and evaluating aspects of rural development or quality of life considering different types of indicators, applications, and objectives (Abreu et al., 2022; Comíns and Moreno, 2013; Cvijanovic et al., 2020). Rural development could be defined as the set of initiatives aimed at promoting the modernization of rural areas, the creation of new employment opportunities, the sustainability and efficiency of farms

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and the preservation of ecosystems (Paz Ballivián, 2011; Abreu and Mesías, 2020). Quality of life implies a broader concept than economic output and standard of living. It includes all factors influencing what is valued in life, beyond its material aspect (European Union, 2017). Considering these definitions, the term 'vivacity' of rural territories establishes a connection between quality of life and rural development. This is because it addresses the comprehensive reality of rural areas, encompassing factors that impact both quality of life (such as social well-being and access to services) and rural development (such as economic opportunities and sustainability).

By highlighting opportunities for a sustainable future and reducing challenges associated with rural locations, vivacity reflects the objectives of rural development (modernization, employment, sustainability) while also promoting the well-being of inhabitants—a key component of quality of life. It seeks to encourage individuals to remain rooted in rural territories, balancing economic development with the improvement of living conditions, thereby linking these two concepts.

In summary, it integrates both the material and non-material aspects of quality of life with the structural and economic goals of rural development, providing a more holistic understanding of what it means to live and thrive in rural areas.

Our study sought to provide a more systematic means of measuring rural opportunity and constituting 'vivacity' in the rural context.

To achieve this goal, we conducted a detailed qualitative analysis of the literature on rural development. Traditionally, conducting such qualitative analysis uses programs that require reading and coding by researchers, a task that is time-consuming and error prone (Siiman et al., 2023). However, new technologies offer new possible pathways. Artificial intelligence (AI) technology has recently emerged and established itself across most areas of society as a benchmark for technological progress, reflected in the growing number of publications in this field (Perrault et al., 2019). AI, which involves the ability of algorithms to replicate how a human thinks and acts (Aghion et al., 2017), can be particularly useful in fields of application such as health, technology, economics, and education, among others (Chen et al., 2020; Ferreira et al., 2021; Yu et al., 2018). In this sense, AI presents offers data processing solutions, including for textual analysis, and is applicable to qualitative research methodologies in the collection and management of large volumes of information and data (Lennon et al., 2022).

The general objective of this study was to conduct a systematic review of rural development indicators that are suitable for evaluating the vivacity of rural territories and classifying them. The specific objectives are as follows: (1) to perform a qualitative literature analysis on indicators that allow for the evaluation of the vivacity of rural territories, (2) to establish dimensions or groupings of the indicators identified in the literature analysis, and (3) to assess the potential of AI to assist researchers in the described qualitative analysis. This study aimed to address the following research questions: What indicators have been used to evaluate aspects related to rural development in rural territories? Which of these rural development indicators are related to rural vivacity? How can these indicators be grouped into dimensions and subcategories for better systematisation of the information? Is the classification performed by AI consistent with that conducted by researchers?

## 2. Background on measuring rural development levels

Rural development has been studied extensively and can be defined as a set of initiatives aimed at promoting the modernization of rural areas: generating new employment opportunities, sustainability, improving the efficiency of agricultural enterprises, and preserving or conserving ecosystems (Abreu and Mesías, 2020). To measure rural development, various indices have been created over time, such as the Human Development Index (HDI) (UNDP, 2009), the Social Development Framework (Davis, 2004), and the Multidimensional Poverty Index (Poverty, 2017). Considering that rural development is a

multidimensional concept, these indices utilise indicators related to economic, demographic, social, environmental, and governance, all of which are highly relevant to this concept. The selection of specific indicators grouped into categories enables policymakers to adapt and develop new policies and assess existing ones, which is necessary in highly variable environments (Abreu and Mesías, 2020).

Economic indicators are fundamentally related to the agricultural sector, which remains critical in rural areas (Comíns and Moreno, 2013). Some refer to the income of rural residents, considering whether their sources are agricultural or otherwise (Morozova et al., 2023). Employment is also an important economic factor in rural areas, which are often characterised by low wealth and a weak economic context (Rees et al., 2012; Van Herwijnen et al., 2018). Social welfare indicators allow for assessing the level of development of the healthcare system, the condition of institutions, and available medical services for rural residents, as well as the number of medical workers providing these services. Education level is also important for evaluating social welfare and is often measured in terms of the basic knowledge and literacy of individuals living in rural areas, along with their access to basic services (Nieto Masot et al., 2020; Morozova et al., 2023). Sociodemographic indicators, such as population density, help differentiate between systems with low and high population concentrations. Other commonly used sociodemographic indicators include the ageing index, which measures one of the main disadvantages associated with rural areas, as along with birth and mortality rates (Nieto Masot et al., 2020; Masot and Alonso, 2015). Environmental indicators are closely linked to agriculture and are relevant to water usage, agricultural pollution, and the preservation of natural areas (Zalidis et al., 2004). Finally, governance indicators are related to the level of stability and general trends in state/regional policy as well as legal changes (Harbiankova and Gertsberg, 2022). They also measure citizens' trust in institutions and their civic and political participation, cooperation, and social cohesion, which enable greater efficiency in public policies (Charron et al., 2014).

## 3. AI as an analytical tool

Qualitative data analysis has long enabled researchers to organise large volumes of textual and audio-visual data, annotating, coding, identifying particular words, phrases, or codes, and visualising relationships within the data (Twining et al., 2017). However, the coding and application processes, as well as interpreting the results, remain laborious tasks performed by researchers and often require significant time investment. These issues have prompted considerable progress in the utilisation of various AI tools, particularly in natural language processing and machine learning, to automate certain tasks within the process or at least significantly reduce the time dedicated to them.

Following the implementation of various AI tools, OpenAI publicly launched the latest version of its ChatGPT large language model, GPT-4, in March 2023, an AI language model capable of generating human-like responses. Prompts are natural language instructions that users provide to the AI model to generate a response. Currently, prompts in ChatGPT are made through text inputs, such as questions, statements, or phrases, commonly referred to as 'prompts'. When ChatGPT receives these prompts, it processes the text and generates responses that continue the conversation (Rivas and Zhao, 2023).

Various studies have been conducted on the use of AI technologies to automate aspects of qualitative data analysis, showing promising results regarding the application of this technology. These studies require the use of data collected from the investigated activity to train the AI model and even data similar to those provided in the research. The training also requires manual coding of at least one subset of the data by human analysts (De Araujo et al., 2023). In a large study utilising ChatGPT that included 25 tasks and a significant number of prompts, it was observed that the tool performed reasonably well in conducting quantitative analyses but exhibited inferior performance in tasks requiring certain reasoning abilities (Kocón et al., 2023).

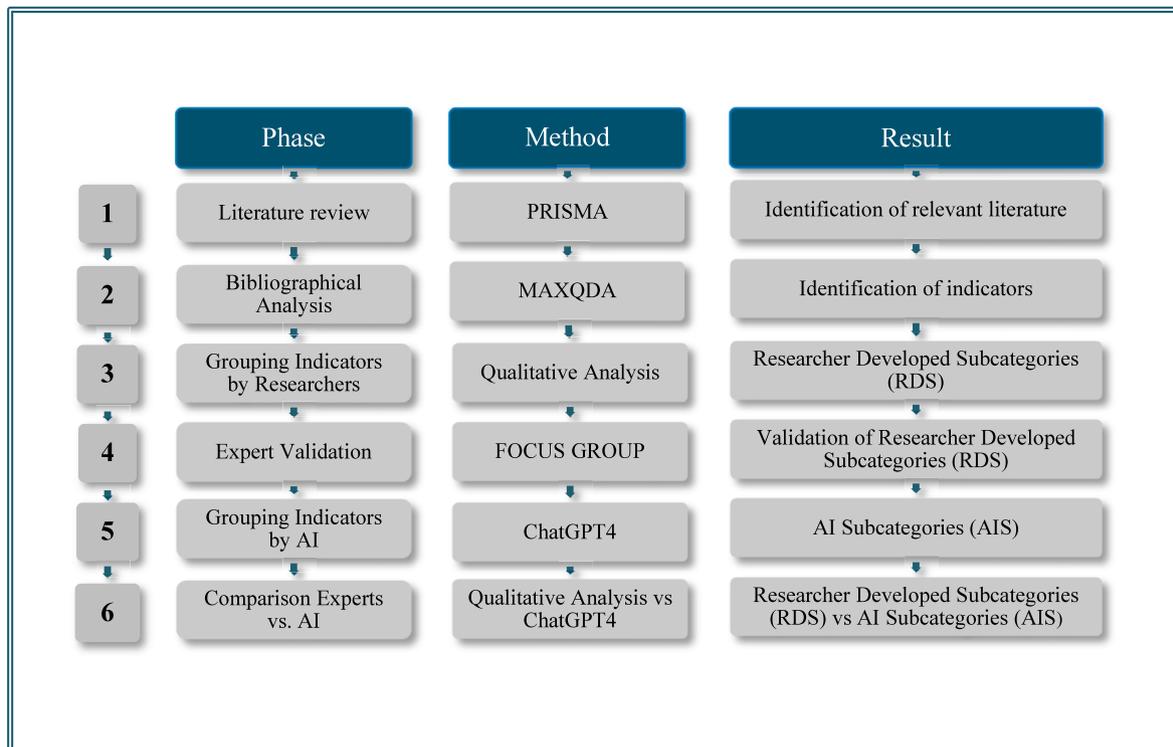


Fig. 1. Road map followed in the article.

In addition to being useful in coding and interpreting results, these tools can offer a more robust and objective analysis than researchers, eliminating personal biases or subjectivity (Condor et al., 2022; Rose and Johnson, 2020).

#### 4. Methodology

The methodology employed in this study is developed through several stages, including an extensive literature review and expert validation at various phases of the process. A diagram of the total procedure followed in this article is shown in Fig. 1.

##### 4.1. Literature review

First, a systematic review of the literature on rural development was conducted to identify the most commonly used and relevant indicators for assessing rural vivacity. The review was conducted using the PRISMA method (Fig. 1) and targeted articles published in English between 2013 and 2023. An exhaustive bibliographic search was performed of two primary research databases (Scopus and Web of Science) in July 2023 using the following search: “rural areas” AND “rural development” AND index OR indicators OR “quality of life” in the title, abstract, and keywords. The search was limited to regions within European countries. A total of 379 articles were identified across both databases, and other relevant studies were obtained from additional sources. Subsequently, duplicates were removed and articles deemed irrelevant to the research objectives based on a review of the abstracts were excluded, resulting in 92 articles. After a complete reading of each of these articles, 64 studies were finally included and considered relevant.

##### 4.2. Bibliographic analysis

A bibliographic analysis was conducted using the qualitative analysis software MAXQDA 22. This is a software for the analysis of qualitative and mixed methods data that allows for the analysis of all types of data, such as interviews, focus groups, round tables, articles, media, surveys,

among other sources of information (Marjaei et al., 2019). On the other hand, it allows the interpretation of qualitative data through various coding functions. Therefore, this software has been selected for its ability to facilitate the qualitative analysis of the literature and the selection of indicators.

First, the available abstracts were read and the full texts were reviewed where the abstracts were not available. A preliminary screening was then performed, focusing on studies that utilised related indicators for themes pertinent to opportunity or vivacity in rural areas. Once selected, the complete articles were read and coded. To analyse the information, a series of primary codes were defined (objectives, themes, indicator types, data collection, and analysis methodology), along with secondary codes for each primary code, which facilitated the processing of the reviewed literature.

Subsequently, various bibliometric analyses were performed to examine the localisation of the reviewed works, the keyword analysis, the information source types (primary or secondary) and the types of indicators found.

In this phase, we selected from the rural development indicators identified in the literature, those most capable of reflecting the level of opportunity in rural areas, thereby contributing to the definition of the term ‘vivacity’.

##### 4.3. Grouping indicators into subcategories or variables

###### 4.3.1. Classification by researchers

In the bibliographic analysis, the indicators were classified into different types or categories: economic, social well-being, sociodemographic, environmental, and governance.

This classification was discussed and agreed upon by 17 experts (scientists and researchers) in rural development from nine Spanish universities during two group sessions, these experts are agricultural economists with extensive experience in the field who work in rural development. Subsequently, more specific subcategories or variables were defined for each type of indicator, involving a screening process to eliminate repetitions or indicators whose meanings were not clearly

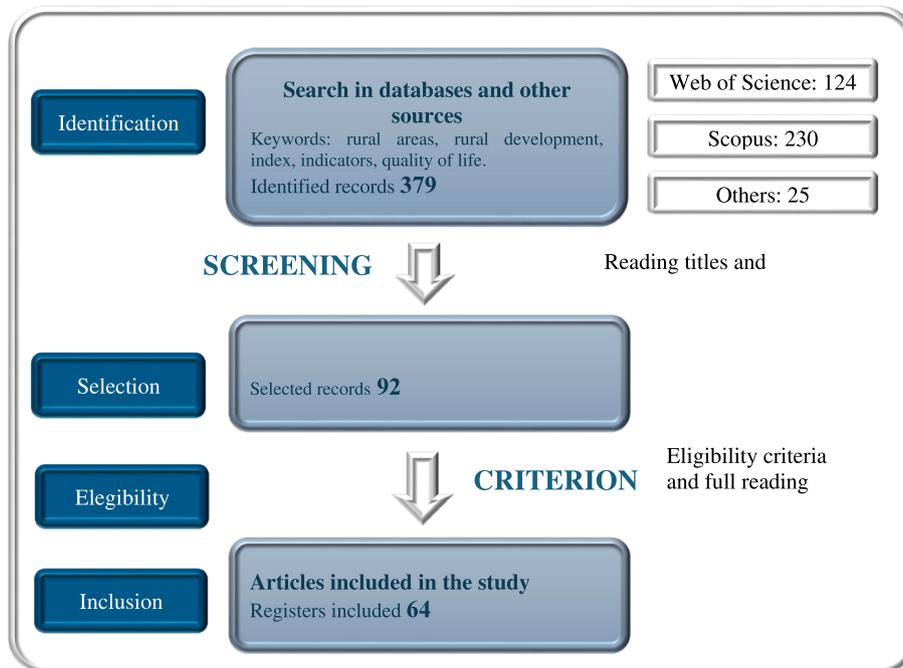


Fig. 2. Flowchart of the search and selection process (PRISMA). Source: Own elaboration

defined.

#### 4.3.2. AI classification

To use AI for classification, prompts were entered in a single chat session using ChatGPT 4. This tool was chosen because it is free and universally accessible, as well as for its substantial capacity to perform a wide range of tasks, including translation, answering questions, summarisation, plan generation, and conversational interaction (Hamilton et al., 2023). The initial prompt used was: 'Classify the following indicators into categories: LIST OF INDICATORS'. In response to this first prompt, many indicators remained unclassified, prompting a second prompt: 'Classify the indicators again without leaving any out and without repeating indicators across different categories. The indicators are as follows: LIST OF INDICATORS'. The responses to this prompt did not always align with the request, leaving some indicators unclassified or grouped too broadly.

Subsequently, more specific prompts were used, and ChatGPT was asked to make more appropriate classifications. However, the results did not improve, in some cases worsening for all tested indicators. Furthermore, when the classification was made to include all indicators,

ChatGPT created categories that were too small, sometimes with only a single indicator per category, while leaving some unclassified, which was inconsistent with the request. It then became very difficult to revert to the previous setting, even when initiating a new conversation, leading to a "learning" effect on the part of ChatGPT, both in the input profile and in the generated conversation, which complicated the continuation of the analysis. This may be because the data provided by the AI tool were biased by previous conversations, rendering it incapable of generating original data beyond its training data. Therefore, it was decided to include only two prompts.

The responses generated after the two prompts were evaluated by the researchers, comparing the degree of similarity between the subcategories or variables established by the researchers and those generated by AI.

The results obtained from the qualitative analysis of the literature as well as the classification of indicators into subcategories performed by the researchers and those conducted by AI are described in the Results below.



Fig. 3. Geographical location of the reviewed papers. Source: Own elaboration

**Table 1**  
Sources of information used in the works reviewed.

Sources of information	N° Works
<b>Secondaries</b>	53
Scientific literature	15
Databases (INE,Census ...)	28
Not detailed	10
<b>Primaries</b>	20
Interviews and ethnographic studies	5
Expert consultation and Delphi analysis	6
Surveys	6
Focus groups	3

Source: Own elaboration

**Table 2**  
Types of indicators used in literature.<sup>a</sup>

Type of indicator	N° Works
<b>Economic</b>	55
<b>Social welfare</b>	45
<b>Sociodemographics</b>	38
<b>Environmental</b>	27
<b>Governance</b>	11
<b>Other</b>	22

<sup>a</sup> There may be more than one type of indicator per item analysed; Source: Own elaboration.

## 5. Results

### 5.1. Bibliographic analysis

#### 5.1.1. Localisation of the studies

Regarding the localisation of the analysed works, the country with the highest predominance was Spain, accounting for approximately 28 % of the references, followed by Romania (13 %). Most studies on this topic were conducted in Russia, Italy (with 11 % each), Portugal (9 %), and Serbia (7.5 %). The remaining countries included the Czech Republic, Poland, England, Bulgaria, Austria, Ukraine, Turkey, and Scotland, each representing a very small percentage, all representing below 2 %. These locales are presented in Fig. 2.

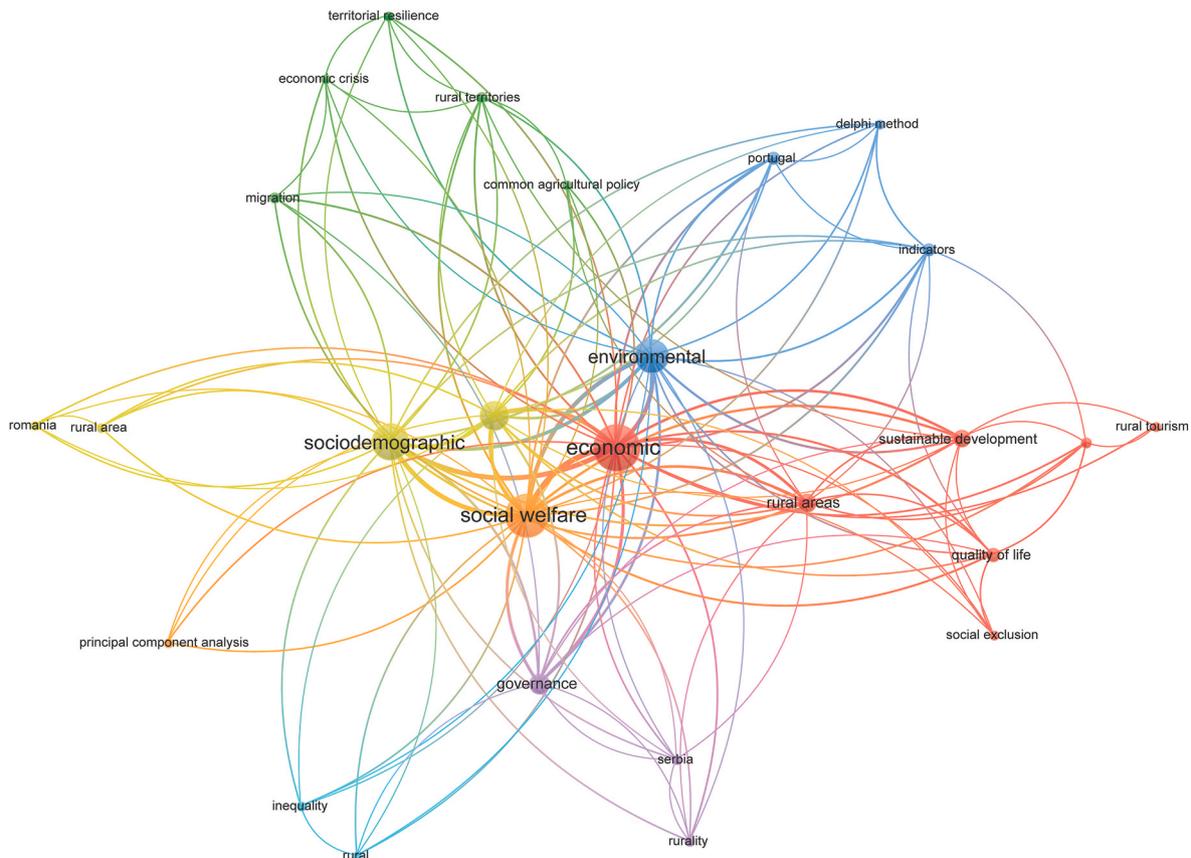
#### 5.1.2. Keyword analysis

To identify the main research trends in the literature on rural development, an approach based on both the frequency of codes (keywords) and thematic analysis was utilised.

First, the relative frequency of keyword usage and the relationships between them in the reviewed publications were analysed in a word map, shown in Fig. 3. The larger the circle, the more frequently a particular word appears in the keywords of the reviewed articles. Fig. 3 also shows the relationships between different keywords, indicating that economic and social well-being indicators are the most frequently detected in the literature and have the highest number of connections with areas and rural development, followed by sociodemographic and environmental indicators. Finally, governance indicators were found to have the least presence in the reviewed literature.

#### 5.1.3. Types of sources

Regarding the information sources used in developing indicators,



**Fig. 4.** Keyword map.  
Source: Own elaboration



**Table 3**  
Categories of indicators, subcategories and number of indicators.

Indicator category	Subcategories	Number of indicators	
<b>Economic</b>	Primary sector	65	
	Secondary sector	9	
	Tertiary sector: tourism and other services	21	
	Employment-unemployment	28	
	Income-income	25	
	Level of economic activity	27	
	Financing	13	
	Entrepreneurship	11	
	Innovation	7	
	<b>Social welfare</b>	Accessibility-mobility	42
		Infrastructure	16
Education		13	
Health-illness		13	
Technology		11	
Housing		10	
Quality of life		8	
Leisure		8	
Social services		8	
Culture		7	
Safety		4	
<b>Sociodemographics</b>	Population evolution	9	
	Age, ageing and youth	15	
	Migration	11	
	Population size and density	10	
	Gender	5	
<b>Environmental</b>	Level of education	13	
	Land use	18	
	Environmental expenditure/investment	9	
	Water	11	
	Energy	4	
	Climate change and erosion	7	
	Natural resources	23	
	Waste	6	
<b>Governance</b>	Emissions	10	
	Participation	14	
	Articulation	2	

Source: Own elaboration

'Tertiary sector: tourism and other services' (21). The subcategories 'Financing' (13), 'Entrepreneurship' (11), 'Secondary sector' (9), and 'Innovation' (7) had the least number of economic indicators.

**5.2.4. Social well-being indicators**

Regarding social well-being (Table 3), there were a total of 140 indicators, with the most significant subcategory being 'Accessibility-mobility', which included 42 indicators (30 % of the total indicators). This was followed by the subcategories 'Infrastructure' (16), 'Education' (13), 'Health-disease' (13), 'Technology' (11), and 'Housing' (10 indicators). 'Quality of life', 'Leisure', and 'Social services' all had 8 indicators. Finally, the categories with the least indicators were 'Culture' (7) and 'Security' (4).

**5.2.5. Sociodemographic indicators**

Regarding sociodemographic indicators (Table 3), the most common subcategories were 'Age, aging, and youth', and 'Level of education' with 15 and 13 indicators, respectively. These were followed by the subcategories 'Migration' (11), 'Population evolution' (10), and 'Population growth' (9). The subcategory with the least relevance in the sociodemographic indicators was 'Gender', with a total of 5 indicators.

**5.2.6. Environmental indicators**

Regarding environmental indicators (Table 3), a total of 88 indicators were identified, with the most predominant subcategories being 'Natural resources' and 'Land use', with 23 and 18 indicators respectively, accounting for 26 % and 20 % of the total indicators in this

**Table 4**  
Categories of economic indicators made by researchers and IAs, organised according to their coincidence.

Indicators	RDSs	1° AIS	2° AIS
Family agricultural population with remunerated activity outside agricultural holding	1	1	1
Total income primary sector	1	1	1
Total primary sector GVA	1	1	1
Agricultural age structure	1	4	1
Typical products rate	1	1	1
Irrigation water use/UAA	1	NC	1
Livestock standard units/UAA	1	1	1
Organic UAA/UAA	1	1	1
GVA Agriculture	1	1	1
Employment Agriculture	1	1	1
Average farm size	1	1	1
Agricultural land	1	1	1
Arable land	1	1	1
Agriculture, forestry, and fishing, value added	1	1	1
Food production index	1	1	1
Livestock production index	1	1	1
Crop production index	1	1	1
Employment in agriculture	1	1 y 4	NC
Employment in agriculture, female	1	1 y 4	NC
Employment in agriculture, male	1	1 y 4	NC
Farm surface area and SAC	1	1	1
Certified productions (DOP, IGP, TSG)	1	1	1
Rented useable agricultural area	1	1	1
Cost for seeds and plants	1	NC	1
Cost of fertilizer	1	NC	1
Crop protection costs	1	NC	1
Animal feed costs	1	NC	1
Cost of machinery used in farms	1	NC	1
Energy costs	1	NC	1
Total financial subsidies allocated by the CAP	1	NC	1
Payments for the rural development	1	NC	1
Decoupled payments	1	NC	1
Share of agriculture in GVA	1	6	1
Amount of state aid agricultural enterprises	1	6	1
Capital investments in agricultural enterprises	1	6	1
Level of development of agricultural land	1	1	1
Cultivated area level	1	1	1
Agricultural land endowment per hectare per rural inhabitant	1	1	1
Number of enterprises engaged in the primary sector	1	1	1
Profit level of primary sector enterprises	1	1	1
Rate of loss-making enterprises in the primary sector	1	1	1
Ratio of transported primary sector products to the total	1	1	1
Proceeds from the sale of agricultural activities	1	1	1
Cost of consumed products obtained from personal holdings	1	1	1
Proportion of employees in the primary sector	1	1	1
Share of agricultural land	1	1	1
Hectares of rainfed crops	1	1	1
Hectares of irrigated land	1	1	1
Percentage of the number of farms with less than 50 ha	1	1	1
Percentage of the number of farms with more than 50 ha	1	1	1
Number of holdings per 100 ha of Useful Agricultural Area	1	1	1
Agricultural index	1	6	1
Agricultural GDP per capita	1	6	1
Number of cattle per capita	1	1	1
Number of sheep per capita	1	1	1
Mean disposable agricultural and self-employment income ratio	1	NC	1
Agricultural production per-1 ha	1	1	1
Agricultural products purchase per 1 ha	1	1	1
Gross value added to agriculture	1	1	1
Accidents at work in individual farming	1	1	1
Agriculture (% of GDP)	1	1 y 6	1
Average economic farm size	1	1	1
Labour productivity in agriculture	1	NC	1
Farmers with other gainful activity	1	NC	1
Municipality share in Serbian crop production	1	NC	1
Employment Manufacturing	2	3	3
Share of manufacturing in GVA	2	NC	3
Proportion of employees in the secondary sector	2	NC	3

(continued on next page)

Table 4 (continued)

Indicators	RDSs	1° AIS	2° AIS
Trade indicators	2	NC	3
Industrial index	2	NC	6 y 3
Construction index	2	NC	6 y 3
Industrial GDP per capita	2	NC	6
Infrastructure:Market, Engineering, Transport, Communication	2	NC	3
Energy productivity	2	NC	3
Number of places in tourist accommodation	3	NC	3
Employment Services	3	3	3
Agrotourism and rural tourism	3	3	3
Area of retail trades	3	3	3
Working licenses on the services sector	3	3	3
Share of construction in GVA	3	3	3
Share of services in GVA	3	3	3
Tourist units	3	3	3
Tourist occupancy during the weekend	3	3	3
Foreign tourists	3	3	3
Average length of stay	3	3	3
Overnight stays by national tourists	3	3	3
Overnight stays by foreign tourists	3	3	3
Places offered	3	3	3
National tourists	3	3	3
Occupancy	3	3	3
Tourism indicators	3	3	3
Service index	3	3	3
GDP per capita of services	3	3	6
Agritourist facilities	3	3	NC
Use of agritourist accommodation	3	3	NC
Gender inequality in the labour market	4	NC	4
Female labor renewal in rural areas	4	NC	4
Employment rate	4	4	4
Unemployment rate	4	4	4
Number of labour contracts	4	4	4
Job opportunities	4	4	4
Job creation	4	4	4
Employment turnover index	4	4	4
Level of employment	4	4	4
Laboral input	4	1 y 4	4
Labour market performance	4	4	4
Population employed in rural areas	4	4	4
Employment rate in rural areas	4	4	4
Unemployment rate in rural areas	4	4	4
Rural population employed by activity sectors	4	4	4
Tourism Personnel	4	4	4
Annual average number of SS affiliates	4	4	4
% SS affiliates/active population	4	4	4
Young unemployed population	4	4	4
Distance of % of unemployed by gender from equilibrium	4	4	4
Occupational structure of the region	4	4	4
Average number of employees per 1000 inhabitants	4	4	4
Number of employment opportunities per 1000 inhabitants	4	4	4
Activity rate	4	4	4
Duration of the contract	4	4	4
Occupation by qualification type	4	4	4
Low-skilled workers	4	4	4
Farm labor force	4	NC	1
Average monthly earnings	5	4	4
Average earnings per capita	5	4	4
Gross family income	5	4	4
Per capita purchasing power	5	4	4
Proportion of people living below 50 per cent of median income	5	4	4
Level of income	5	4	4
Rural/urban poverty rate	5	4	4
Income inequality index	5	4	4
Economic wellbeing	5	4	4
Sources of income	5	4	4
Farm net income	5	4	4
Average monthly size of disposable income of the population	5	4	4
Total resources of households in rural areas, on average per household per month	5	4	4
Average income per capita	5	4	4
Savings per inhabitant	5	4	4
Rural property tax per inhabitant	5	4	4

Table 4 (continued)

Indicators	RDSs	1° AIS	2° AIS
Total sales revenues to population	5	4	4
Total equity to population	5	4	4
Sum of earnings before taxes to population	5	4	4
Average gross wage	5	4	4
Community income per 1 resident	5	4	4
Mean retirement	5	4	4
People at risk of poverty or social exclusion	5	4	4
Economic situation: Income	5	4	4
Poverty rate	5	4	4
GDP per capita	6	6	NC
Economic growth	6	6	6
Labour productivity	6	6	6
Economic activity	6	6	6
Activity rate (%)	6	6	6
Net investments	6	6	6
Gross regional product per capita	6	NC	6
Number of economic agents	6	6	6
Productivity	6	6	6
Industrial parks	6	NC	6
Number of enterprises	6	NC	6
Fiscal licences	6	NC	6
Turnover per capita	6	6	6
Turnover (per employee)	6	6	6
Active business density	6	6	6
Number of firms/1000 inhabs	6	6	6
Firms in industrial sectors/1000 inhabs	6	6	6
Firms in construction sector/1000 inhabs	6	6	6
Firms in services sector/1000 inhabs	6	6	6
Production	6	6	6
Thriving, diverse and resilient businesses that meet the needs of local people	6	6	6
Number of employees	6	6	6
Taxable base per declarant	6	6	6
Cooperation/creation of business associations	6	6	6
Cooperative networks	6	6	6
Economic diversity	6	6	6
Internationalisation of businesses	6	6	6
Crop subsidies	7	6	6
Livestock subsidies	7	6	6
Environmental subsidies	7	6	6
Less favoured areas subsidies	7	NC	6
Market-related expenditure	7	NC	6
Direct aid	7	6	6
Rural development expenditure	7	6	6
Entrepreneurship assistance	7	6	6
Business investment	7	6	6
Level of resources	7	6	6
Community expenditures per 1 resident	7	6	6
Interregional projects	7	NC	6
Local development	7	NC	6
Total assets in farms	8	NC	6
Business (Creation)	8	NC	6
Net Business Creation	8	NC	6
Budgetary revenue from personal income taxes per capita	8	NC	6
Budgetary revenue from local taxes (per capita)	8	NC	6
Entrepreneurial capacity	8	NC	6
Economic activity index	8	NC	6
Total amount of subsidies for projects implemented in the municipality	8	NC	6
Calculation of the subsidy received in the given municipality per agricultural area	8	NC	6
Total amount of subsidies for projects implemented in the municipality	8	NC	6
Calculation of subsidy received in given municipality per capita	8	NC	6
Research and development expenditure as a proportion of GDP	9	6	6
Innovation capacity of regions	9	6	6
Patents generated	9	6	6
Start-ups	9	6	6
Research and innovation	9	6	6
Governmental funds granted to agricultural research and development	9	6	6
Measuring the effectiveness of local development policies	9	6	6

1: Primary sector; 2: Secondary sector; 3: Tertiary sector: Tourism, other services and construction; 4: Employment-unemployment; 5: Income-income; 6: Level of economic activity; 7: Financing; 8: Entrepreneurship; 9: Innovation; 1° AIS→ 1: Agriculture and livestock; 3: Tourism and services; 4: Social and demographic; 6: Economic.; 2° AIS→ 1: Agriculture and livestock; 3: Tourism and services; 4: Social and demographic; 6: Economic.

category. These were followed by the subcategories 'Water' (11), 'Emissions' (10), and 'Environmental investment/expenditure' (9). The environmental subcategories with the least prominence were 'Climate change and erosion' (7), 'Waste' (6), and 'Energy' (4 indicators).

5.2.7. Governance indicators

Regarding governance indicators (Table 3), only 16 indicators were identified altogether, classified into two categories: 'Participation' (14) and 'Articulation' (2).

5.3. AI classification

For each of the indicator types, the classification into researcher-developed subcategories (RDS) and artificial intelligence subcategories (AIS) are described in this section.

Regarding economic indicators (Table 4), ChatGPT generated four subcategories from the first prompt, classifying 161 of the 206 indicators and leaving 45 unclassified. Many of the indicator classifications coincided with those made by the researchers. However, the subcategories 'Employment/Unemployment' and 'Income' were combined into a single subcategory, called 'Social and Demographic', which is not an appropriate designation for economic indicators. Additionally, the AI tool combined the RDSs termed 'Economic Activity Level', 'Financing', and 'Innovation' into a single AIS called 'Economic', which is too general and not as precise as the classifications proposed by the researchers.

After the second prompt, the AI tool generated the same number of subcategories as in the first; however, the number of unclassified indicators was significantly reduced, with 200 of the 206 indicators classified. Regarding the RDS 'Secondary Sector', some indicators from this subcategory were placed within the AIS 'Tourism and Services', in contrast to the more specific subcategory proposed by researchers related to the secondary sector, making this grouping incorrect and less precise.

Furthermore, similar to the first question, ChatGPT developed broader subcategories, combining them into very general categories, or even conceptually incorrect ones, as many of the indicators included in the 'Economic' AIS did not correspond to that nomenclature.

Regarding social well-being indicators (Table 5), ChatGPT generated five subcategories from the first prompt, grouping 112 of the 140 indicators and leaving 28 unclassified. It also combined the 5 RDSs 'Quality of Life', 'Leisure', 'Social Services', 'Culture' and 'Security' into a single AIS called 'Sociocultural Well-being and Security', which is too general.

Following the second prompt, the AI tool generated one less category, and the number of indicators not included in any subcategory increased to 38. Additionally, the RDSs 'Education' and 'Health-Disease' were grouped into a single AIS called 'Education and Health'. Finally, as in the first prompt, the RDSs 'Quality of Life', 'Leisure', 'Social Services', 'Culture', and 'Security' were combined into a single category called 'Quality of Life and Well-being', which is too broad and does not fully correspond to the selected indicators.

Regarding sociodemographic indicators (Table 6), ChatGPT generated four AISs from the first prompt, classifying 50 of the 63 indicators, and leaving 13 unclassified. It also combined 34 indicators (54 %) into a single subcategory called 'Demography', which is much less specific than the researchers' classification. While there is some agreement in the AISs 'Migration' and 'Level of Education', it omits clear from classification, such as 'Stock of immigrants from abroad residing in each municipality' or 'Proportion of the resident population with at least the

Table 5

Categories of social welfare indicators by researchers and IAs, organised by similarity.

Indicators	RDSs	1° AIS	2° AIS
Distance to the nearest city or urban segment	1	1	1
Nearest railway station	1	1	1
Proximity to the nearest road	1	1	1
Distance from the principal city	1	1	NC
Travel time to access other essential services	1	1	1
Distance from major urban areas	1	1	1
Potential accessibility index	1	1	1
Accessibility to non-decentralised services	1	1	1
Satisfaction with access roads to my settlement	1	1	1
Settlement's traffic connection (sufficient number of bus and railway lines)	1	1	1
Quality of the roads in the settlement	1	1	1
Distance to the nearest city	1	NC	NC
Daily movements	1	1	1
Time needed to reach a social facility (min)	1	1	1
Transport environment accessibility	1	1	1
E-accessibility of public services	1	1	1
Availability of multi-purpose public service center	1	NC	NC
Number of settlements with different types of trade	1	3	3
Road network density	1	2	2
Share of arterial roads	1	2	2
Accessibility to cities	1	1	1
Accessibility to main roads	1	1	1
Access to public transport	1	1	1
Rail network access, fibre-optic coverage, 4G telephony coverage, data coverage	1	1	1
Average waiting time for emergency ambulance services	1	1	1
Accessibility of transport for primary health care	1	1	1
Service radius of the professional organisation	1	NC	NC
Service radius of the consumer service institution	1	NC	NC
Average travel time by public transport to the centre of the district	1	1	1
Average travel time to the nearest federal highway	1	1	1
Average travel time to the nearest regional airport	1	1	1
The service radius of the school	1	NC	NC
The accessibility radius of the educational institution	1	NC	NC
Average travel time of pupils to a pre-school education institution	1	NC	NC
Average travel time for students to educational institutions	1	NC	NC
Driving license	1	1	1
Access to infrastructure (transport and telecommunication services)	1	1	1
Distance from the provincial capital	1	NC	1
Length of motorway per 1000 km2	1	2	1
Mobility and quality of services	1	2	1
Distance to important institutions: variable/time ratio	1	NC	1
Distance to important institutions	1	NC	1
Public facilities and services	2	NC	NC
The technological infrastructure equipment of the settlement	2	2	2
Local infrastructure	2	2	2
Public utility installations	2	2	2
Vacancies in nursing homes	2	NC	NC
Transport infrastructure	2	2	2
Basic supplies	2	2	2
Electricity consumption per capita	2	2	2
Dispersion of water from the distribution system	2	2	2
Electricity supply	2	2	2
Electricity consumption per capita	2	2	2
Non-renewable energy per capita	2	NC	NC
Energy consumption per 1 inhabitant	2	2	2
Population connected to gas network	2	2	2
Population connected to sewage network	2	2	2
Availability of education and health services of the required quality	2	2	2
Education opportunities	3	NC	NC
Number of preschool institutions	3	NC	NC
Number of primary schools	3	2	NC
Number of secondary schools	3	2	NC
Number of colleges and universities	3	2	NC
Accessibility of cultural institutions	3	2	NC
Educational structure	3	3	3

(continued on next page)

Table 5 (continued)

Indicators	RDSs	1° AIS	2° AIS
Professional education	3	3	3
Coverage of pre-school children's schools	3	3	3
Education services	3	2	3
Training courses	3	3	3
Education and training	3	3	3
Physicians (No.) per 1000 inhabitants	3	NC	NC
Availability of education and health services of the required quality	4	3	3
Accessibility and quality of hospitals	4	3	NC
Access to education and health services	4	3	3
Health centers per inhabitant	4	3	3
Population coverage with hospital beds	4	3	3
Health services	4	3	3
Emergency ambulance service radio	4	3	3
Emergency medical assistance service radio	4	3	3
Average waiting time for emergency ambulance service	4	3	3
Waiting time for pre-hospital medical care	4	3	3
Health	4	3	3
Healthy citizens (Citizens with low rates of disease)	4	NC	NC
Proportion of population covered by a mobile network	4	NC	3
Number of households with data networks	5	NC	NC
Number of telephones per inhabitant	5	2	NC
Mobile PAF service radius	5	2	NC
Fixed PAF accessibility radius	5	NC	NC
Access to ISDN services	5	NC	NC
Level of digitisation	5	2	NC
Computer skills	5	NC	NC
Internet penetration	5	NC	NC
Share of households with internet connection	5	NC	NC
Internet users/100 people	5	NC	NC
Proportion of conventional dwellings of usual residence	5	NC	NC
Share of conventional dwellings of usual residence with facilities	6	6	NC
Required level of housing	6	6	NC
Dwellings owned/Total dwellings	6	6	NC
Housing quality	6	6	NC
Rate of households with equipment	6	6	NC
Number of dwellings completed during the year	6	6	NC
Housing	6	6	2
Sustainable housing	6	NC	2
Sustainable community buildings	6	6	2
Satisfaction with hygiene in the settlement	6	6	2
Human well-being	7	6	2
Living conditions	7	7	7
Social environment	7	7	7
Dedication to the household	7	7	7
Quality of life	7	7	7
Human development	7	7	7
Level of stress	7	7	7
Opportunities for outdoor recreational	7	7	7
Number and availability of sports and recreational facilities	8	7	7
Variety of content for children and adults	8	7	7
Recreational and socialisation opportunities to combat social unrest	8	7	7
Recreational usability of various areas (Fincas)	8	7	7
Recreational areas	8	7	7
Dedication to leisure activities	8	7	7
Family and social life	8	7	7
Social and health services	8	7	7
Work of social services	9	7	7
Number of social facilities	9	7	7
Access to services	9	7	7
Expenditure on social assistance (per capita)	9	7	7
Places in social services/1000 inhabitants	9	7	7
Access to social services	9	7	7
Social problems	9	7	7
Access to cultural goods	9	7	7
Opportunities for recreation and culture	10	7	7
Number and accessibility of cultural institutions	10	7	7
Schools/libraries per inhabitant	10	7	7
Cultural expenditure	10	7	7
Percentage of active readers in the community	10	7	7
Socio-cultural well-being	10	7	7
High levels of personal security	10	7	7
Safety of life in my neighborhood	11	7	7

Table 5 (continued)

Indicators	RDSs	1° AIS	2° AIS
Crime rate	11	7	7
Safe and secure citizens	11	7	7

1: Accessibility-mobility; 2: Infrastructure; 3: Education; 4: Health-illness; 5: Technology; 6: Housing; 7: Quality of life; 8: Leisure; 9: Social services; 10: Culture; 11: Safety; 1° AIS→ 1: Accessibility and transport; 2: Infrastructure; 3: Education and Health; 6: Housing and quality of life; 7: Socio-cultural wellbeing and safety; NC: Not classified; 2° AIS→ 1: Accessibility and transport; 2: Infrastructure; 3: Education and Health; 7: Quality of life and wellbeing; NC: Not classified.

first cycle of secondary education relative to those who have completed the third cycle of secondary education’.

After the second prompt, ChatGPT generated the same number of subcategories as the researchers did, with two AISs (migration and education) showing considerable agreement. However, the AI tool did not identify the subcategory ‘Gender’, which is important from the perspective of sociodemographic indicators. Regarding the RDSs ‘Population Evolution’ and ‘Age’, ChatGPT disaggregated them into ‘Demography and Population Structure’, ‘Health’, and ‘Economy’, a distinction that does not correspond to the sociodemographic indicators.

As in the previous cases, after the second prompt, four indicators remained unclassified despite being specifically indicated.

Regarding environmental indicators (Table 7), ChatGPT generated seven AISs from the first prompt, classifying 67 of the 88 indicators, and leaving 21 unclassified. Furthermore, it encompassed a significant number of indicators that aligned with the RDS. Concerning the RDS titled ‘Environmental expenditure/investment’, the AI tool disaggregated it into two subcategories: ‘Environmental management and conservation’ and ‘Socioeconomic aspects’, with the latter not corresponding to environmental indicators. Additionally, it disaggregates the RDS titled ‘Natural resources’ into ‘Biodiversity and nature conservation’ and ‘Landscape and cultural heritage’, classifying the indicators more specifically but excluding some that should belong to these categories.

After the second prompt, ChatGPT generated the same number of subcategories as the researchers, showing considerable agreement, and once again subdivided the category ‘Natural resources’ into ‘Biodiversity and nature conservation’ and ‘Landscape and cultural heritage’. Notably, the number of unclassified indicators increased to 24 after the second prompt, which was higher than that in the first prompt, despite the request to classify all indicators.

Finally, regarding governance indicators (Table 8), in the first prompt, the AI program ChatGPT generated three subcategories from the first prompt in which all indicators were classified. It disaggregated the RDS ‘Participation’ into the AIS ‘Political participation and democracy’ and ‘Citizen participation and community development’, showing nearly full agreement with the researcher classifications. Lastly, the AI tool generated the classification ‘Institutional and administrative development’, which aligns with that of ‘Articulation’, except for two indicators. Given these results, introducing additional prompts was deemed unnecessary.

Subsequently, a bar chart showing the percentage of agreement between the categories developed by the experts and by the AI is displayed (Fig. 6).

## 6. Discussion

This study conducted a qualitative analysis of rural development indicators identified in a systematic review to assess the vivacity of rural territories and investigate the possibilities that AI (specifically the ChatGPT program) offers for such an analysis. Regarding the vivacity of rural areas, economic and social well-being indicators were the most prominent in the reviewed literature.

**Table 6**  
Categories of socio-demographic indicators made by researchers and AI, organised by similarity.

Indicators	RDSs	1°AIS	2°AIS
Depopulation	1	1	1
Maternity rate	1	1	NC
Mortality	1	(1)	(1)
Weight of population variation in the total resident population	1	NC	(1)
Cumulative population growth rate	1	1	(1)
Rate of natural increase	1	1	(1)
Infant mortality rate	1	(1)	(1)
Birthrate	1	(1)	(1)
Average annual population growth	1	1	NC
Rural population age distribution	2	1	1
Mean age	2	1	1
Life expectancy	2	(1)	1
Age structure	2	1	1
Ageing index	2	1	1
Youth index	2	1	1
Over-ageing index	2	1	1
Median age	2	1	1
Population over 75 years old	2	1	1
Proportion of population aged 16 or under	2	1	1
Proportion of population aged 65 or over	2	1	1
Young-to-old-population ratio	2	1	1
Ratio of senior to young population	2	NC	1
Youth dependency rate	2	(1)	NC
Age dependency ratio	2	(1)	NC
Masculinity index	3	1	7
Rural women of reproductive age	3	1	7
Rural young female population	3	1	7
Rural female population	3	1	7
Proportion of men	3	NC	7
Change in population	4	1	7
Population concentration	4	1	7
Population density	4	1	7
Population dispersion index	4	1	7
Demographic Potential Index	4	NC	7
Number of households	4	1	7
Initial population at time 0	4	1	7
Proportion of population living in municipalities with more than 5000 inhabitants	4	NC	7
Population size	4	1	7
Average household size	4	1	7
Rural exodus	5	5	5
Foreigners from low- and middle-income countries	5	5	5
Migration flow	5	5	5
Rural internal migration	5	5	5
Labour migration	5	5	5
Proportion born outside the municipality	5	NC	5
Proportion of non-migrant population	5	NC	5
Proportion of residents outside the municipality	5	1	5
Residuals of the demographic drag	5	NC	5
Stock of immigrants from abroad residing in each municipality	5	1	5
Net migration rate	5	5	5
Literacy	6	6	6
University education	6	6	6
Incidence of adult graduates	6	6	6
Adult population with medium or higher education in rural areas	6	1	6
Low-educated population	6	1	6
Young population without post-compulsory education	6	1	6
Proportion of university students	6	NC	6
Proportion of young people and adults with ICT skills	6	NC	6
Proportion of resident population with at least lower secondary education out of those with completed upper secondary education	6	1	6
Proportion of the labour force with tertiary qualifications	6	NC	6
Proportion of population illiterate and without formal qualifications	6	NC	6
Proportion of population with secondary education	6	NC	6
Upper secondary education rate	6	6	6

1: Population evolution; 2: Age, ageing and youth; 3: Gender; 4: Population size and density; 5: Migration; 6: Level of education; 1°AIS→ 1: Demography and (1): Health; 5: Migration; 6: Education; NC: Not classified; 2°AIS→ 1: Demography

and population structure, (1): Health and (1): Economy; 5: Migration; 6: Education; 7: Other; NC: Not classified.

This finding aligns with the results obtained in previous research, where economic and social well-being indicators exhibited significant relevance. [Alamá-Sabater et al. \(2021\)](#) demonstrated that economic conditions and variables related to social well-being have a significant positive effect and a substantial contribution to demographic dynamics. Similarly, [Anichin et al. \(2017\)](#) observed that income and poverty levels were relevant indicators. Another study conducted in Aragón (Spain) noted that demographic growth largely depends on the region's economic activity and its capacity to generate employment and income, as well as the availability of social well-being-related services ([Ayuda et al., 2023](#)). In a study evaluating various rural development programmes, significant importance was given to economic indicators related to economic growth, labour productivity, and job creation ([Comíns and Moreno, 2013](#)). In a study conducted in Romania, local infrastructure, employment levels, income sources, and access to public health and educational services were found to play crucial roles in the development of various rural areas ([Dragan et al., 2022](#)).

Although other indicators are less prevalent in the literature, they are also important in measuring the vivacity of rural territories. For example, in terms of sociodemographic indicators, ageing and the renewal rate of rural populations have been considered the most relevant factors in rural development, where a lack of an active population could impede the development of these areas ([Abreu and Mesías, 2020](#)). Population density is also a widely studied indicator associated with economic growth variables such as innovation and productivity, which are higher in densely populated areas ([Straka and Tuzová, 2016](#)). Similarly, [Camaioni et al. \(2013\)](#) show that population ageing and demographic contraction are highly relevant variables in rural European areas. Regarding environmental indicators, the importance of indicators related to natural resource endowments, environmental maintenance costs, pollution, landscapes, and the potential impact of climate change on the dynamics and development of rural areas have been emphasised ([Sánchez-Zamora and Gallardo-Cobos, 2019](#); [Viccario et al., 2021](#)). Finally, regarding governance indicators, population participation and territorial cooperation stand out ([Medeiros, 2019](#)).

It is important to highlight that there are interactions between the different indicator types highlighted in the reviewed literature, suggesting that vivacity may depend on a combination of these indicators.

The AI-generated classifications were more generic than those developed by researchers, thereby establishing broader subcategories. Moreover, many of the indicators included in the AI classifications lacked coherence, either because of their meaning or because of the existence of a more appropriate category. Notably, many of the indicators remained unclassified or were included in more than one category despite explicitly defining this condition in the prompt. This indicates a certain lack of logic in the analytical process, generating results that do not align with those specified in the prompts during the response regeneration ([Curry et al., 2024](#); [Qureshi, 2023](#)). This may be due to the tool's inadequate understanding of the meanings of these indicators and, therefore, its inability to classify them. Thus, it can be asserted that the AI tool (ChatGPT-4) exhibited limited contextual understanding, operating based on pattern recognition, which resulted in a restricted capacity to comprehend the context and underlying meaning of the text it was processing. This can lead to errors in generating text that accurately reflects the intended meaning of provided prompts along with a lack of common sense, potentially resulting in non-sensical or inappropriate responses to certain prompts. This indicates limitations concerning data analysis, which is consistent with the claims made by [Hamilton et al. \(2023\)](#) in their study on the exploration of AI use in qualitative analysis.

It has also been noted that the AI tool generates very broad categories, which aligns with the findings of [Antaki et al. \(2023\)](#) who asserted that ChatGPT's analysis was imprecise, combining and

**Table 7**  
Categories of environmental indicators made by researchers and IAs, organised by similarity.

Indicators	RDSs	1 <sup>a</sup> AIS	2 <sup>a</sup> AIS
Area of organic farming	1	1	1
Agricultural coverage	1	1	1
Land use	1	1	1
landscape features	1	(6)	(6)
Reforestation and afforestation	1	NC	1
Impact of forest fires	1	NC	NC
Forest area	1	1	1
Forest surface-area	1	1	1
Agricultural and forestry land uses dynamics	1	1	1
Impact of sustainable management	1	2	2
Abandoned agricultural land	1	NC	1
Local land management for sustainability and biodiversity	1	NC	NC
Share of agricultural area under productive and sustainable agriculture	1	1	1
Impact of protected areas	1	2	6
Incidence of organic agriculture	1	2	6
Proportion of the area fertilised with mineral fertilisers	1	NC	NC
Percentage of the area fertilised with organic fertilizers	1	NC	NC
Ratio of areas of forest reproduction to areas of deforestation	1	1	1
Environmental expenditure of municipalities per inhabitant	2	(2)	NC
Implementation of agri-environmental measures	2	(2)	2
Environmental protection expenditure	2	2	2
Environmental well-being (Investment)	2	(2)	2
Environment (clean air and water, healthy food and green spaces)	2	NC	NC
Public expenditure for the protection and enhancement of cultural goods and activities	2	2	2
Share of equity investments in environmental protection in agriculture in the total volume of equity investments	2	(2)	2
Areal impact of the (Rural Development Programme) on the visual diversity of the rural landscape.	2	2	2
Aid intensity for landscape unit	2	2	2
Proportion of bodies of water with good ambient water quality	3	3	NC
Proportion of treated wastewater	3	3	NC
Water quality	3	3	3
Water bodies	3	3	NC
Groundwater quality	3	NC	3
Quality of environmental components (air, water, soil)	3	NC	NC
Estimated soil loss by water erosion	3	1	3
Water consumption	3	3	3
Number of rural wastewater treatment plants, collective and individual	3	3	3
Dispersion of water from the distribution system	3	NC	3
Number of annually constructed rural wastewater treatment plants	3	3	3
Energy production from renewable sources	4	NC	NC
Renewable energy sources (wind, photovoltaic, biomass)	4	NC	NC
Non-renewable energy per capita	4	NC	NC
Renewable energy share in the total final energy consumption	4	2	NC
Climate change	5	NC	5
Climatic conditions	5	NC	5
Erosion control index	5	1	NC
Surface-area with low risk of erosion	5	1	NC
Areas at risk of desertification	5	1	NC
Soil water erosion	5	1	NC
Wind erosion of soil	5	1	NC
Sites for terrestrial and freshwater biodiversity that are covered by protected areas	6	6	6
Biodiversity (recovery and enhancement of plant and animal species)	6	6	6
Quality of natural capital (biodiversity, landscape diversity, their aesthetic value)	6	6	6
High Nature Value Areas	6	6	6
Ecosystem stability	6	6	6
State of the ecosystem	6	6	6
Parks and protected areas	6	6	6
Protected areas	6	6	6
Proportion of Natura (2000) Network area	6	6	6

**Table 7 (continued)**

Indicators	RDSs	1 <sup>a</sup> AIS	2 <sup>a</sup> AIS
Animal richness	6	6	6
Plant richness	6	6	6
Expenditure on the protection and conservation of cultural and natural heritage	6	2	NC
Biocultural diversity index	6	NC	NC
Landscape and cultural heritage	6	(6)	(6)
Natural and protected areas index	6	2	NC
Burned area	6	(6)	(6)
Natural environment	6	NC	(6)
Percentage of landscape types with outstanding quality	6	(6)	(6)
Surface area classified as outstanding in relation to the municipal surface area	6	(6)	(6)
Aragon Tourist Trails in the municipality	6	(6)	(6)
Municipal area classified in some category of Protected Natural Spaces	6	(6)	(6)
Environmental capital	6	(2)	2
Percentage of area classified as Protected Natural Space	6	(6)	NC
Proportion of urban waste selective collected	7	NC	7
Waste management	7	2	7
Rural landfills and their area	7	2	NC
Reducing losses and waste	7	NC	7
Selective collection of municipal waste	7	NC	7
Total share of waste generated by agriculture, forestry and fisheries	7	NC	7
GHG emissions per capita	8	8	8
Greenhouse gas emissions from production activities	8	8	8
Ammonia emissions from agriculture	8	8	8
Emissions of pollutants to air from stationary sources (Agriculture)	8	8	8
Carbon dioxide emissions to air from stationary sources (Agriculture)	8	8	8
Reverse CO2 emissions	8	8	8
Environmental pollution level	8	3	8
Potential greenhouse gas emissions from vehicles	8	8	8
Greenhouse gas emissions from agriculture	8	8	8
Level of contaminants removed from the soil	8	3	3

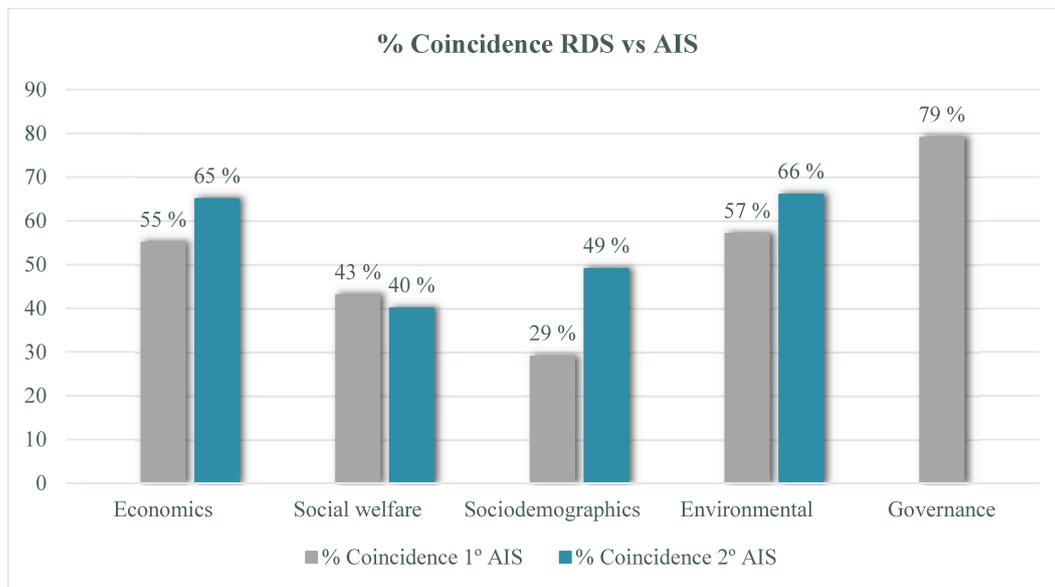
1: Land Use; 2: Environmental Expenditure/Investment; 3: Water; 4: Energy; 5: Climate Change and Erosion; 6: Natural Resources; 7: Waste; 8: Emissions; 1<sup>o</sup> AIS → 1: Natural resources and land use; 2: Environmental management and conservation and (2) Socio-economic aspects; 3: Environmental quality; 6: Biodiversity and nature conservation and (6): Landscape and cultural heritage; 8: Emissions; NC: Not classified; 2<sup>o</sup> AIS → 1: Natural resources and land use; 2: Environmental management and conservation; 3: Environmental quality; 5: Climate change and environmental conditions; 6: Biodiversity and nature conservation and (6): Landscape and cultural heritage; 7: Waste management; 8: Emissions and pollution; NC: Not classified.

**Table 8**

Categories of governance indicators made by researchers and IAs, organised by similarity.

Indicators	RDS	1 <sup>a</sup> AIS
Women and political representation at local level	1	1
Electoral turnout rate	1	1
Public consultation process	1	(1)
Participation in political bodies	1	1
Average voter turnout in elections	1	1
Participación del sector privado	1	(1)
Rotación media de votantes	1	1
Community participation and accountability in land management planning and decisions	1	(1)
Involvement of the authorities in the local development effort	2	2
Administrative status	2	2
Institutional environment	2	2
Politics and institutions	2	1
Territorial cooperation entities covering different scales	2	(1)
Association networks	2	(1)

1: Participation; 2: Articulation; 1<sup>o</sup> AIS → 1: Political participation and democracy and (1): Citizen participation and community development; 2: Institutional and administrative development.



**Fig. 6.** Percentage of coincidence between RDS and AIS.  
Source: Own elaboration

modifying data, likely because of its probabilistic synthesis approach and its goal of producing content regardless of the input. However, in the case of environmental indicators, the accuracy was higher, which could occasionally guide researchers toward more appropriate classifications (Antaki et al., 2023). Another important issue is the bias generated. As previously mentioned, AI models are trained on large datasets, and their understanding of language and concepts is based on the patterns they have observed in these datasets. Therefore, if the training data is not verified to be free from bias, there is a risk of biased interpretation from the AI tool (Hamilton et al., 2023; Siiman et al., 2023). In this study's analysis, it appears that the AI tool does not comprehend a certain number of indicators, leaving them unclassified or misclassifying them. This may be due to a lack of training data, as biased, incomplete, or unrepresentative data can affect the accuracy of the results (Hamilton et al., 2023).

## 7. Conclusion

The need to revitalise rural territories is evident. Achieving this requires identifying and classifying key indicators that influence rural potential and shape both the present and future development of these areas. In this context, we introduce the term *vivacity* as a novel conceptual approach, offering a distinct perspective compared to previously used terms, which, in our view, fail to fully capture the opportunities present in rural territories. This study aimed to address these gaps through a systematic review of the literature on rural development indicators in rural areas. Based on this, we propose a set of indicators that allow for the measurement of this level of *vivacity* in rural territories. The bibliographic results demonstrate that economic indicators (primary sector, employment, and income) and social well-being indicators (mobility, infrastructure, healthcare, and education) play significant roles in enhancing *vivacity* and dynamism in rural regions.

Additionally, the potential of AI as a tool to assist researchers in qualitative analysis has been explored, highlighting the differences between the classification proposed by this study's researchers, in consensus with 17 expert researchers in rural development, and the generative AI tool ChatGPT-4. Considering the results, ChatGPT cannot meet the standards of a human analyst at present, allowing for directed analysis only under close scrutiny of the results. Therefore, AI-assisted qualitative analysis does not eliminate the need for human

involvement; it remains essential to engage human expertise and judgment to ensure that data interpretation aligns with the research objectives and context, thereby ensuring adequate consistency in categorizing indicators.

One limitation of this review is that it was conducted exclusively in Europe. Further analysis could determine whether the obtained results are transferable to regions outside Europe. Additionally, a potential bias may have been introduced due to the predominance of Spanish experts. Finally, a further limitation is related to the search terms used in the literature review as alternative terms might yield different outcomes. All these limitations could be addressed in future research by expanding the scope of the study.

Regarding future research trends, the continuous advancement of AI tools presents a significant challenge regarding their understanding and the tasks that they may be capable of performing in the future within academia and research. Technological evolutions in this regard may necessitate further examination of the capabilities of these tools for qualitative research.

## CRedit authorship contribution statement

**Emilio Hernández-López:** Conceptualization, Writing – review & editing, Software, Data curation, Writing – original draft, Investigation, Methodology, Formal analysis. **Laura Martínez-Carrasco:** Formal analysis, Validation, Writing – review & editing, Software, Conceptualization, Writing – original draft, Supervision, Methodology, Investigation, Data curation. **Margarita Brugarolas:** Writing – original draft, Supervision, Formal analysis, Investigation, Visualization, Methodology, Writing – review & editing, Validation, Software, Project administration, Conceptualization, Funding acquisition, Data curation.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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