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Adaptation of Index Methods of Assessing Environmental Quality in Rural Conditions Using the Example of the Index of Urban Environmental Quality in the Russian Federation

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Abstract: The paper examines the problem of assessing the quality of the environment in rural areas and private housing development areas of urban settlements, which remain insufficiently studied in comparison with urban agglomerations. The existing methods of assessing the urban environment are analyzed for applicability in rural areas. Their limitations for the rural context are identified: focus on high population density, underestimation of agricultural pollutants (pesticides, fertilizers), irrelevance of infrastructure accessibility criteria. Based on a comparative analysis of urban and rural environments according to 8 key criteria (infrastructure, healthcare, safety, ecology, etc.), it was substantiated that the village is inferior to the city in most indicators, except for environmental conditions and stress levels. An adaptation of the Russian methodology for forming the urban environment quality index is proposed: out of 36 indicators, 23 can be applied to rural areas after modification (for example, assessing access to water through wells/bores instead of centralized systems). For a comprehensive assessment, it is recommended to add new criteria that comprehensively assess the quality of the environment. It is proposed to assess areas of private urban development with limited access to infrastructure using rural methods. It is established that the study contributes to overcoming the methodological gap between urban and rural approaches by offering hybrid indicators relevant to the global context.

1 INTRODUCTION

The assessment of the quality of human habitat has traditionally focused on urban areas, where numerous indices have been developed, such as the Urban Quality of Life Index (UQoL) or the Sustainable Cities Index (SCI). However, rural settlements and privately built areas within cities remain understudied in the context of comprehensive environmental assessment. This creates gaps in understanding the integrated development of regions, especially in the context of growing interest in decentralization and sustainable agriculture.

Rural areas are characterized by low density of development, prevalence of natural landscapes, limited infrastructure and different socio-economic conditions compared to cities. This requires adaptation of existing methods for correct assessment.

Traditional urban indices that focus on building density, public transportation, and service concentration become irrelevant in a rural context. For example, the Walk Score indicator, which measures pedestrian accessibility, becomes meaningless in areas where the nearest store is several kilometers away.

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The relevance of the study is due to:

1. Growing interest in the development of rural areas within the framework of the national project "Integrated Development of Rural Areas".
2. The need of objective tools for the distribution of budget funds.
3. The lack of a unified methodology that takes into account the specifics of rural areas and private development areas.

The quality of the rural environment is a concept that is currently rarely used in scientific circulation. Also, there are no officially introduced terms and concepts that would be sufficiently close to the problem of this study. At present, in Russia, only the concept of “quality of the urban environment (living)” has been officially introduced into scientific circulation, defined as the ability of the urban environment to satisfy the objective needs and demands of city residents in accordance with the generally accepted norms and standards of life at the given time. Therefore, the quality of the rural environment can be explained similarly to the quality of the urban environment. In this case, the quality of the rural environment will be the ability of the rural environment to satisfy the objective needs of rural residents. With this approach, it becomes clear that the methodological basis for studying the quality of rural and urban environments will be similar in many ways, and the differences will consist only in the criteria of the quality of these two environments.

It should be noted that private development areas within the boundaries of urban settlements in terms of environmental quality should be assessed separately from them, since the living conditions of people in private development areas of cities are in many ways more similar to rural settlements. This is confirmed by the predominance of lands intended for individual housing construction, private farming and gardening within the boundaries of private development areas, which is also observed in rural areas. Within the city limits, private development areas are usually represented by various gardening and vegetable gardening non-profit partnerships (SNT and ONT), located at a great distance from city centers and important infrastructure facilities; accordingly, the assessment of the quality of the environment in such areas should be carried out using methods adapted for rural areas. The criterion for classifying settlements as rural or urban areas when choosing a method for assessing the quality of the environment in this case should primarily be the distance from the most important infrastructure facilities.

Compared to urban areas where multi-story buildings predominate and population density is higher, areas with private development have significantly lower levels of social infrastructure and its availability. Such areas also have more favorable environmental conditions and a higher level of greenery.

In 2019, a methodology for forming an urban environment quality index (UEQI) was developed and approved in the Russian Federation. However, the quality of the environment in smaller rural settlements, as well as in private development areas, remains ignored. This can be explained by the fact that currently fewer people live in rural areas than in cities, and the dynamics of rural population decline persist. However, these facts do not allow us to say that there is no need to assess the quality of the environment in rural areas and areas of private urban development.

Of course, from an ecological point of view, rural settlements and private development areas are much more prosperous than urban areas with a huge population density. This is manifested in a lower degree of environmental pollution due to anthropogenic activity, as well as in a larger share of green areas, among which the first place in rural areas is occupied by limited-use green areas on private household plots. Also, the advantages of rural residential areas in environmental terms include the high quality of the visual environment, expressed in the absence of aggressive and homogeneous visual fields harmful to humans, as a result of which people in rural areas are less susceptible to various psycho-emotional disorders.

A completely different situation is observed if we consider rural settlements according to the criteria of management efficiency, modernity and relevance of the environment, its identity and diversity, as well as safety, according to which points are distributed as a result of calculating 36 indicators according to the approved methodology. With this approach, rural settlements and private development areas are inferior to cities in many ways, and the quality of the environment in them is significantly lower than in urban areas, despite better environmental conditions and less exposure to stress for rural residents.

The main factors reducing the quality of the environment in rural areas are the low level of development of social infrastructure, low level of health care, lack of centralized water supply, heating and sewerage in some settlements, lack of amenities for the elderly and disabled, insufficient safety measures on the roads, etc. In many ways, this situation with the quality of the environment in rural areas is connected with the lack of interest of the state authorities of the Russian Federation in raising the standard of living in rural settlements and areas of private development.

In this regard, the problem of environmental quality in rural areas is currently very urgent in the Russian Federation and requires the development of effective methods for assessing environmental quality to identify priority areas of funding for improving the quality of the rural environment.

2 MATERIALS AND METHODS

Before considering the existing methods of assessing the quality of the environment and their adaptation to rural conditions, it is necessary to study the specifics of the rural environment in the Russian Federation. Since the study is aimed at adapting the methodology for forming the index of the quality of the urban environment to rural conditions, first of all, it is necessary to identify the differences in the criteria for the quality of the human environment in urban and rural areas. In the future, these data will be used to test the existing methods of assessing the quality of the environment for their compliance with the criteria for the quality of the environment of rural areas and areas of private development.

The criteria of the quality of urban and rural environments should include the main environmental factors that influence the comfort of life of population. The data obtained during the comparative analysis of urban and rural environments are presented in Table 1.

Table 1: Comparative analysis of the characteristics of urban and rural environments according to the main criteria of environmental quality.

Criterion	Features of urban environment	Features of the rural environment
Infrastructure	Availability of trading platforms and a wide market of services; high availability of public utilities	Limited availability of goods and services; many residents do not have access to water and heating systems
Health welfare	Large hospitals; modern equipment; highly qualified specialists; competition from private clinics	Large hospitals only in regional centers; outdated equipment; shortage of personnel, especially highly specialized ones; low level of medicine
Employment and income	Variety of professions, high wages, career opportunities	Predominance of agricultural and seasonal work, low incomes, lack of career opportunities
Culture and Leisure	A large number of cultural and leisure centers; various concerts and public events	Limited opportunities (local clubs, events only on major holidays)
Education		

	A wide choice of schools, colleges, universities, additional education courses (AE)	Limited number of schools; lack of universities, colleges and pre-school courses
Housing	Often high property prices; variety of options; predominance of apartment buildings	Limited choice of housing; prevalence of low-rise buildings; property prices not always lower than in the city
Safety	High crime rate; high probability of emergency situations (ES); rapid response of emergency services	Low crime rate; low probability of emergencies; slow response of emergency services
State of environment	Polluted air; physical pollution (noise, vibration); low level of greenery	Low air pollution; no physical pollution; high level of greenery

As a result of the comparative analysis of urban and rural environments, it was revealed that the urban environment has an advantage over the rural environment in almost all of the analyzed criteria of environmental quality. The only exceptions are the criteria of "safety" and "environmental quality". However, according to the criterion of "safety", the rural environment has a disadvantage in the form of a slower response of emergency services to emerging emergencies. In general, the analysis once again proves that it is irrational to assess the quality of the rural environment using the same methods as the urban environment, since the village will always be inferior to the city in most of the criteria of environmental quality.

The basis for developing a methodology for assessing the quality of the rural environment in the Russian Federation can be some methods used in the EU and the USA, as well as the methodology for forming the urban environment quality index (UEQI) developed in the Russian Federation.

To adapt the methodology, the following indices were analyzed:

1. ***Urban Quality of Life Index (UQoL)*** – a comprehensive indicator that assesses the level of comfort, safety and well-being of city residents based on social, economic, environmental and infrastructural criteria.
2. ***Sustainable Cities Index (SCI)*** – a ranking that assesses the ability of cities to balance social well-being, economic growth and environmental responsibility.
3. ***Green City Index*** – an international ranking that evaluates the sustainability and environmental friendliness of cities based on various criteria related to environmental protection, energy efficiency, quality of life and natural resource management.
4. ***Walk Score*** – a metric that evaluates the walkability of a location (such as an address, neighborhood, or city) based on its proximity to amenities such as shops, restaurants, schools, parks, and public transportation. a metric that evaluates the walkability of a location (such as an address, neighborhood, or city) based on its proximity to amenities such as shops, restaurants, schools, parks, and public transportation.
5. ***Air Quality Index (AQI)*** – a universal indicator that assesses the level of air pollution and its potential impact on human health.
6. ***Index of quality of urban environment of the Russian Federation*** – the value (in points) of the state of the urban environment, obtained as a result of a comprehensive assessment of quantitative and measurable indicators characterizing the level of comfort of living in the relevant city.
7. ***NExt proXimity (NEXI)*** – allows you to measure the level of service availability

based on OpenStreetMap data, guided by the principles of the 15-minute city.

8. ***Environmental Performance Index (EPI)*** – a composite indicator that measures countries' performance in terms of environmental health and natural resource management.

9. ***Sustainable Process Index (SPI)*** – a tool for assessing the environmental sustainability of industrial, agricultural or technological processes designed to measure their impact on the environment.

Urban methods were studied through the prism of their applicability to rural conditions. The data obtained are presented in Table 2.

Table 2: Comparison of existing indices for assessing environmental quality in terms of their applicability to rural conditions.

Index	Key parameters	Restrictions for rural areas
UQoL	Infrastructure availability, ecology, safety	Focused on high population density
SCI	Economics, energy efficiency,	Not take into account the agricultural sector of the economy
Green City Index	transport, management with wastes, greening	The criteria do not take into account most of the characteristics of rural areas
Walk Score	Pedestrian accessibility	Not applicable due to the great distance between objects
AQI	Air quality	Low air pollution levels in villages
UEQI (RF)	Infrastructure, ecology, safety	Orientation of criteria to urban conditions
NEXI	Availability of basic services	Remoteness of objects, seasonal unavailability
EPI	Water and air quality, biodiversity	Pollutants in villages are different from those in cities
SPI	Social welfare	Irrelevance of urban criteria of social well-being

Based on the data in Table 1, it follows that currently no methods for assessing the quality of the environment have been developed that would be suitable for use in assessing the quality of the rural environment, since most of the criteria applicable in urban areas are not suitable for rural areas. For example, the criteria for accessibility of social infrastructure used in existing methods are irrelevant for rural areas, since in villages all social facilities, as well as stores, are located at a great distance from each other, which is significantly influenced by low population density. The assessment of the availability of infrastructure facilities in rural areas should be carried out using other indicators that take into account their remoteness and underdeveloped transport network. Most of the indices considered do not take into account the state of agricultural landscapes and the specifics of the agricultural sector of the economy. Pollutants in rural areas differ significantly from those in urban areas, where emissions of harmful gases and aerosols into the atmosphere predominate, while in villages soil pollutants (pesticides, mineral fertilizers, heavy metals) predominate.

According to statistical data, according to VTsIOM polls (2023), as well as European surveys of population satisfaction with the quality of social infrastructure, regardless of the standard of living in different countries, lower satisfaction with social infrastructure is always observed among residents of rural areas, in contrast to residents of urban areas, who are often more satisfied with social infrastructure. Based on this, when developing a new methodology for assessing the quality of the rural environment, it should be taken into account that the low quality of social infrastructure development in rural areas is a factor, a positive change in which is currently not expected.

It is necessary to consider in more detail the methodology for forming the urban environment quality index (UEQI), which was approved by the order of the Government of the Russian Federation of March 23, 2019 N 510-r “On approval of the methodology for forming the urban environment quality index”.

The methodology under consideration is based on the assessment of the quality of the urban environment by 36 indicators, characterizing the well-being of the city by 6 spaces and 6 criteria. The methodology has the main goal of identifying existing and most pressing problems of each city to improve the effectiveness of future decisions and projects for the development of the urban environment, which corresponds to the national goals of the provisions of the Decree of the President of the Russian Federation of May 7, 2018 N 204 "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" and the national project "Housing and Urban Environment".

The Ministry of Construction of Russia is responsible for the annual formation of the index of cities of the Russian Federation. By April 1 of each year, in accordance with the order, the calculation of the indices of the quality of the urban environment of most cities in the country must be carried out. The calculation of the index is carried out by the Ministry of Construction and Housing and Public Utilities of the Russian Federation based on data received from local governments and regional government bodies. Until now, the index of cities was formed for 1,117 cities of the Russian Federation, without taking into account new regions that became part of the state after 2022 as a result of events in Ukraine.

From 2019 to 2024, there was a generally positive trend in the quality of the urban environment in Russian cities, as evidenced by the increase in the share of cities with a favorable environment by 161 from 2023 to 2024, due to which the number of such cities reached 920. This proves the high efficiency of the methodology and its major role in identifying key areas of urban environment development, as well as priority activities and projects receiving subsidies and investments.

The ICG methodology allows federal government bodies and the President of the Russian Federation to easily track the results of the work of regions and municipalities to improve the living conditions of the population in cities without the need to directly visit them and communicate with representatives of local authorities. This makes the methodology one of the most important tools for achieving environmental and social well-being throughout the country as a whole.

A large number of indicators assessing various characteristics of the urban environment on a 10-point scale are an advantage of this methodology and allow for a comprehensive assessment of the quality of the urban environment. The sum of the scores of all 36 indicators is the desired value of the urban environment quality index.

3 RESULTS

During the assessment of the applicability of each of the 36 indicators of the methodology for forming the ICGSS for adaptation to rural conditions, it was revealed that indicators numbered 1, 4, 6, 17, 20, 23, 24, 28, 29, 30, 34 cannot be used for the purposes of the study. The reasons for this are either the orientation of the indicators exclusively towards the urban environment, or their irrelevance for rural areas due to the presence of certain limitations. However, the remaining indicators (25 out of 36) can be used to develop an adapted methodology for assessing the quality of the rural environment. The applicability of the selected indicators for use in developing the adapted methodology is presented in Table 3.

Table 3: Evaluation of the applicability of indicators of the methodology for the formation of the ICG in rural areas.

№	Description of the indicator in accordance with the ICG methodology	Applicability in rural areas and adaptation options
1	Area of residential premises equipped with basic utilities (water supply, sewerage, gasification) as a % of the total area (m^2)	All residential buildings equipped with both centralized and non-centralized communications, such as wells, boreholes, septic tanks, boiler rooms, etc., should be taken into account.
2	Share of processed solid waste in total volume of generated solid waste (tons)	Applicable without modifications
3	Variety of services in the residential area (% of the total area of the residential area) (m^2)	It can be used, but the calculation must be made as the ratio of the area of functionally diverse areas to the total area of the settlement/district
4	Share of fatalities as a result of road traffic accidents (RTA) in the total population (people)	Applicable without modifications
5	Proportion of streets with storm sewers/drains in the total length of streets (km)	Applicable without modifications
6	Road congestion (coefficient)	Intensity of vehicle traffic on the main roads in the territory of the settlement/district must be taken into account
7	Number of streets with high density of trade and services (units)	Indicator can only be used for large rural settlements where there are streets, at least 25% of the length of which in the 50-meter zone is occupied by trade and service facilities
8	Pedestrian accessibility of points of attraction within an 800-meter zone from each residential building (coefficient)	For rural areas, it is relevant to use pedestrian accessibility standards in accordance with SP 42.13330.2016 “Urban planning. Planning and development of urban and rural settlements" (hereinafter referred to as SP "Urban development"). It is necessary to assess the accessibility of institutions, organizations and service enterprises

№	Description of the indicator in accordance with the ICG methodology	Applicability in rural areas and adaptation options
9	Share of public green areas in the total area of green areas (ha)	Indicator should be replaced by the provision of green areas for public use in m^2 per person, which is regulated by the Joint Venture "Urban Development"
10	Overall level of greenery (%)	Applicable without modifications
11	State of green spaces based on the calculation of the vegetation index (coefficient)	Method for determining the indicator for small settlements and areas can be changed to a visual assessment of the condition of tree stands, due to the high complexity of calculating the vegetation index
12	Proportion of residents with access to public green areas within a radius of up to 800 m (persons)	Applicable without modifications
13	Length of streets provided with lighting as a % of the total length of streets (km)	Applicable without modifications
14	Area of the city where mechanical cleaning is carried out as a % of the total area of the city (m^2)	For rural areas, it is optimal to take into account all methods of cleaning territories, as well as mowing grassy vegetation.
15	Concentration of cultural heritage sites (units per hectare)	Applicable without modifications
16	Pedestrian safety near educational facilities, health care, culture and sports (units per m^2)	Applicable without modifications
17	Provision of sports grounds and facilities within the 800-meter zone (%)	Applicable without modifications
18	Number of road accidents in relation to the population (ratio)	Applicable without modifications
19	Share of city residents living within walking distance of the nearest public transport stop (%)	Radius of the permissible distance of the nearest bus stop from a residential building should be taken, according to the SP "Urban

№	Description of the indicator in accordance with the ICG methodology	Applicability in rural areas and adaptation options
		Development" for small and medium-sized settlements with low-rise buildings - 800 m
20	Proportion of population with access to quality drinking water from centralized water supply systems (%)	For rural settlements and areas not provided with a centralized water supply, it is necessary to assess the population's access to quality drinking water from water intake structures for public or individual use (wells, boreholes, springs)
21	Number of attractive city streets most frequently mentioned in photo publications (units)	It is more appropriate to estimate the number of all objects of interest noted in the publication of photographs, taking into account the 1-kilometer zone around populated areas and districts
22	Share of residents working in the non-production sector of the economy (%)	Applicable, but it would be more appropriate to replace it with the provision of residents with jobs in the territory of the settlement/district or in the immediate vicinity of it
23	Proportion of city residents aged 14 years and over involved in the decision-making process on urban development (%)	It is necessary to take into account the number of requests from residents to local government bodies in person or electronically, as well as the proportion of requests that received a response or decision.

It follows from the data in Table 3 that 10 of the 36 indicators of the analyzed methodology are suitable for use in assessing the quality of the rural environment without changes, since they are not oriented toward urban conditions. 13 indicators can be adapted to rural conditions. Consequently, as a result of adapting the methodology for forming the UEQI, 23 indicators were identified that can be used to develop a new methodology for assessing the quality of the rural environment. However, most of the identified indicators characterize one criterion of environmental quality – infrastructure development. It follows that in order to develop a methodology adapted to rural areas, it is necessary to create new indicators that would characterize all the environmental quality criteria listed in Table 1 of this article.

As a result of the analysis of the methodology for the formation of the ICGSS for the applicability of indicators in rural conditions, the main shortcomings of this methodology as a comprehensive system for assessing the quality of the environment were identified. The analysis of the methodology for the formation of the ICGSS showed that this methodology mainly evaluates such criteria as housing conditions, the level of infrastructure development, its accessibility, safety and modernity. The ecological criterion of the methodology is limited to indicators assessing the level of greening, provision of public green areas, as well as road congestion, which is associated with the presence of constant emissions into the atmosphere. Consequently, the methodology does not allow for a full assessment of the state of the environment from the point of view of negative anthropogenic impact on all its components (air, surface and ground water, soil, land resources). The analyzed methodology also insufficiently evaluates the socio-economic conditions of the environment, the main ones of which include: the level of income of the population, the level of unemployment, the provision of jobs, the provision of social benefits, social status, cultural and educational potential. This methodology also overlooks such an important indicator as the crime rate, which is one of the key indicators of the quality of the environment of populated areas.

We believe that the quality of the environment in private housing estates within urban settlements, which also include SNT and ONT located at a distance from important infrastructure facilities, should also be assessed using a methodology adapted for rural areas. The measure of remoteness of important infrastructure facilities, such as institutions, organizations and service enterprises, should be taken in accordance with paragraph 10.4 of Article 10 of the SP "Urban Development". Provided that the radius of accessibility of the majority of infrastructure facilities on the greater part (>50%) of the territory of the studied private development area exceeds the standard values established by this set of rules for urban settlements, such territory should be equated to rural areas and the quality of the environment should be assessed using an adapted methodology.

4 DISCUSSION

In many countries, there is growing interest in rural development in the context of combating urban imbalances, food security and environmental sustainability. Rural areas are critical for preserving biodiversity, reducing carbon footprints and adapting to climate change, which requires their comprehensive assessment.

Adaptation of urban environmental quality assessment methods to rural conditions is a rare area of research. Most studies focus either on cities or villages, without offering integration. The topic has high global relevance due to the universality of rural problems and moderate scientific novelty, since the adaptation of urban methods is just beginning to be studied. However, the proposed approach to assessing environmental quality through a combination of environmental, infrastructural and socio-economic indicators for rural and semi-urban areas can be considered a breakthrough in the context of the Russian Federation and understudied regions of the world. The study offers a template for creating national indices of rural environmental quality adapted to local conditions.

An innovative aspect of the conducted research is also the inclusion of private development areas (SNT, ONT) in the rural context, although previously they were considered as part of cities.

The study revealed that existing indices for assessing the quality of the environment are not applicable to rural areas, as they are largely focused on urban conditions. Existing urban indices (UQoL, SCI, Walk Score, etc.) are not applicable to rural areas due to low population density, remoteness of infrastructure, and other environmental and socio-economic factors (e.g., the predominance of the agricultural sector, lack of centralized communications). The same applies to areas of private urban development, which often have rural characteristics due to their great distance from important infrastructure facilities. However, the use of these indices for adaptation to rural environment conditions is possible. This was proven by the example of adapting 36 indicators of the Russian methodology for forming the UEQI, which is largely oriented towards urban environment conditions, but can serve as a foundation for creating an adapted index of rural environment quality.

By assessing the applicability of the indicators of the studied methodology and their adaptation, the most suitable indicators for use in assessing the quality of the rural environment were identified, characterizing mainly the development of infrastructure, in connection with which the need was identified to create new indicators that would take into account all environmental criteria.

As a result of the applicability assessment of the indicators of the analyzed methodology, significant shortcomings of the methodology for forming the

UEQI were also identified, consisting in the limited nature of the assessed criteria, as a result of which the assessment of the quality of the environment carried out according to this methodology cannot be considered comprehensive, i.e. characterizing all aspects of the quality environment. In this regard, the development of new index methods should be carried out taking into account the identified shortcomings of existing methods, so that the obtained data on the quality of the environment of populated areas are comprehensive.

The proposed methodology for assessing the quality of the rural environment directly contributes to the achievement of the UN Sustainable Development Goals (SDGs) established by the UN General Assembly in 2015, thereby ensuring synergy between the environmental, social and economic aspects of sustainable development.

Prospects for further work include integrating the proposed methodology into international assessment systems (e.g., taking into account climate risks), as well as using remote sensing data and artificial intelligence to automate the collection of indicators. The implementation of these steps will contribute to achieving global sustainable development goals and improve the quality of life in rural areas of the world.

5 CONCLUSION

The study confirms the critical need to develop specialized methods for assessing the quality of the environment for rural areas and private housing developments, which remain in the shadow of urbanized approaches. An analysis of existing indices revealed their limited applicability to the rural context due to fundamental differences in population density, infrastructure structure, types of pollution, and socio-economic conditions.

The key result of the work was the adaptation of the Russian ICG methodology: 23 of the 36 indicators can be used to assess the rural environment after modification (for example, taking into account decentralized water supply systems, revising the criteria for accessibility of services). However, a comprehensive analysis requires the introduction of new indicators reflecting the specifics of rural areas. The methodology allows for reducing urban-rural inequality through an objective analysis of weak areas (healthcare, education, roads).

Of particular importance is the proposal to evaluate private development areas (SNT, ONT) according to rural criteria given their remoteness from urban infrastructure. This will eliminate the methodological gap in planning the development of mixed territories.

The proposed approach is consistent with the UN SDGs and can be adapted to other countries where rural areas suffer from underfunding and methodological marginalization.

The results of the study confirm that the development of specialized indices for rural areas is a prerequisite for their sustainable development. Further work should be aimed at integrating climate risks and automating data collection through remote sensing technologies.

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