

Modeling of Sustainable Development of Economic and Landscape Zones of the Mountainous Territory of the Kabardino-Balkarian Republic

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Abstract: The article studies and analyzes the indicators of sustainable development of the mountainous territory of the Kabardino-Balkarian Republic, which determine the level of economic security in the region. In the context of modern transformations, the importance of analyzing the indicators of sustainable development of the mountainous territory and their impact on the development of socio-ecological and economic systems is increasing. Special attention is paid to multi-ethnic regions, which are characterized by both a high degree of national and cultural identity and the erosion of conservative ethno-landscape areas. The article provides an exclusive author's definition of the terms "mountainous territory" and "sustainable development." These areas have been zoned based on their natural and socioeconomic characteristics.

1 INTRODUCTION

In the era of great changes in the traditional way of life of the human population, researchers are increasingly focusing on studying the indicators and parameters of sustainable regional development, their impact on ethno-cultural diversity, the evolution of the development of mountainous territories with different cultures and peoples, and the development of agriculture. The traditional nature and integrity of socio-economic and ecological-landscape territories. The relevance of these issues is increasing as the boundaries of ethno-landscape are blurring. In this context, special attention is paid to territories where, along with multi-ethnicity and the preservation of national cultures, special ecological, economic, and social systems - ethnocultural landscapes - continue to be reproduced. The Kabardino-Balkarian Republic is undoubtedly a prime example of such regions.


The uneven distribution of productive forces across Russia's territory, the direction of migration flows towards the "West" and several major cities in the country, and significant differences in wages, infrastructure, and natural resource potential have made sustainable regional development a highly

relevant scientific, practical, socio-political, and economic issue.

In our works, we have repeatedly given the author's definition of the term "mountainous territory," which is an area with rugged terrain and relative elevations of 500 meters or more above sea level, where the natural and climatic conditions create unique local biological, ecological, social, economic, linguistic, and ethno-cultural systems. Mountainous territories are characterized by topographic (latitude, longitude, and altitude), climatic, and biological indicators.

By regional development, we mean development that is aimed at achieving a high quality of life for the region's population and includes positive dynamics in terms of integral indicators of quality of life. It is clear that it is impossible to achieve a high quality of life without the conditions for the reproduction of the social, natural resource, economic, and environmental potential of the territory.

The concept of "stability" means "viability," which is defined as "capable of life and development," i.e., a region that possesses the property of stability is capable of survival and development in its specific environment.

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For systems such as a region, we define a specific threshold of quality of life in that region for a given period of time. This threshold will be referred to as the safety threshold, below which the degradation of natural resources, ethno-cultural, environmental, and other components of the regional system begins, as well as the accumulation of a critical mass of social unrest and system collapse.

The features of sustainable development in the region are an interesting area of study for many scientific teams and research groups. However, there are not many studies on the zoning of mountainous territories based on the characteristics of socio-economic systems and ethno-landscapes, as well as on the research and modeling of sustainable development in mountainous economic and landscape zones. In the study of this problem, I would like to mention G. E. Avakyan, who believes that "a mountainous territory should be understood as a space where all quantitative and qualitative changes occur in vertical zones, where the profile, nature, and conditions of agricultural production, and especially the productivity of collective social labor, differ significantly from those of the plains and especially the low-lying regions" (Avakyan, 1989).

In today's speed and scale of urbanization of territories, methods of planning regulation of anthropogenic loads in the process of formation of the structure of settlements play a significant role. The works of A.N. Guni (Gunya, = 2010) are the methodological foundation for resolving environmental problems in mountainous territories.

The study of the features of socio-economic development, settlement, and demographic development of mountainous areas was based on the works of R.A. Buraev (Buraev, 2005), N.A. Arakcheev, A.D. Badov, and others (Arakcheeva Badov 1998).

P.M. Ivanov (Ivanov, 2006), S.A. Makhosheva (Galachieva, SMakhosheva, Kokov, 2017; Makhosheva, Kandrokova, 2019; Makhosheva, Gurtuev, Ivanov, 2024), A.O. Gurtuev (Makhosheva, Gurtuev, Ivanov, 2024; Gurtuev, Boziev, Ivanov, 2025), Abdulmanapov P.(Abdulmanapov, Galbatsdibirova, 2015), Gadieva A. N. (Gadieva, 2020), Sheina S. G. (Sheina, Fedorovskaya, Chubarova, 2022), Kosmacheva N. M., (Kosmacheva, Cherkasskaya, 2020), and others have made significant contributions to the study of the socio-economic development of mountain regions, the rational and careful use of the rich natural resources of the mountains, and the role of municipalities in ensuring the sustainable development of mountainous territories.

2 RESEARCH OBJECTIVE

Study and analysis of indicators of sustainable development of the mountainous territory of the KBR.

The object of the study. The territorial framework of the study includes the four economic and landscape zones of the KBR, which we have identified based on a number of related economic and landscape-zonal indicators. These indicators include the steepness and height of the slopes, the dissected nature of the terrain, the soil cover, biodiversity, the instability of the slopes, the landscape zonation, the accessibility of the interior territories, the economic structure, the natural resource potential, the recreational load, resource use, and the environmental, social, linguistic, and ethnocultural parameters. The earlier zoning of the mountainous territory of the Kabardino-Balkarian Republic has the following structure (economic and landscape mountain zones of the Kabardino-Balkarian Republic) (Gurtuev, Ivanov, 2022):

I. Western mountain economic and landscape zone (the northern side of Elbrus, the Malkinsky Gorge up to the Kavkaz highway).

II. Central Mountain Economic and Landscape Zone (Prielbrusye National Park, the city of Tynyauz, and all rural municipalities of the Elbrus District, part of the Baksan and Chegem Districts up to the Kavkaz Highway).

III. Nalchik Mountain Economic and Landscape Zone (rural municipal settlements in the south and west of Nalchik up to the Caucasus Range).

IV. Eastern Mountain Economic and Landscape Zone (Khulam and Cherek Gorges, parts of the Lesken and Uruk River basins above the Kavkaz Highway).

3 MATERIALS AND METHODS OF RESEARCH

The study was based on data from the Federal State Statistics Service of Russia and its Kabardino-Balkarian branch, the household books of the municipal formations of the mountainous territory of the Kabardino-Balkarian Republic, service-providing organizations, and the authors' materials obtained during field research.

During our research, we used scientific methods such as economic and statistical analysis, analytical and comparative methods, observation, description, and simulation modeling. We also used methods of

analysis, synthesis, and cartography to identify economic and landscape zones within the mountainous territory of the Kabardino-Balkarian Republic.

4 THE RESULTS OBTAINED AND THEIR DISCUSSION

The threshold value of the economic security indicator

is the limit value of the sustainable development indicator, exceeding or underachieving which leads to the beginning of degradation processes in the territory. In other words, this is something that should not be allowed. The target guideline answers the question: "What should we strive for?" The target guideline corresponds to or exceeds some established norm regarding a well-being state in terms of certain indicators of the population's quality of life.

The i -th indicator of the region's sustainable development is:

1. production security;
2. investment security;
3. the nature of changes in the region's gross domestic product;
4. scientific and technical security;
5. foreign economic security;
6. energy security;
7. financial security;
8. social security;
9. demographic security;
10. criminalization of society;
11. food security;
12. environmental safety.

From the interaction scheme of the control and operating structures noted at the very beginning, where the operating structure reflects information about the state of the region, which is received at the input of the control structure in the form of sets of logical conditions, as well as from the content of the logical conditions defined above for all sustainable development indicators, it follows that the state of the region has three types according to the levels of economic security:

– normal state, when $\alpha_i = 1$, i.e., when the current value

of the economic security indicator is greater than or equal to the target;

– pre-crisis state, when $\alpha_i = 0$, i.e. when the current value

is between the target guideline and the safety threshold;

– crisis state, when $\alpha_i = n$, i.e. when the current value of the economic security indicator falls below the safety threshold.

To formalize the concept of sustainable regional development

let us refer to the definition of this concept: "the ability of a region to preserve and develop the value of the necessary parameters of the quality of life within (above) the safety threshold in the face of wide fluctuations of external and internal disturbances (social-political, socio-economic, technogenic, natural-climatic, etc. nature), threatening the fall of the quality of life, determines the sustainability of regional development."

For our purposes, let us return to algorithmic algebras (AA) and give two definitions (Shilova, Shilov, 2015). We introduce the parallel execution operation in AA, which is denoted by the symbol $*$. This operation has the following properties:

$$\begin{aligned} (S * P)Q &= SQ * PQ, & S(P * Q) &= SP * SQ \\ S * S &= S, & S * \emptyset &= \emptyset * S = S, \\ S * E &= E * S = S, & S * P &= P * S, \end{aligned}$$

Where, E and \emptyset – respectively, the identity and indeterminate operators.

By scanning $r(S, m, M)$ operator expression S on the element m information set M , we call the word in the alphabet $Y = (y_1, y_2 \dots)$, which is obtained as a result of execution of this expression S , where $y_1, y_2 \dots$ are the basis operators.

Let's call the operator expression S applicable if at least one interpretation of the unfolding $r(S, m, M)$ it is finite.

Let's denote the conjunction $\beta_1 \wedge \beta_2 \wedge \dots \wedge \beta_m$ using β ,

where m - number of quality of life indicators.

Let $\alpha = \alpha_1 \wedge \alpha_2 \wedge \dots \wedge \alpha_n$, where n - the number of indicators of economic security in the region.

We will now give a formalized definition of sustainable regional development.

A region has the property of sustainable development if the following operator expression is applicable:

$$\{ \{ \{ \alpha_1 (E \vee P_1 \vee K_1) * \alpha_2 (E \vee P_2 \vee K_2) * \dots * \alpha_n (E \vee P_n \vee K_n) \} \} N \} \\ t = T \quad \mu \quad \gamma$$

Where, $\mu = \beta (1 \vee 0 \vee 0)$, $\gamma = \alpha (1 \vee 0 \vee 0)$, P_i

and K_i - operators performed in the pre-crisis and crisis states of the region, respectively, to bring the region back to normal.

N - an operator executed under normal conditions in the region,

T - is the time period under consideration, and t - is the current time.

This expression is called the algorithmic formula for sustainable regional development. How does this formula work? The process begins with a check of the condition $t = T$. If it is false, then enter the loop and check $\mu = \beta (1 \vee 0 \vee 0)$ i.e., condition β .

If $\beta = 1$ (the current values of all quality-of-life indicators have reached the target), then $\mu = 1$ (we exit the loop), and the region enters the normal state (N is executed).

As soon as β takes the value of 0 or n (the region enters a pre-crisis or crisis state, respectively) μ takes the value γ , that is, to verify the condition α . From the definition α it shows a generalized assessment of the severity of the crisis situation in the region

$i - i$ indicators economic security (for all α_i , the value is checked to see if it is 1 or 0 or n). If $\alpha = 1$, that $\gamma = 1$, this means that we exit the inner loop and return to the check μ , i.e., to assess the quality of life in the region.

By $\mu = 0$, hardly all of them α_i they will be equal 1. Most likely in this case $\alpha = 0$ or $\alpha = n$. Then $\gamma = 0$, i.e., we enter the inner loop and proceed to parallel execution of statements $\alpha (E \vee P_i \vee K_i)$, $i = 1, \dots, n$. Depending on the meaning of each of them α_i

(i.e., the severity of the crisis situation is determined in all areas and sectors of the region) in each i now we go either to the program P_i (a program for overcoming the pre-crisis situation), or K_i (a program for overcoming a crisis). After that, we return to the verification γ , i.e. to the question: have we overcome the states $\alpha_i = 0$ and $\alpha_i = n$?

If not, then the loop repeats again. If yes, then we exit the inner loop and check. This process continues until it becomes $\mu = 1$ through $\beta = 1$, i.e. until the current state of the quality of life reaches the target. If this process ends after a finite number of steps (i.e. the operator expression is applicable), then the region has the property of sustainability.

5 CONCLUSION

The simulation model we have developed is universal and can be used to study the problems of sustainable development in mountainous areas of all regions in southern Russia.

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