DETERMINING ECOLOGICAL STABILITY WITHIN THE SPATIAL PLANNING OF THE TERRITORY OF THE REPUBLIC OF MOLDOVA

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Abstract: *In a period when environmental responsibility is becoming more and more important, Republic of Moldova has to take decisive steps in favour of a more sustainable and environmentally friendly future. In this context, the rational use of land resources is one of the effective ways to promote these positive changes. When we recognize the need to invest in a greener future, we understand that this choice is not just a symbolic gesture, but a smart and important step for those who want to live today and in the future in a greener environment.*
The main purpose of the article is to determine the sustainability and ecological stability of the environment on the territory of the Republic of Moldova and to develop recommendations for the development of the territory from a social, economic and ecological perspective, in the context of the protection of limited natural resources. The article presents generalized values of regional environmental indicators of sustainable development and assesses the natural and anthropogenic instability of the environment.

Keywords: Cadastre; Territorial Organization; Land Resources; Sustainable Development; Ecological Stability of the Territory; Ecology

1. Introduction

It has been proven that sustainable development is based on the balance of economic, social and environmental stability. Furthermore, the greatest concern is related to the environmental aspect. The upcoming reform of decentralization will certainly be aimed to solve the environmental problems, but this process is long-term and requires significant resources. Determining the stability of the environment and the anthropogenic load on the territory of mergedterritorial communities plays a key role in ensuring the sustainable development of rural areas. The ecological development of the region is an important component of sustainable spatial development and the basis for harmonizing the objectives of socio-economic development with the principles of environmental protection.

Scientific novelty. It is proposed to consider the development of environmental protection in the region as a systemic category that combines social, economic and environmental components. The interaction of these components implies a transition to ecologically balanced production and consumption structures, increasing the efficiency of environmental management and developing environmental infrastructure.

Practical significance. It is proposed to evaluate the environmental dimension of spatial development of territories according to the following indicators: air quality, biodiversity status, use ofland resources, presence of green areas, population's access to water, use of renewable energy sources, energy resource status, atmospheric emission volumes, land loading and water resource efficiency, wastewater disposal system efficiency, radiation level and environmental safety, waste generation and management, contribution of

commercial entities to environmental payments, public participation in environmental protection, greenhouse gas emissions, as well as the population's satisfaction with the state of the environment.

2. Materials and methods.

The methodological basis of the study includes general theoretical methods of scientific knowledge, such as the dialectical method, system analysis and the basic principles of general economic theory. To analyze the level of ecologically sustainable development of the regions, methods of comparative and structural analysis and statistical groupings were also used. The tabular and graphical method was used to visually display the dynamics of indicators. The methodology was carried out using the example of the Republic of Moldova as a whole and separately by regions.

The initial materials for conducting the study were systematized information from the land cadastre for 2023 [6]. The content of the work is focused both on the results of previous publications of the authors and on the works of other scholars in the country and abroad.

3. Results and discussion.

Problem statement. In the modern socio-economic and difficult political conditions on the territory of Republic of Moldova, in order to increase the efficiency of business structures management and ensure an adequate level of population’squality of life, it is important to solve the problems of ecological development of the territory within the regions or administrative entities. Today there are many problems in the country. One of the main ones is that the administrative-territorial structure at the district level is outdated. Districts are still of the Soviet type. The structure is inefficient: it uses a lot of resources and is not profitable. Consequently, this hinders the development of local self-government. The problems of crisis, pandemic, war and concern with the refugee problem were the main reasons that blocked the implementation of the necessary reforms. In this matter, Ukraine has advanced and now, even during military operations, is trying to develop and implement socio-economic projects (comprehensive plans) on the territories of newly created communities.

Therefore, the Government of Moldova should promote the adoption by the Parliament of adequate environmental laws to fully implement the environmental provisions of EU legislation stemming from the Association Agreement. New approaches should be adopted when developing environmental policy and legislation, including convergence with the key principles governing EU framework legislation[1].

Determining the degree of sustainability and stability of ecological systems is an important and urgent task today. Sustainability is one of the key parameters of any system, including environmental. It is defined as the ability of an ecosystem to maintain its structure and functions under the influence of external factors. Ecological stability is characterized by the ability of ecosystems to resist internal abiotic and biotic factors, as well as anthropogenic influence. Taking into account these parameters it makes possible to apply a systematic and scientific approach to the choice of measures to improve the ecological balance in regions.

Therefore, in order to ensure the environmental stability of the region, it is necessary to determine the level of anthropogenic impact on the territory and optimize it, this is especially important for rural areas. Environmental pollution, improper use of the potential of natural resources and insufficient implementation of environmental innovations lead to an environmental crisis, which is accompanied by a crisis in the socio-economic system of entire regions. Therefore, today special attention should be paid to the diagnosis of ecological

development. It is also necessary to develop and make management decisions on the greening of production in the regions, to increase the economic efficiency and competitiveness of commodity producers, taking into account the environmental factor. When analyzing the issue of greening production, it should be noted that now energy consumption is an objective condition for the existence of mankind.

In the scientific research concerning the literature on the nature of Moldova, there has been a tradition of identifying 3 main natural-geographical zones - North, Center, South and Left Nistru.

The purpose of this scientific study was to conduct an assessment of the ecological stability and sustainability of the territory of the Republic of Moldova, as well as the individual regions mentioned above for the year 2023. The main tasks included: analysis of the structural distribution of the land fund of the Republic of Moldova and the study of changes in land use, assessment of the environmental parameters of a balanced territorial organization, taking into account current anthropogenic loads, as well as analysis of the environmental sustainability and stability of the country's territory, taking into account abiotic and biotic elements and their impact on the integrity and balance of individual regions.

Throughout the territory of the Republic of Moldova, where within natural regions and administrative districts, plowing reaches over 75%, and the area of degraded land is constantly increasing, the relevance of this type of research is obvious.

Analysis of the latest research. Soil degradation is becoming a growing problem for the country, as over 45% of land is affected by erosion and over 112.400 hectares are at risk of desertification. In recent years, soil erosion has captured new areas with an area of approximately 7 thousand hectares each year.

The main causes of soil degradation include poor agricultural practices - problems related to ignoring crop rotation and returning organic matter to the soil - as well as natural causes - geological structure and rainfall runoff, and many other reasons.

In the modern conditions of global challenges, changes are observed also in production, consumption and logistics technologies. These changes significantly affect all aspects of life, both in rural areas and in cities. The environmental aspect plays an important role in the modern development of rural areas in developed countries of the world. Transformations in the rural environment are viewed through the prism of automation of production processes in the context of historical development. As for the greening of production, the process of forming environmental awareness and the corresponding culture took place in stages. Many scientists have studied the greening of production and the sustainable development of rural areas and communities, taking into account environmental factors.

In the late 1980s and early 1990s, Slovak scientists (I. Riborski, E. Gojke, E. Klementova and V. Heinige) proposed and developed a methodology for assessing the influence of land composition on the level of ecological stability of the territory, which made it possible to a certain extent to compare, evaluate and optimize the structure of land use.

In Republic of Moldova, scientists have monitored the ecologically sustainable development of rural areas in the context of global challenges and have researched rational environmental management as an element of sustainable development of rural areas: S. Andrieş, V. Cerbari, I. Crupenicov, T. Leah, A. Ursu, D. Bolteanschi and others.

When calculating stability, the determination of the coefficient characterizing the ecological value for the environment of each element of the territory (Kýj) was carried out taking into account the results of the calculations of Kэj proposed by P. P. Borshchevsky [1], who applied this technique on the example of one of the regions of Ukraine.

Kostyshin A. A., Tibolova L. M. [2] proposed a developed methodology for

introducing correction factors for relief to determine the environmental stability of the territory for agricultural lands. And it is precisely these environmental stability coefficients, adjusted for relief, that are recommended to be used when making management and design decisions.

O.P. Kanash [4] proposes that environmental premises for land use optimization be determined using the index of environmental inconsistency of existing land use and the excess of acceptable plowing.

Significant theoretical and practical developments in determining environmental stability and anthropogenic load on the territory of united territorial communities were achieved in the context of the implementation of administrative-territorial reform in Ukraine[5].

Therefore, the main formulation of this article will be the determination of environmental stability and anthropogenic load on the territory of the Republic of Moldova as a whole and in the context of natural regions.

In the field of land use, there are various methods for assessing the ecological sustainability of territories. For example, many of the scientists listed above propose measuring environmental sustainability using a coefficient, the values of which can be used to determine the following categories: unstable territory (with Kst.ec. ≤ 0.30); unstable stable (at Kst.ec. = 0.31 ... 0.50); moderately stable (with Kst.ec. = 0.51 ... 0.67); and stable (with Kst.ec. > 0.67).

Currently, there is no developed land structure optimized from an ecological point of view for Moldova. What is common in approaches to solving this problem is the recognition of the need to reduce the share of agricultural land, especially multi-annual plantations, as the share in the country's land fund. When determining quantitative indicators, it is important to take into account the landscape, soil structure and framework regulatory documents.

In the past, large territories of our state contributed to the development of an extensive system of agricultural land organization, as well as to the formation of an extensive way of thinking and life. Increasing the area of arable land has always been considered the only way, althoughharmful for the future, to increase agricultural production.

Rational use of land resources and their protection include three main areas:

- ✓ economic, associated with protecting the land from depletion and increasing its fertility;
- ✓ environmental, aimed at preventing land pollution and combating its consequences;
- ✓ social, which involves ensuring the minimum acceptable level of well-being of the population, especially in rural areas.

Social, economic and organizational obstacles that limit the possibility of increasing the area of natural landscapes without anthropogenic load significantly complicate the task of achieving harmony between society and nature. The degradation of land resources makes it necessary to develop a scientifically based state policy in the field of their use and protection, as well as to create mechanisms for the preservation and improvement of national wealth - productive lands.

The ability of a territory or a natural-technogenic system to withstand anthropogenic impact and maintain ecological balance determines its natural security. It is known that the stability of an ecosystem increases with the increase in its biological diversity, and the stability or security of a territory increases with the increase in its landscape diversity.

The presence of environmental protection zones and the uniform distribution of areas with natural biogeocenoses also help to increase the natural protection of the territory.

The highest degree of ecological and economic balance can be achieved through the conscious and joint formation of new socio-economic systems, in cooperation with self-government bodies, the business environment, scientific communities and the population.

The index of environmental non-compliance with existing use and exceeding the permissible level of plowing [2] assesses the ecological state of territories by natural-geographical zones and provinces.

The ecological stability coefficient of a territory is based on the level of sustainability of individual types of terrain. It allows assessing the ecological stability of various administrative-territorial entities both qualitatively (unstable, conditionally stable, moderately stable and stable) and quantitatively (through the values of the coefficients).

The indicator of ecological stability of a territory is used for organization of land monitoring, which includes monitoring the state of the land fund in order to quickly identify changes caused by human activity. Also, this indicator is used in the development of territorial organization projects, for ecological and economic justification of crop rotations, land management, land use planning, prevention and elimination of negative consequences, including control and protection of limited land resources.

The rational use of natural resources is determined by indicators of the structure of land use and the quality of the ecological potential of the land. To assess the impact of land composition on the ecological sustainability of the territory, it is proposed to calculate environmental stability coefficients.

The composition of the land in any natural-territorial complex or administrative-territorial entity has a significant impact on the ecological stability of the territory. Research shows that the increase in agricultural development and arable land leads to an unbalanced load and a decrease in the ecological sustainability of landscapes, which determines soil degradation and the development of erosion processes. At the same time, an increase in the share of ecologically sustainable lands (forests, wetlands) contributes to the formation of more stable landscapes.

In modern complex ecological and economic conditions, the assessment of the stability of the territorial structure remains relevant. However, with the development of scientific knowledge, the need for the integrated application of various methods and approaches to the formation of sustainable agricultural systems and the use of integrated assessment indicators becomes obvious.

Table 1. Land characteristics on the territory of Moldova

Geographic regions (areas)	Total area	Agricultural land, total	Locality lands	Land intended for industry, transportation, etc.	Land for environmental protection	Forest lands	Water lands
	ha	*ha*	*ha*	*ha*	*ha*	*ha*	*ha*
	%	*%*	*%*	*%*	*%*	*%*	*%*
North	1001671	767061	93481	17995	427	93508	29199
	29.6	76,58	9.33	1,79	0,04	9.34	2.92
Center	1120320	724036	115611	19050	2057	230093	29473
	33.09	64,63	10.32	1.7	0,18	20.54	2.63
South	922850	718378	60424	12152	651	106195	25050
	27.26	77,84	6.55	1.32	0,07	11.51	2.71
Left bank of the Dniester	340103	249126	50650	10883	1075	22383	5986
	10.05	73,25	14.89	3.19	0,32	6.58	1.76
Total	3384944	2458601	320166	60080	4210	452179	89708
	100	72,6	9.5	1.8	0,12	13.4	2.6

Source: developed by the author based on data from the Land Cadastre of the Republic of Moldova, 2023 year [6]

Natural and agricultural zoning (Table 1) makes it possible to take into account the diversity of natural and economic indicators, as well as territorial and economic characteristics of the structure of the land fund and the state of the soil cover, including geomorphological, climatic, erosion and other characteristics of the territories. Detailed zoning of the territory provides the opportunity to fully take into account territorial differences in natural and economic conditions, which ensures a more accurate understanding of the regional characteristics of the area, such as the qualitative state of the soil, water regime, emissions from enterprises, the nature and directions of geochemical migrations and other aspects.

From the calculations in Table 1, we see that the Central region of the total area of Moldova occupies the largest area - 33.09%, the North region - 29.6%, the South region - 27.26%, and the Left Bank of the Dniester is almost a third smaller in area. As for the category of land use, the situation is slightly different. Agricultural lands are predominantly in the South, North and Left Bank of the Dniester regions - 77.84%, 76.58%, 73.25%, which indicates the high degree of cultivation of these territories, and the Central region accounts for 64.63%. This figure is lower than in the entire country - 72.6%, but the previous regions have a higher value than in the entire republic.

The general coefficient of ecological stability of the territory (Kst.ec.) is usually calculated using the following formula:

$$K_{st.ec.} = \frac{\sum K_{1i} \times P_i}{\sum P_i} \times K_r, \textbf{ (1)}$$

where K1i is the coefficient of ecological stability of land type i; Pi – land area of type i; Kr is the coefficient of morphological stability of the relief (Kr = 1 for stable territories and Kr = 0.7 for unstable territories) [1].

The methodology for assessing the influence of the structure of the land fund on the level of ecological stability of the territory involves taking into account not only the total area of land of various categories, but also the introduction of the environmental properties of each type of land, which are reflected in the coefficient of environmental stability.

Table 2. Standard value of the environmental stability coefficient for different types of terrain

Type of terrain	The ecological stability coefficient of the territory (K1)
Built-up area and roads	0.00
Arable land	0.14
Vineyards	0.29
Forest strips	0.38
Orchards, bushes	0.43
Gardens	0.50
Meadows	0.62
Pastures	0.68
Ponds and marshes of natural origin	0.79
Forests	1.00

Source:[2]

Table 3 Grading scale for the values of the ecological stability coefficient of the territory

Ecological stability of the territory	The value of the ecological stability coefficient of the territory
Unstable Unstable stable Moderately stable Stable	<0,3 0.34 – 0.50 0.51 – 0.66 >0.67

Source:[2]

Environmentally favorable elements include areas with natural vegetation, such as meadows (Spaj.), forests (Spăd.), steppes (Sst) and other types and combinations thereof, as well as lands with water resources (Sa), and other similar areas.

Elements that have a negative impact include anthropogenically modified areas, such as land under settlements (Sloc), buildings and road infrastructure (Sdr), land under quarries and mineral extraction sites, unauthorized waste disposal sites (Scar), arable land (Sa), land used for industry, transport and communications (Sind), livestock farms, as well as eroded areas that may have a negative impact on the territory.

Table 4 Calculations of the ecological stability of the territory of Moldova

Land use categories	$K_{st.ec.}$	Northern region	Central Region	Southern Region	Left bank of the Dniester	Total area, ha
Agricultural land, ha	0.14	767061	724036	718378	249126	2458601
K1i Pi		*184802.4*	*184014.2*	*164712.6*	*46424.7*	*579953.9*
Land of villages, towns, municipalities	0.0	93481	115611	60424	93508	29199
K2i Pi		*0*	*0*	*0*	*0*	*0*
Land intended for industry, transport, communications and other special purposes	0.01	17995	19050	12152	10883	60080
K3i Pi		*179.9*	*190.5*	*121.5*	*108.8*	*600.8*
Land for environmental protection, sanitary purposes and land development	0.9	427	2057	651	1075	4210
K4i Pi		*386.1*	*1851.3*	*585.9*	*967.5*	*3789*
Forestry lands	1.0	93508	230093	106195	22383	452179
K5i Pi		*93508*	*230093*	*106195*	*22383*	*452179*
Waterbed lands	0.79	29199	29473	25050	5986	89708
K6i Pi		*23067*	*23284*	*19790*	*4728.9*	*70869.3*
Total		1001671	1120320	922850	340103	3384944
Kni Pi		301943.6	439432.5	291405.6	74613.4	1107392
Kec.st		0.3	0.39	0.32	0.22	0.33

Source: developed by the author based on tables 1, 2 and 3.

The calculations given in table 4 indicate a not very favorable environmental situation in the republic as a whole, and separately by regions.

In general, the coefficient of ecological stability of the territory in the republic is 0.33. This, according to Table 3, indicates an unstable and vulnerable stable situation in the country. The same assessment is given separately for each region, with the exception of the Left Nistru Region, which is assessed as “unstable”. The area of this region occupies a little more than 10% of the entire territory of Moldova, which, in turn, indicates the implementation of

activities that are responsible for environmental stability (afforestation, grassing of lands and other activities).

To assess the significance of both positive and negative impacts, it is necessary to identify the highest priority elements that will make the greatest contribution to the processes of stabilization or destabilization of the studied territory.

Calculations based on the Kst.ec. coefficient reflect the level of ecological stability of the studied territory, which is important to take into account when choosing appropriate measures for its protection and transformation.

When calculating the environmental sustainability and stability of regional territories, data on the structure of the land fund of the studied region are used. The territory of the entire Moldova includes lands of all categories (according to art.3, paragraph 3, the Land Code of Moldova, provides for 6 categories of land use). On average, almost 73% of the total area of the region falls on agricultural lands, of which 88.9% is agricultural lands (lands systematically used for agricultural production), and non-agricultural lands represent only 1.1%.

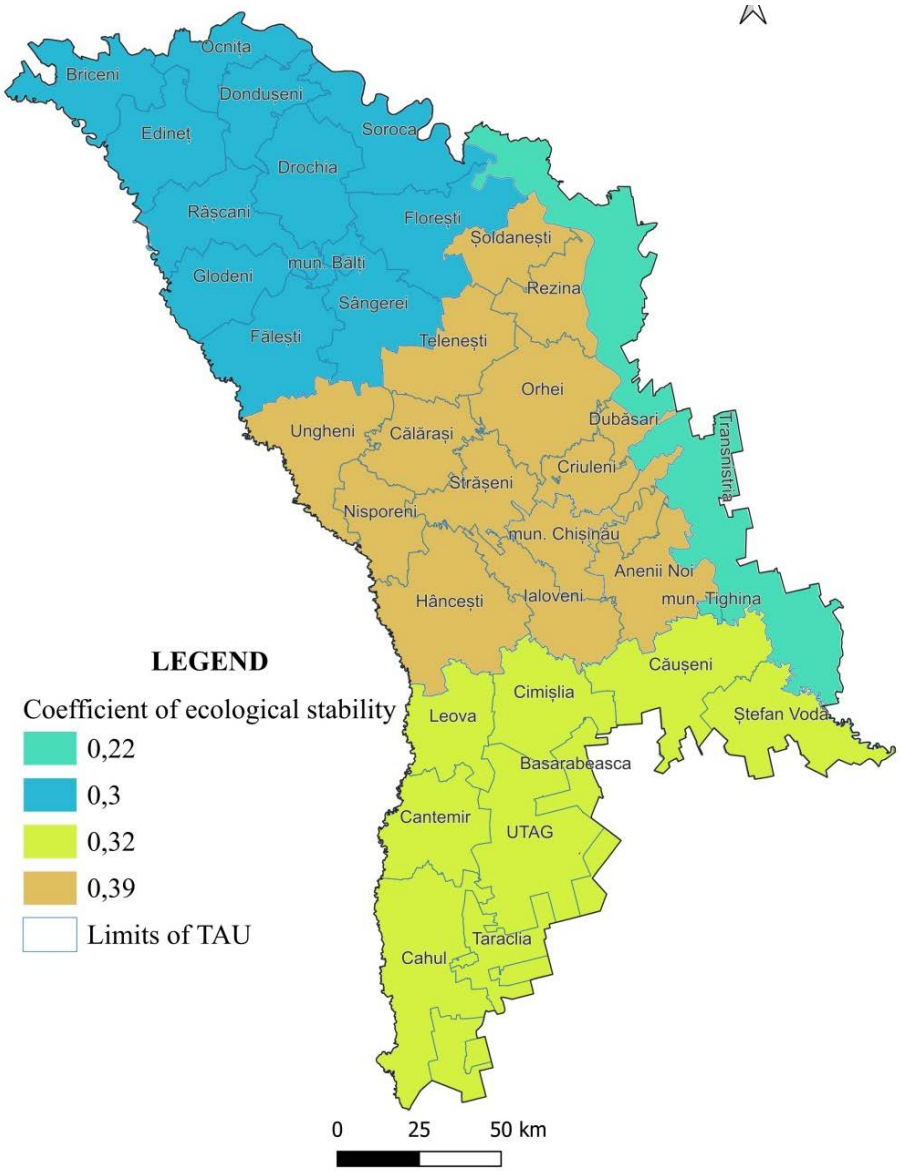

Figure 1. Variation in ecological stability of the territory of the Republic of Moldova
Source: developed by the author based on table 4

The methodology for assessing the influence of the land fund structure on the level of ecological stability of the territory involves taking into account not only the total area of land by destination category, but also the environmental characteristics of each type of land. These characteristics are reflected in the ecological stability coefficient, which takes into account the ecological significance of each type of land.

Since 72% of the studied area is classified as agricultural land, of which approximately 93% is occupied by agricultural land, it is necessary to take into account the ratio of stabilizing and destabilizing influences in the agro-ecological landscape, especially in this category of land.

The stabilizing elements of the agricultural fund are considered to be arable land intended for the cultivation of perennial crops, such as pastures and hayfields. Destabilizing are arable land that is systematically used for annual crops, the intensive exploitation of which (annual plowing, land improvement and improvement works) reduces the ecological sustainability of the territory.

4. Conclusions

Thus, analyzing the environmental situation on the territory of the Republic of Moldova according to the main environmental parameters, taking into account the maximum permissible and optimal load, from the point of view of the environmental stability level and sustainability, we can conclude that the territory is currently characterized as slightly unstable with clearly expressed violations of natural structures (the value of the Kst.ec. indicator in the North Region -0.3, the Central Region - 0.39, the Southern Region - 0.32) and as unstable (Kst.ec. = 0.22 in the Left Bank of the Nistru River). This is due to the fact that the territory of the entire republic maintains a high level of arable land cover - over 70%, with optimal environmental parameters from 40% to 45%, an extremely low share of forest areas - this figure in general, 13.4%, remains below the maximum permissible ecological significance (the norm is the range from 20% to 30%), an insignificant area of nature conservation areas - 0.12%.

All calculations indicate that a systematic reduction of the anthropogenic load on the land fund of Moldova through environmental zoning, the creation of an environmental framework, an increase in the area of specially protected natural areas, forest lands, as well as a more rational use of land resources (reduction of the area of productive lands) will contribute to increasing the ecological balance of the regional territory.

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