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ESTIMATION OF ECOLOGICAL STABILITY OF SMALL TOWN BUCHA IN KYIV REGION

The purpose of the study is to assess the ecological balance of the small town Bucha in Kyiv region for the environmental justification of the long-term plan for the development of the urban landscape. The integrated assessment of the ecological state of the town territory is researched taking into account the heterogeneity of the impacts and ecological significance of each biotechnical element of the town. The analysis of the distribution of urban lands according to the General City Development Plan allowed tracing the dynamics of the areas of certain categories and the changes associated with it in the ecological state of urban territory. Ecological balance of the urban landscape was determined by the analysis of ecogeographic indicators, which are represented by the coefficients: anthropogenic load, anthropogenic transformation, natural protection, ecological stability, absolute and relative tension of the ecological and economic condition of the town. It's established that the coefficients of anthropogenic load, ecological stability and natural protection of the landscape are 4.25, 0.15 and 0.66 respectively, according to which the town is characterized as an ecologically unstable urbun landscape. The coefficient of anthropogenic transformation of the territory, which characterizes the share of anthropogenic modified territories in the structure of land use, will increase from 0.66 (now) to 0.75 (after 20 years), which in both cases corresponds to the increased value. The ecological and economic state of the territory is not balanced by the degree of anthropogenic load and rational correlation of ecologically stabilizing lands. Prognosis data indicate a further deterioration of the environmental situation. The expediency of use of ecogeographic indicators for optimization of general planning of the town territory is substantiated.

Keywords: *anthropogenic load; ecogeographic indicators; ecological fund; urban environment.*

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ОЦІНКА ЕКОЛОГІЧНОЇ СТАБІЛЬНОСТІ МАЛОГО МІСТА БУЧА У КИЇВСЬКІЙ ОБЛАСТІ

Проведено комплексну оцінку екологічного стану невеликого містечка на прикладі міста Буча Київської області. Оцінка базується на неоднорідності впливу та екологічної значимості кожного елемента біотехнічної системи міської території у розумінні поєднання екологічно стабілізуючих угідь (луки, ліси, пасовища, водойми) з іншими площами (забудова, дорожня мережа тощо). Аналіз розподілу міських земель відповідно до Генерального плану розвитку міста забезпечив можливість простежити динаміку територій окремих категорій та зміни, пов'язані з нею, в екологічному балансі міських територій. Коефіцієнт антропогенного навантаження становить 4,25, що вказує на його високий рівень, а коефіцієнт екологічної стійкості ландшафту 0.15 характеризує місто як нестійку територію. Отже, місто Буча є екологічно незбалансованим: поєднання високого антропогенного навантаження з підвищеним значенням коефіцієнта природного захисту 0,66, а прогнозні дані вказують на подальше погіршення екологічної ситуації. Обґрунтовано доцільність використання екогеографічних показників для оптимізації загального планування міста.

Ключові слова: *антропогенне навантаження; екогеографічні показники; екологічний фонд; міське середовище.*

Introduction

Determining ecological stability of ecosystems is the basis of the general planning of the development of urban areas that is the main component of the conception of development a sustainable urban environment. At present, global sustainability is critically dependent on towns that are centers of not only socio-economic development but also of key environmental issues, and their dynamic unstable development trajectory should be directed towards more desirable areas by planning on the principles of sustainable development [1]. The interest in restoring urban ecosystems as part of such adaptation strategies is increasing globally [2].

Changes in land use at the town level can also have widespread environmental consequences: the higher the ecological values of the territory transformed into a building, the more significant the negative impact on the environment [3]. Little is known about the dynamics of urban green spaces that counteract the effects of urbanization [4, 5].

When considering issues of stability and optimiza-

tion of land use, a system of indicators of investigated processes and quantitative estimations is required, as well as knowledge of qualitative and quantitative characteristics of the elements of the landscape [6]. Most urban land-use researches have been conducted in Europe, North America and China [7].

Urban planning is mainly in land use decisions [8]. Accurate and timely information on the structure of land cover and its changes is crucial for decision-making in urban planning [9]. Butrym [10] believes that the coefficient of ecological stability of the urban area is one of the indicators that allow evaluating the effectiveness of the greening system of a town.

The research is carried out within the framework of development of conceptual foundations of the system of green plantations in small towns of Kyiv region in the context of ecologically balanced development. More than 68% of the population of the Kyiv region live in towns, 77% of them are small. This category is the most widespread and least studied. In Kuybida & Bilokon opinion [11], the general plans of small towns should focus primarily on the search for territorial resources to increase their resilience and attractiveness for business and tourism, while strictly limiting the sources of environmental and technological danger, which will allow small towns to become the basis for harmonizing social life, social stability and the cultural revival of society.

The purpose of the study is to provide a comprehensive assessment of the ecological balance of the small town Bucha in Kyiv region with a view to substantiated correction of the long-term urban development plan that would contribute to its ecological stability, as well as to compare the results with the indicators for the territories of other small towns in the region.

Objects of the research

The area of Kyiv region (without Kyiv city) is 4.7% of Ukraine, and the population is 4.1%, of which 68.1% is urban. There are 26 towns in Kiev region of which 20 are small (towns with population of 10 to 50 thousands). The population of Bucha town is 27.9 thousands. The town is located in the central part of the region at 23.0 km southwest of Kiev ***(Fig. 1).***

Bucha is part of a suburban metropolitan area, limited to a radius of 60-80 km, whose priority direction is the preservation of a common landscape and recreational system of green plantations. Territory of the town is located in the Kyiv Polissia region, according to agroclimatic zoning – in the area of sufficient heat supply, moderate humidification (the average annual rainfall is more than 650 mm), in the floodplain of the river of the same name, on swamp and peat soils. Living conditions of the population are rated as moderately favorable.

The structure of the housing fund of the city is 56.5% represented by multi-apartments buildings and 43.5% by estate buildings. According to the town general plan, the total area of the territories that can be developed for housing building is 470.0 hectares, including 62.0 ha of garden companies, which are being reconstructed for estate development. It should be noted that such a trend is no exception and is widely spread throughout the world [12].

Methods of the research

To optimize the functional structure of current anthropogenic landscapes and reduce the anthropogenic loads on the environment, the ecological balance of the ratio of the main types of land or the optimality of the structure of the land fund is estimated [10]. The assessment is based on inversely proportional indicators of the ecological stability of the territory and the indicator of anthropogenic load on the territory, which characterizes the importance of the structure of land use categories for the ecological stability of the region and takes into account different characteristics of the land. The principle of their calculation is identical: the ratio of the amount of land plots taking into account their quality, is taken in the form of correction coefficients to the total area of land.

To analyze the ecological balance of the town's territory, ecogeographic indicators that could be used to estimate urban areas were determined, namely: anthropogenic load coefficient, coefficient of anthropogenic transformation, factor of natural protection, coefficient of ecological stability, coefficients of absolute and relative tension of the ecological and economic status of territory. To calculate indicators we used the City Master Plan materials. To assess the degree of balance of the territorial structure of towns, the integral indicators were calculated. Assessment of the ecological fund and natural protection of the territory was carried out according to the method of Kochurov [13]. Types and categories of land in the general plans of the towns did not always coincide with the methods described, so the method of expert assessments of land use received points in accordance with the degree of anthropogenic transformation. The coefficient of

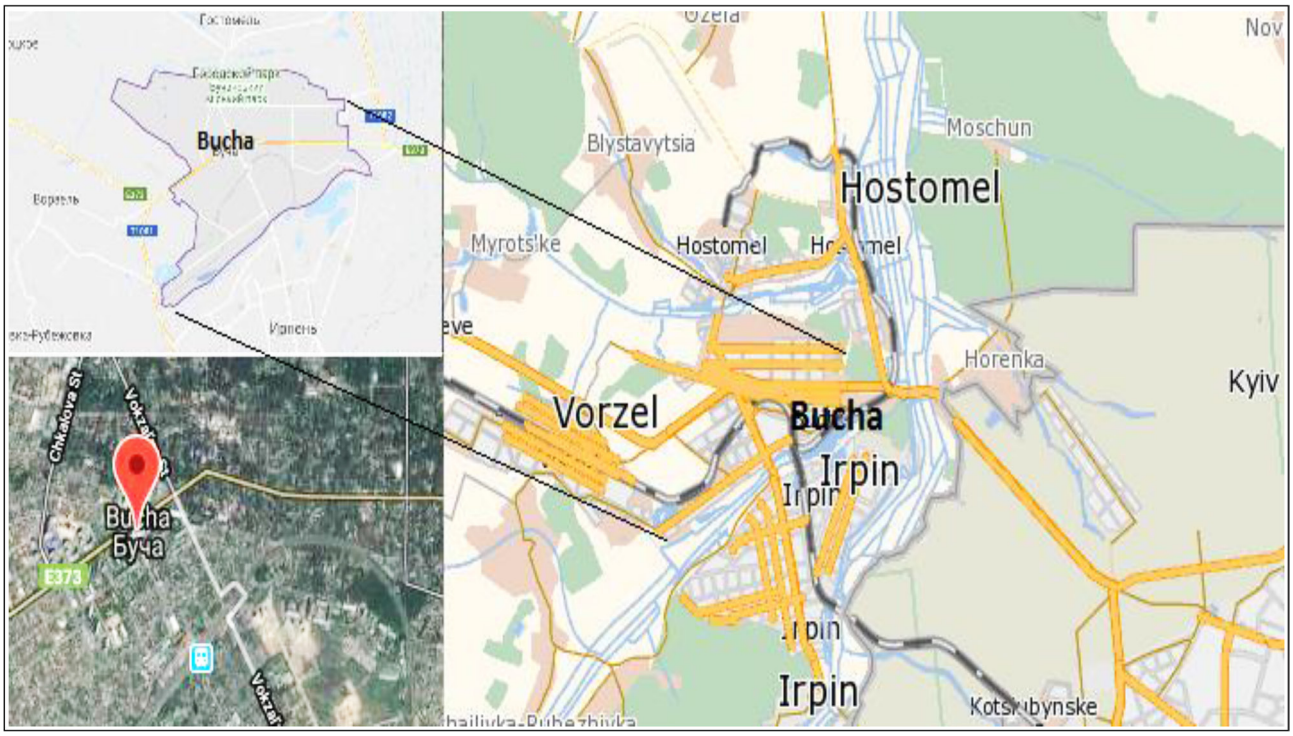

Fig. 1. The scheme of location Bucha town and the configuration of its territory

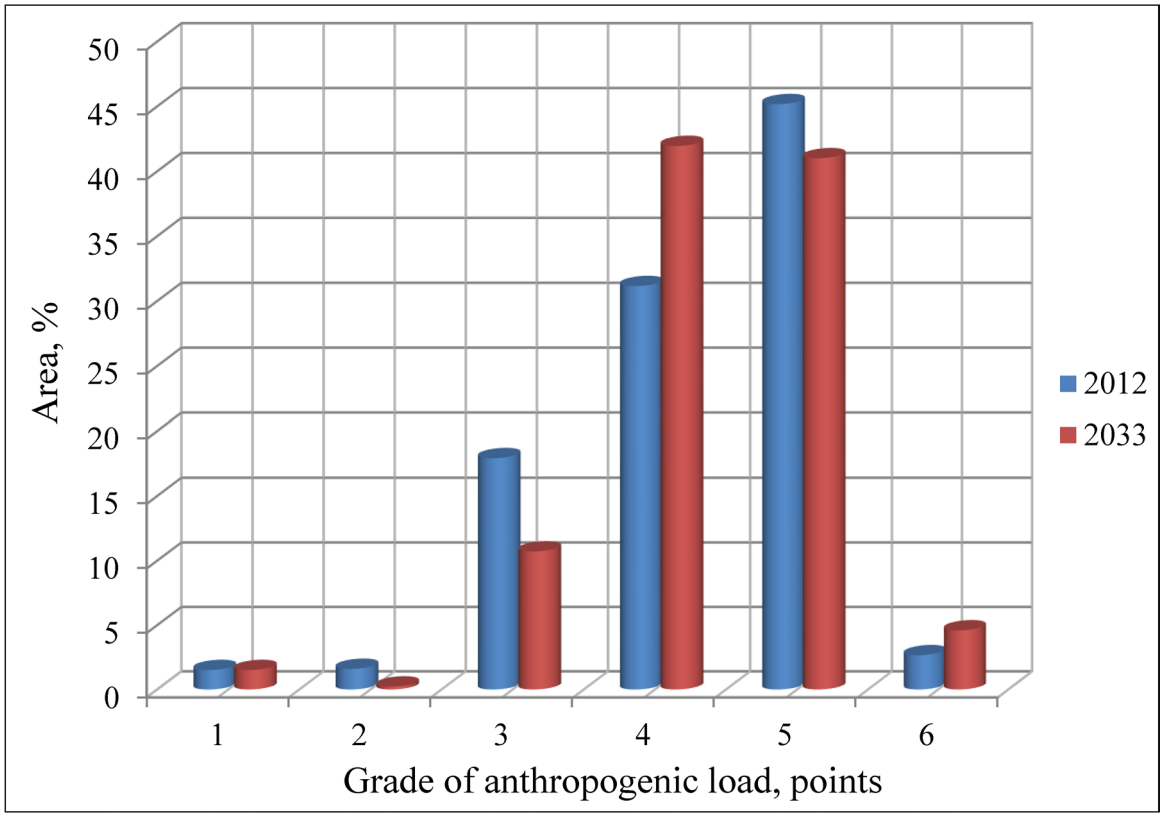

Fig. 2. The dynamics of the distribution of land by the grade of anthropogenic load (2012 and 2033 years), %

anthropogenic load was determined as the weighted average point on the available areas of land of a certain type of land use and their inherent ballistic points; coefficient of anthropogenic transformation of the territory – as the ratio of areas of agricultural lands, buildings and roads to the total area of the territory [14]. The coefficient of ecological stability was calculated as the ratio of areas under different types of land use, taking into account relevant indices (ecological significance factors for land categories that characterize the impact of biotechnical elements on the environment) [10, 6] corrected for the coefficient of morphological stability of the relief (0.7 for unstable) to the area of the total territory.

The coefficients of absolute (*CAT*) and relative (*CRT*) tensions of the territory were calculated as the ratio of the area of land with high anthropogenic load to the area with lower load. The algorithm of calculations is presented in the publication [15].

For the integrated assessment of the territory, the integral coefficient of natural protection (*CNP*) was used, which was determined by Kochurov [13]. The value of the *CNP* less than 0.5 indicates a critical level of protection of the territory.

Antrhropogenic transformation of the territory was determined using the integral index developed by Hoffmann and specified be Shishchenko [16] and Khryschuk & Bespal'ko [17]. It allowed to calculate the coefficient of anthropogenic transformation [15]. In addition, the coefficients of ecological stability of the territory proposed by the Slovak scientists were calculated [18].

When calculating the coefficient of stability of urban areas by the method developed be Muchová et al. [19] to the lands with a lower degree of degradation (0-1) we have included all the green plantations, garden societies, located in the forest recreation areas, water surfaces, agricultural land. The stable elements included water surfaces, forest, all categories of green spaces and garden communities (i.e., all land under any perennial plantations), and to ecologically unstable – built and degraded land were used in the calculation by the method of Streďanský & Šimonides [20].

Results and discussions

Within the town, the formation of functional zones continues by the types of prevailing use: rural and rural-recreational, production-communal, landscape-recreational and external transport. Such a planning organization of the territory (with the allocation of distinct functional zones) is typical for the development of a compact town.

The landscape public areas of Bucha town are represented by parks, squares, boulevards and urban forests of 99.6 hectares. The structure of land use directly affects the stability of the landscape *(Table 1)*.

The structure of urban lands by the degree of anthropogenic load is illustrated by ***Fig. 2***.

The structural division of the town's lands is

Table 1.

Classification of town's land for the grade of anthropogenic load

Types and categories of land	Point	Area, ha		*CEST**
		2012 Y	2033 Y	
Residential apartment building	5	305.7	442.7	0.05
Homestead building	4	567.3	900.3	0.5
Enterprises, institutions, establishments	5	179.0	260.0	0.05
Landscaped territories of general use	4	99.6	134.1	0.43
Streets, roads, squares	5	88.3	107.0	0.03
Industrial area	6	70.8	122.0	0.03
Communally-warehousing territories	5	65.4	153.0	0.03
Recreation bases	4	86.8	70.5	0.38
Garden societies	4	74.4	10.2	0.43
Water surfaces	1	40.1	40.1	0.79
Agricultural area	3	476.0	0	0.14
Landscape zone	3	0	227.0	0.38
Green plantations of special purpose	3	0	58.0	0.43
Forest	2	42.6	6.0	0.38
Other territories	5	562.1	127.2	0.03
Total		2658.1	2658.1	

*Note: *CEST* is the coefficient of ecological significance of the territory [6].

dominated by the territories, which are assigned 4 and 5 points for the degree of anthropogenic load. The total amount of land with a high level of anthropogenic load (4-6 points) in 2012 amounted to 79.0%, and according to the indicators of general planning by 2033 it will increase to 87.6%. Moreover, although the area of land with a rank of 5 points will somewhat decrease (due to decreasing in the category of "other lands"); the area of land will increase by 6 points (due to the expansion of manor development). The area of industrial land will increase in 1.7 times. Instead, the area of land with anthropogenic load of 1-3 points (ecologically stabilizing territories) will decrease from 21.0 to 12.4% due to reduction or disappearance of land with grades 2 and 3 points (forests and agricultural land). Particularly it is worried the reduction in 7 times the size of urban forests and the consequences of their reduction should be taken into account.

The coefficient of anthropogenic load of the town territory is 4.25, which corresponds to a high level; by the indicators of general planning to 2033, it will remain high and even increase to 4.35. For comparison, the average for the Kyiv region the magnitude of the anthropogenic load factor is 3.4, and for such small towns of the region as Ukrainka and Obukhiv, respectively, is 2.78 and 3.66 [21]. In general, anthropogenic load on the territory of Bucha town exceeds the average value in the region by 25%. Taking into account the obtained values of the indicator of anthropogenic load, we can confidently say that, unfortunately, the ecological balance of the territory while developing long-term plans for the development of small towns does not yet focus. It is traditionally believed that the environmental problems will concern the territories of small towns in the last turn, which, unfortunately, as we see, is far from reality. The total area of ecological fund of the town is 691.02 ha (26% of the total town's area), and in the long term it will decrease to 661.94 ha or to 24.9% of the total area *(Table 2)*.

The coefficient of natural protection of the town's territory is 0.26, and in the future it will further decrease by 4.2% to 0.25. In both cases, the value of the coefficient is less than the normative minimum of 0.5, which indicates the critical level of protection of the territory within the town boundaries and necessity of expansion of protected areas within urban boundaries. Unfortunately, in Ukraine, where the inventory of green spaces in small towns has never been developed, natural areas as ecologically stabilizing urban areas are not paid attention, such a category of plantations is not even mentioned in the classification of green spaces of towns. Usually, it is natural areas, like urban gardens, that unconditionally fall under the expansion of urban development. A typical European trend for the growth of "sealed" urban areas [22] is also observed in Ukrainian towns. According to the results of our studies of the territories of other small towns in Kyiv region, the total area of their environmental fund ranged from 13.9 to 47.5% of the urban area.

The calculation of the coefficients of anthropogenic transformation of the town territory is shown in the *Table 3*, and the values of the calculated coefficients are given in the *Table 4*.

Coefficient of ecological stability is 0.15 (the territory is environmentally unstable), and according to plan indicators, by 2033, it will increase to 26.7% and will amount to 0.19, which will improve the situation insignificantly, and the town's territory will remain ecologically unstable. For comparison, the coefficient of ecological stability of Ukrainka town is 0.64, which is close to the norm, while the Obukhov town is 0.33, which is twice higher than that of Bucha [21]. For the small towns we studied previously, this figure ranged from 0.12 to 0.40, that is, in all cases, the territory of small towns was environmentally unstable.

Coefficient of transformation of the territory, which characterizes the share of anthropogenically-modified territories in the structure of land use of the study area,

Table 2.

Calculation of the total area of the ecological fund of the Bucha town

Coefficient of ecological stability *CES*	Point	Area, ha		Area**CES*	
		2012 Y	2033 Y	2012 Y	2033 Y
0.4	4	828.1	1115.1	331.24	446.04
0.6	3	476.0	285.0	285.6	171.00
0.8	2	42.6	6.0	34.08	4.80
1	1	40.1	40.1	40.1	40.1
Area of natural reserve fund	-	-	-	691.02	661.94
Total area of the town	-	2658.1	2658.1	-	-

will increase from 0.66 to 0.75, which in both cases corresponds to the increased value. That is, if now the natural territories make up one third of urban territory (34%), then in 20 years their share will decrease and will make only a quarter of the city territory.

The state of the town is characterized as unstable; there is an increase in the area occupied by elements of negative environmental impact, primarily buildings. To increase the stability of the territory, it is necessary to preserve and restore natural systems, expand the area of urban green spaces. At present, the provision of green areas to residents of the city is about 35 m^2 per capita, and all green plantations are 108 m^2 per capita. By 2033, we provided that the projected population is 30.5 thousands, the provision of greenery will be about 45 and 140 m^2 per capita. It is the norm of planting greenery, that is, the minimum regulatory provision for green spaces of general use is guided during the general planning of urban areas. However, as it turns out, even such an improvement (growing greenhouse greening by 28.5-29.6%) does not compensate for the negativity of planned land use changes and expansion of built-up areas, which will eventually go against the declared in the program of the local town council the task of improving the quality of life of the population and rational land use.

Table 3.

Calculation of coefficients of anthropogenic transformation of the territory of Bucha town

Index of depth of transformation *I*	Grade *G*	Area, %		Area**G***I*	
		2012 Y	2033 Y	2012 Y	2033 Y
1.50	10	8.5	14.4	127.5	216
1.35	8	18.2	26.4	196.56	285.12
1.30	7	21.3	33.9	193.83	308.49
1.25	6	17.9	0	134.25	0
1.20	5	9.8	18.8	58.8	112.8
1.10	3	21.2	4.8	69.96	15.84
1.05	2	1.6	0.2	3.36	0.42
1.00	1	1.5	1.5	1.5	1.5
Coefficient of anthropogenic transformation				7.86	9.40

Table 4.

Ecogeographic indicators of Bucha town

Indicator (coefficient)	Year		Rate	Evaluation
	2012	2033		
Anthropogenic load	4.25	4.35	≤3	High
Anthropogenic transformation	0.66	0.75	≤0.65	Increased
Ecological stability	0.15	0.19	≥0.67	Unstable territory
Natural protection	0.26	0.25	≥0.5	Low level of natural protection
Absolute tension of EEST*	10.80	18.40	1	Not balanced
Relative tension of EEST*	2.14	11.78	1	Not balanced
Area of ecological fund, %	26.0	24.9	57-70	Insufficient
Anthropogenic transformation:	7.86	9.40	2.00-3.80	Excessively transformed
by Muchová et al. [18]	0.45	0.26	> 1.21	Very low degree of environmental stability
by Streďanský, Šimonides [19]	0.15	0.26	> 3.01	Essentially unstable landscape
by Řeháčková and Pauditšová [22]	0.21	0.27	> 3.50	Very low degree of environmental stability
by Kupková [23]	6.74	3.87	= 1.00	Predominance of anthropogenic elements
by Löw [24]	0.15	0.18	= 1.00	Disturbed landscape

*Note: EEST – the coefficient of ecological and economic status of the territory [absolute – the ratio of industrial areas (6 points) to water (1 point)]

As it turned out, the territory of small Bucha town combines high anthropogenic load with a critical level of natural protection. According to our calculations, the town is absolutely not balanced by the absolute and relative tensions of the ecological and economic conditions of the territory, the corresponding coefficients exceed the norm at times, and this trend will continue in the future and will further deteriorate by 5.4 times. High values of the coefficients of absolute and relative environmental stress indicate an unfavorable environmental situation and justify the need to expand the environment of stabilizing, protected areas.

Coefficients of the stability of the territory calculated by Slovak scientists methods illustrate the same picture: the urban area had a very low degree of environmental stability (0.15 and 0.18 against 1.21) by Muchová et al. [19], a significantly unstable landscape (0.15 and 0.6 versus 3.01) by Streďanský, Šimonides [20], a very low degree of ecological resilience (0,21 and 0,27 versus 3,50) by Řeháčková and Pauditšová [23], the predominance of anthropogenic landscape elements (6.74 and 3.87 against 1.00) by [24], disturbed landscapes (0.15 and 0.18 against 1.00) by Löw [25].

Taking into account the obtained results and the dynamics of the development of the territory, we consider the untrustworthy achievement of the ecological balance of the city territory within the existing boundaries, without its expansion. We support the idea that urgently it is necessary to determine which of the models of urban growth (intensification or extensification) has a lower overall impact on biodiversity and is the most environmentally acceptable [26].

We also came to the conclusion that the interconnected nature of the landscape indicators requires their joint use in the analysis of environmental processes in compact towns to optimize their environmental qualities, as well as to enhance the nature conservation of towns, consistent with the recommendations of [27]. As [28], we believe that the protection of the ability of urban ecosystems to provide services in Ukraine requires extensive institutional reform, as well as the improvement of the architectural and spatial structure to support green spaces.

Conclusions

The analysis of the territorial structure of the small Bucha town indicates its ecological imbalance, the prevalence and expansion of the ecologically destabilizing territories. The tension of the ecological and economic conditions of the town's territory is not balanced by the degree of anthropogenic load and the potential of the sustainability of nature and will not improve in the future. In order to ensure the sustainable development of urban areas in general planning we consider it expedient to take into account not only urban, economic and social, but also environmental indicators, to link them to a single principle of environmentalization of territories.

The measures proposed by the general plans for the long-term development of towns should be compromise, the development of the territory should be accompanied by ecologically balanced decisions and provide for strengthening of the natural basis of towns and increase of ecological stability, which can be checked with the help of integral indicators: coefficients of ecological stability of the territory, natural protection of the territory and others. We consider it expedient to use ecogeographic indicators in the system of general planning in order to optimize perspective design decisions. In this case, their normative and optimal values for urban areas should be specified.

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