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IMPROVEMENT OF THE SYSTEM OF INDICATORS FOR MEASURING THE ECOLOGICAL COMPONENT OF SUSTAINABLE DEVELOPMENT OF REGIONS

Abstract. Over the last decade «indicator thinking» has become more widespread. The need to have a tool to assess the processes taking place, give them a retrospective analysis and try to predict their future require the formation of appropriate indicators and quantitative indicators. These trends are evident in the concept of sustainable development. This concept is based on the development of sustainable measures: understanding the relationship between the economy, society and the environment; supporting the equitable allocation of resources and preserving opportunities for this generation and all future ones.

The article reflects a research initiative focused on data processing to improve the system of indicators for measuring the ecological component of sustainable development of regions. In order to characterize, classify and predict the conditions that may lead to sustainable regional development, the Poltava region was used as a studied area. For the developing of the methods and processing of data, the existing legal framework and national studies were taken into account, thus setting the parameters for the key indicators that are necessary for the assessing the ecological component levels of sustainable development. The calculation of the integrated indicator of the ecological component of sustainable development of Poltava region and Ukraine was carried out in the work based on the statistical methods and a number of data obtained for the period 2010—2020. This makes it possible to make management decisions at the regional level, which in turn will analyze the reasons for their deviation from the relevant indicators in the country as a whole.

The proposed system of indicators of sustainable development has the advantage that the indicators included in it show the impact of anthropogenic pressure not only on the ecosystem, but also the impact on economic activity through the degradation of natural resources. This system also allows to assess the level of territorial disproportion, to identify the sources of the most negative temporal-territorial environmental impacts, to assess the effectiveness of management decisions implemented in the region.

Keywords: sustainable development, region, indicators, integrated sustainability indicator, methodology, evaluation

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УДОСКОНАЛЕННЯ СИСТЕМИ ІНДИКАТОРІВ ВИМІРЮВАННЯ ЕКОЛОГІЧНОЇ СКЛАДОВОЇ СТАЛОГО РОЗВИТКУ РЕГІОНІВ

Анотація. За останнє десятиліття все ширше починає розповсюджуватися так зване «індикаторне мислення». Потреба мати інструмент для оцінки процесів, що відбуваються, дати їм ретроспективний аналіз і спробувати передбачити їхнє майбутнє вимагають формування відповідних індикаторів і кількісних показників. Ці тенденції яскраво проявляються в концепції сталого розвитку, яка ґрунтується на постулатах: розуміння взаємозв'язку між економікою, суспільством і довкіллям; підтримка справедливого розподілу ресурсів та збереження можливостей для цього покоління і всіх наступних. Потреби та інтереси людей не мають суперечити інтересам і потребам розвитку природи.

Відображено дослідницьку ініціативу, орієнтовану на обробку даних для удосконалення системи індикаторів вимірювання екологічної складової сталого розвитку регіонів. Для характеристики, класифікації та прогнозування умов, які можуть призвести до сталого регіонального розвитку, досліджуваною територією було використано Полтавську область. Для розроблення методики та обробки даних було враховано чинну правову базу, національні дослідження, тим самим устанавлюючи параметри для ключових показників, потрібних для характеристики рівнів екологічного компонента сталого розвитку. Здійснено розрахунок інтегрального показника екологічної складової сталого розвитку Полтавської області та України на основі статистичних методів і даних, отриманих за період 2010—2020 років. Це дає можливість ухвалення управлінських рішень на рівні регіону, що, у свою чергу, дозволить провести аналіз причин їх відхилення від відповідних показників у цілому по країні.

Запропонована система індикаторів сталого розвитку має перевагу, оскільки включені до неї показники показують вплив антропогенного навантаження не тільки на екосистему, а й вплив на господарську діяльність через деградацію природних ресурсів. Система також дозволяє оцінити рівень територіальної диспропорційності, виявити джерела найбільш негативних темпорально-територіальних екологічних впливів, оцінити ефективність реалізованих у регіоні управлінських рішень.

Ключові слова: сталий розвиток, регіон, індикатори, інтегрований показник стійкості, методологія, оцінка.

Формул: 0; рис.: 1; табл.: 2; бібл.: 21.

Introduction. Over the years, the evolution of the concept of sustainable development has provided various definitions, interpretations and tools. The basic definition of sustainable development involves the relationship of three dimensions — environment, economy and society. Each of these dimensions is as important as the other. Sustainable development has become a political goal of the United Nations. This was stated at several summits and Conferences in Rio (1992) [1], in compliance with the Johannesburg Declaration (2012) and Resolution A/RES/70/1 adopted by the UN General Assembly in 2015. Ukraine has undertaken a Voluntary National Review of the Sustainable Development Goals and presents it at the High-Level Policy Forum on Sustainable Development on July 10—17, 2020 in New York [2].

Ukraine, alike other UN member states, participates in the global process of sustainable development. In recent years, considerable work has been done to adapt the sustainable development goals considering the domestic context. As a result a national strategic framework for Ukraine for the period up to 2030 has been formed.

Within this strategy there appears a necessity to develop a regional policy based on the principles of sustainable development. To do this, it is obligatory to have indicators that make it possible to determine the state and dynamics of regional development within sustainable development components.

Sustainable development of the region involves taking into account economic, environmental and social aspects, which can be measured by many indicators. However, each region is a complex, dynamic system represented by the availability of different resources, territorial features, and different expectations and capabilities of territorial communities. Therefore, determining of specific indicators of sustainable development appears to be a complicated task.

Undoubtedly, all aspects of sustainable development are important. However, for this research it was decided to focus on the ecological composition at the present stage, developing indicators of the ecological development of the region.

Whilst developing mentioned indicators, the capabilities of statistical information of the region and existing methods of their calculation at the state level were used to the maximum.

Analysis of research and problem statement. Ukrainian scientists are actively engaged in research on the sustainability of regional development, specifically the problems of forming a methodology for assessing the sustainability of regions in Ukraine. In particular, B. Danylyshyn [3] studied the problems of the formation of modern state regional policy and economics of environment in sustainable development context. Z. Gerasymchuk [4] conducts a thorough study of the methodology and mechanism of regional sustainable development policy implementation. I. Goryana [5] investigated the existing methodological approaches to assessing the sustainable development of regions and proposed a method of calculating a single integrated indicator of sustainable development. N. Schlafman and N. Umanets [6] substantiated the expediency of creating a single sustainable regional development model for further development of regional development strategies. Researchers have also adapted global methods for assessing regions' resilience and systematized measures to ensure SDGs in Ukraine [7]. S. Kozlovsky [8] and co-authors determine the feasibility of developing an indicative plan for developing the region and as a tool for using targeted planning. I. Zaykov et al. [9] studied the impact of demographic processes on the national economy of sustainable development using statistical analysis, which used the main national and regional indicators of sustainable development. The issues of sustainability analysis are becoming especially relevant now. Nevertheless, the problem is that not all developed methods are suitable for practical application due to a lack of sufficient statistic data and lack of a single unified assessment methodology, which complicates the analysis of both global and regional trends.

Unsolved aspects of the problem. Despite a number of scientific studies on this issue, the formation of a technique for estimating sustainable development of regions in Ukraine is insufficiently investigated.

The purpose of the article. The study aims to propose improvement to the system of indicators for measuring the ecological component of sustainable development of regions for

regular monitoring of their progress in achieving sustainable development goals and their further use in assessing the sustainability of the regions of Ukraine.

Research results. To assess the process of regional development, it is necessary to form a set of appropriate indicators that determine the ecological component of sustainable development.

The study was based on the following assumptions:

- indicators should be representative for the structure and dynamic behavior of the system;
- indicators should be built on a spatial and temporal scale that corresponds to ecological, economic, and social phenomena;
- indicators must be presented in a format suitable for decision-making, that is quantitatively, legibly and transparently;
- indicators must be sufficient for forecasting.

For Sustainable Development Goals to become effective strategic planning elements at both national and regional levels, it is necessary to create a relevant tool for their assessing. Poltava region was used as an example to calculate the integrated indicator of the ecological component of sustainable development of the region. The *air index* (I_{AIR}), the *land resources index* (I_{LAN}), and the *water resources index* (I_{WAT}) were included in calculating the integrated indicator for the following reasons.

Land plays a fundamental role in the ecological component. Conserving and restoring land resources can play a crucial role in opposing climate change by providing biodiversity and supporting important economic services that simultaneously offer the common organization prosperity and well-being. Productive lands can be an engine of economic growth and a livelihood source for many regions of Ukraine, including Poltava region. Therefore, the relevant integrated indicator of regional sustainable development's environmental component includes the *land resources index* (I_{LAN}). Poltava region has relatively significant land resources. The land fund of Poltava region is 2875.1 thousand hectares. Agricultural development of the region is 75.3 %, plowing — 61.7 %, forest cover — 9.95 %. Over the past 10 years agricultural development of the region has decreased by 0.5 %, on the contrary plowed land gradually increased by 0.3 %. Poltava region is one of the most prosperous regions in terms of fertile soil reserves. Arable land is 90% represented by fertile black soils and their varieties (about 18 types) [10—12].

The state of the air environment in Poltava region remains one of the important regional environmental problems. The level of air pollution in the region is determined by the volume of pollutants' emissions from stationary and mobile sources. Therefore, to assess the change in the dynamics of the integrated indicator of the ecological component of sustainable development of the region, the *air index* (I_{AIR}) is included.

In hydrogeological terms, Poltava region belongs to the Dnipro artesian basin and occupies the central and southeastern part of the Donetsk-Dnipro basin. Analysis of water sources' current ecological state shows that the negative processes in rivers, reservoirs, and ponds continue. Most rivers and streams are silted up, overgrown with swamp vegetation and shrubs, have lost their natural significance, have no drainage capacity, resulting in which floodplains are swampy and flooded, and are not used in agriculture [10; 13—15]. Thus, an important characteristic of the region's ecological component of sustainable development is the *water resources index* (I_{WAT}).

All indicators that affect the components of the above indices are measured in different units and interpreted differently [16—18]. Therefore, they should be brought to a normalized form so that their changes, like the indices themselves, are in the range from 0 to 1. Under these circumstances, values close to 0 will correspond to the worst indicators of the indicator, and the best ones will approach 1 accordingly.

The relevant set of components of the integrated indicator of ecological development of the regional level formed on the basis of statistical data is given in *Table 1*.

Table 1

**Elements of indices of the integrated indicator of the ecological component
of sustainable development of the region**

Air index I_{AIR}		Land resources index I_{LAN}		Water resources index I_{WAT}	
	Weight factor		Weight factor		Weight factor
<i>INO₂</i> — average concentration of nitrogen dioxide in the air of cities, share of MPC ¹	0.09	area of agricultural land, % of the total area of the region	0.16	<i>ISS</i> — the average annual concentration of suspended solids is averaged over the control targets of water bodies of the region, share of MPC	0.22
<i>ISO₂</i> — the average concentration of sulfur dioxide in the air of cities, share of MPC	0.09	built-up land, % of the total area of the region	0.21	<i>IMIN</i> — average annual mineralization is averaged over the control targets of water bodies of the region, share of MPC	0.18
<i>INOX</i> — emissions of nitrogen oxides on the area in the reporting year (t/km ²)	0.1	forests and other wooded areas, % of the total area of the region	0.32	<i>INIT</i> — the average annual concentration of nitrates is averaged over the control targets of water bodies of the region, share of MPC	0.19
<i>ISOT</i> — emissions of sulfur dioxide, on the area in the reporting year (t/km ²)	0.08	application of mineral fertilizers (t per ha)	0.31	<i>IWAV</i> — water was taken from natural sources (m ³ per year per capita)	0.21
<i>IVOC</i> — emissions of non-methane volatile organic compounds to the area in the reporting year, (t/km ²)	0.05			<i>IGAV</i> — water was taken from natural underground sources (m ³ per year per capita)	0.20
<i>IEMAT</i> — emissions of pollutants from road transport in the reporting year, (thousands t)	0.2				
<i>IEKM</i> — emissions of pollutants into the atmosphere from stationary and mobile sources, to the area in the reporting year, (t/km ²)	0.11				
<i>IEPC</i> — emissions of pollutants into the atmosphere from stationary and mobile sources, per capita (kg)	0.12				
<i>ICO₂</i> — carbon dioxide emissions per person (kg per year)	0.25				

Source: based on [10].

The weights of indicators used in the calculation of these indices were determined on the basis of an expert survey of specialists in the fields of ecology, agriculture, as well as representatives of local communities.

The values of the calculated indices and the integrated indicator of the ecological component of the regions' sustainable development are introduced in *Table 2*.

¹ MPC — maximum permissible concentration.

Table 2

**Integrated indicators of the ecological component of sustainable development
of Poltava region and Ukraine**

Year	Air index I_{AIR}	Land resources index I_{LAN}	Water resources index I_{WAT}	An integrated indicator of the ecological component of sustainable development of Poltava region	An integrated indicator of the environmental component of sustainable development of Ukraine
2010	0.139	0.153	0.199	0.491	0.476
2011	0.072	0.117	0.233	0.422	0.482
2012	0.064	0.149	0.199	0.412	0.469
2013	0.057	0.149	0.236	0.441	0.389
2014	0.094	0.149	0.257	0.500	0.518
2015	0.198	0.150	0.175	0.523	0.483
2016	0.219	0.150	0.116	0.485	0.577
2017	0.211	0.171	0.261	0.643	0.673
2018	0.228	0.201	0.173	0.602	0.698
2019	0.317	0.095	0.263	0.674	0.687
2020	0.312	0.114	0.257	0.684	0.712

Source: calculated by authors.

Analyzing the calculated indices of the integrated indicator of the ecological component of sustainable development of Poltava region, it was found out that the ecological pressure on the air and water resources in this region has decreased. In contrast, the state of land and forest resources has deteriorated.

The dynamics of the integrated indicator of the ecological component of Poltava region and Ukraine's sustainable development is shown in Fig.

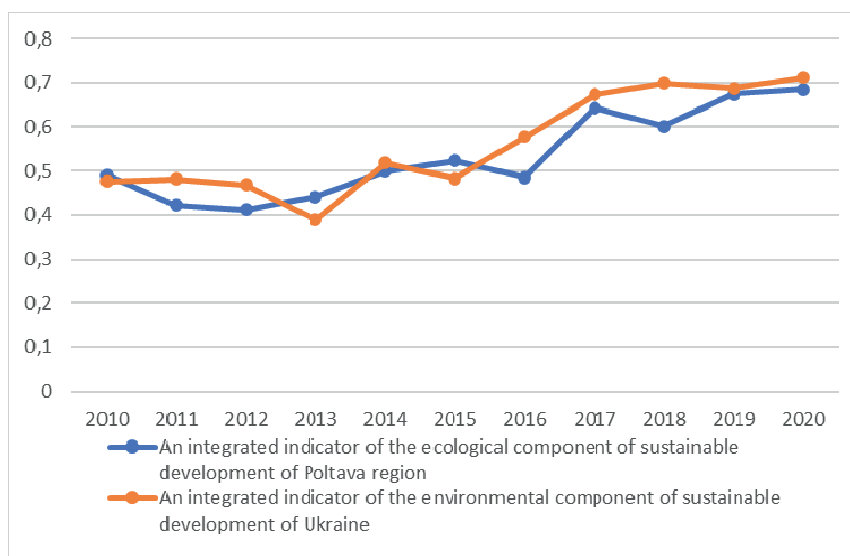


Fig. Dynamics of the integrated indicator of the ecological component of sustainable development of Poltava region and Ukraine

Source: developed by authors.

As shown in *Fig.*, integrated assessment is the simultaneous rationing of both sustainable development indicators and their threshold values. This allows to compare the dynamics of the integral value on one scale, in other words to assess the state of sustainable development. In particular, the values of the ecological component of the integrated indicator of sustainable development of the Poltava region and Ukraine for the specified period.

The integrated indicator of the ecological component of sustainable development [19—21], in general, can be understood as a quantitative tool that analyzes changes, measuring and reporting progress towards sustainable use and management of environmental resources.

For sustainable use and management of economic, social, institutional, and other resources also see the feasibility of calculating the relevant indices and aggregates using the above methodology.

Conclusion. Creating integrated, aggregate indices of sustainable development is a crucial task. As a result, it is a convenient tool for rapid analysis of development and, therefore, the ability to adjust actions in natural resources management and environmental protection at the regional level.

The calculated integrated indicator can be used to justify decisions by quantifying and simplifying many indicators, to facilitate access to information for different categories of users and helps to interpret changes.

The use of an integrated indicator of the ecological component of sustainable development also has prospects for management decisions at the regional level, which in turn will analyze the reasons for their deviation from the relevant indicators in the country as a whole.

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