DOI: 10.22449/2413-5577-2022-1-113-131

Criterion-Statistical Assessment of the Sustainability of Black Sea Local Coastal Eco-Socio-Economic Systems of the Krasnodar Krai

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Abstract

The marine coastal zone is characterized by extremely intense natural processes. It is also an area of particularly intense economic expansion. This makes it necessary to consider the coastal zone as a single eco-socio-economic system, which takes into account the variability of the spatial scale of the impact and stability of the existing processes – from local to district and further to regional and global levels. This requires comprehensive monitoring of the sustainability not only of regions but also of lower-level territories. However, at present, there are no unified methods for determining the sustainability of such coastal territorial systems. The paper proposes a criterion-statistical approach to assess the sustainability of local coastal eco-socio-economic systems in the form of a complex system of indicators by three factors of sustainability: natural-ecological, economic and social ones. As a result, it becomes possible to obtain quantitative estimates for individual factors and those in the form of a comprehensive integral index of the sustainability of the local coastal eco-socio-economic system. The application of the approach allows assessing the sustainability of local coastal systems and performing an appropriate spatial analysis, with the identification of stable (key) and unstable local coastal systems as territorial units of the local level of governance. This approach is universal and is approved in 18 local Black Sea coastal municipalities of the Krasnodar Krai. In the future, the approach will be used for implementation of the *Coastal eco-socio-economic systems of the Krasnodar Krai* GIS, which will allow for spatial territorial planning and forecasting of sustainable development of coastal eco-socio-economic systems at all levels of governance (regional, district and local).

Keywords: coastal eco-socio-economic system, local spatial level, sustainability, criterion-statistical approach, indicator system, Black sea, Krasnodar Krai

Acknowledgments: the reported study was funded by RFBR and Krasnodar Krai Administration, project number 19-45-230001. The detailed information on certain areas of the Black Sea coast from the Taman Peninsula to Anapa was obtained partly with the assistance of the RFBR (project number 20-05-00009) and that for areas from Anapa to the Psou River was obtained with the assistance of the RSF (project number 20-17-00060).

For citation: Gogoberidze, G.G., Rumiantceva, E.A. and Kosyan, R.D., 2022. Criterion-Statistical Assessment of the Sustainability of Black Sea Local Coastal Eco-Socio-Economic Systems of the Krasnodar Krai. *Ecological Safety of Coastal and Shelf Zones of Sea*, (1), pp. 113–131. doi:10.22449/2413-5577-2022-1-113-131

Критериально-статистическая оценка устойчивости локальных береговых эко-социо-экономических систем Черноморского побережья Краснодарского края

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Аннотация

Береговая зона моря характеризуется крайне интенсивными природными процессами. Кроме того, она является областью особенно высокой экономической экспансии. Это приводит к необходимости рассматривать морскую береговую зону как единую береговую эко-социо-экономическую систему, учитывающую пространственные масштабы воздействия и степень устойчивости происходящих процессов: от локального к районному и далее к региональному и глобальному уровням. При этом необходим комплексный мониторинг устойчивости не только регионов, но и территорий более низких иерархических уровней. Однако в настоящее время не существует унифицированных методов определения устойчивости низкоуровневых береговых территориальных систем. В работе предлагается критериально-статистический подход к оценке устойчивости локальных береговых эко-социо-экономических систем в виде совокупности индикаторов по трем факторам устойчивости: природно-экологическому, экономическому и социальному. В результате становится возможным получить количественные оценки устойчивости по отдельным факторам и в виде комплексного интегрального индекса устойчивости локальной береговой эко-социо-экономической системы. Применение данного подхода позволяет оценить стабильность локальных береговых систем и выполнить соответствующий пространственный анализ с выявлением устойчивых (узловых) и неустойчивых локальных береговых систем как территориальных единиц локального уровня управления. Данный подход является универсальным и апробирован на 18 локальных приморских муниципальных образованиях районов Черноморского побережья Краснодарского края. В дальнейшем подход будет использован при реализации ГИС-оболочки «Береговые эко-социо-экономические системы Краснодарского края», что позволит осуществлять пространственное территориальное планирование и прогнозировать устойчивое развитие береговых эко-социо-экономических систем на всех уровнях управления (региональный, районный и локальный).

Ключевые слова: береговая эко-социо-экономическая система, локальный пространственный уровень, устойчивость, критериально-статистический подход, система индикаторов, Черное море, Краснодарский край

Благодарности: исследование выполнено при финансовой поддержке РФФИ и Администрации Краснодарского края в рамках научного проекта № 19-45-230001 р_а. Детальная информация по отдельным районам черноморского побережья от Таманского полуострова до Анапы получена в том числе при поддержке гранта РФФИ № 20-05-00009, от Анапы до реки Псоу при поддержке проекта РНФ № 20-17-00060.

Для цитирования: *Гогоберидзе Г. Г., Румянцева Е. А., Косьян Р. Д.* Критериально-статистическая оценка устойчивости локальных береговых эко-социо-экономических систем Черноморского побережья Краснодарского края // Экологическая безопасность прибрежной и шельфовой зон моря. 2022. № 1. С. 113–131. doi:10.22449/2413-5577-2022-1-113-131

Introduction

Considering various types of economic activities in the seas and oceans, it should be noted that actually all of them are closely linked to the coastal zone. Being a natural border area of three environments, it is characterized by a dramatically intense interaction of natural processes and expansion of the economic activity. This is generally accompanied by an increasing anthropogenic impact on the natural environment. It leads to the necessity to see the coastal zone as a unified eco-socio-economic system given the variability of spatial scales of impact on the natural environment and sustainability of the existing processes: from the local to the district level and further to the regional and global levels. At the same time, talking about sustainability of territorial systems, the factors and parameters of sustainability of global and regional scale are generally considered and less often those of the district spatial level, whereas very little attention is paid to local territorial systems. Though the management of territories as eco-socio-economic systems depends not only on economic and social factors but also on natural ones as well as ecosystem patterns [1–4].

Thus, it is necessary to perform comprehensive monitoring of the sustainability of territorial objects, including the eco-socio-economic analysis of development factors not only for the regions as a whole, but also for the territories of lower hierarchical levels. When applied to a local spatial level, this approach will significantly improve the reliability and validity of comprehensive development forecasts and reflect the feasibility of strategic objectives for development of territories of high spatial scale (districts and regions) in general [5–11].

The paper considers the criterion-statistical approach to the sustainability assessment of local coastal eco-socio-economic systems, which is calculated through a set of indicators of various sustainability factors. A local coastal municipality together with inland waters is considered as a local coastal system. Examples of such coastal systems are the Black Sea coastal municipalities of Krasnodar Krai settlements. This approach allows for a comparative assessment of sustainability of local coastal systems, both as a whole and by various components, and identification of the most significant factors affecting the sustainability of a territorial coastal entity.

Key approaches to the assessment of the sustainability of coastal eco-socio-economic systems

The sustainability of a system is understood as ability of the latter to ensure normal functioning of resource use processes under the existing set of natural, environmental, social-economic and other factors [1]. At present, there are various approaches to the assessment of the sustainability of eco-socio-economic systems, including those focused on coastal territorial entities. However, most of the research addresses the levels of countries and regions, while at the local level, except for cities, mechanisms of balanced development of territories are poorly considered [10, 12, 13]. A number of works are specialized in territorial entities of a certain type [1)], including coastal areas [1, 13–18]. In addition, some works contain to a certain extent a comprehensive approach to the assessment of the sustainability of the territory and consider environmental and economic, economic and managerial and other relationships. But these studies are mostly regional in nature [19–24].

The systems of assessment of the sustainability of territories at the district and local spatial levels have been studied less extensively, mainly due to lack of available statistical data. Methods for assessing the socio-economic development of territories of district municipal entities of the Russian Federation (RF) are the most widespread and developed. The calculation of sustainability is based on integral and partial criteria, reflecting the state (mainly socio-economic) of municipal entities; similar aspects are devoted to the works of foreign authors [25–29]. When building the systems of indicators that allow assessing the sustainability of territorial entities, the statistical approach based on official data of statistical agencies is mainly used. This approach makes it possible to build a mathematical model and establish the relationship between the indicators of various factors under consideration by applying methods of analysis of variance and regression statistics of dual regression equation. Such models are often linked to a specific region [2)] or constituent entity of the Russian Federation [30–36]. In foreign methodologies, a significant part is played by expert systems based on the integral opinion of invited experts as well [12, 15, 26, 27, 29, 37–40].

However, such systems are mostly of a general nature. The result is that the final estimates are less informative and unspecific as well as highly dependent on the experts' subjectivity extent in relation to the territorial entity in question. The wide application of the first group of statistical methods is quite understandable for the regional level, for which a range of statistical products of the global, federal and regional levels is available. But for lower territorial levels (especially for local municipalities) the number of such indicators drops dramatically. In addition, natural parameters gain greater importance, e. g. geomorphological

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1) BSC, 2013. *Guideline on Integrated Coastal Zone Management in the Black Sea.* Turkey: The Commission on the Protection of the Black Sea against Pollution, 2013. Available at: http://blacksea-commission.org/Downloads/Black_Sea_ICZM_Guideline/Black_Sea_ICZM_Guideline.pdf [Accessed: 11 March 2022].

2) Bobylyov, S.N., Zubarevich, N.V. and Solovyova, S.V., 2011. [*Sustainable Development: Methodology and Methods of Measurement*]. Moscow: Ekonomika, 358 p. (in Russian).

indicators of coastal stability, which are not available in statistical digests at all. The variability of such parameters generally cannot be considered using rigorous statistical methods. In this case, it is necessary to use expert-criterion approaches, which allow a quantitative assessment of an element of coastal system stability based on an expert opinion but using an unambiguous system of criteria and classification attributes [1, 15, 38–40]. On the whole, it is evident that the two discussed methods need to be combined into a single criterion-statistical approach to assessment of sustainability of an eco-socio-economic coastal system at the local spatial level.

Factor elements of the criterion-statistical approach to assessment of the sustainability of local coastal eco-socio-economic systems

One of the main convenient methods for assessment of the sustainability of coastal eco-socio-economic systems is the indicator method. It is based on identification of the main factors determining the sustainability of a coastal territorial system and the development of a system of indicators describing these factors. This approach makes it possible both to assess the current sustainability of a coastal system and to analyze the development trends of this territorial system as a whole and by individual factors and to take into account their interrelation. In contrast to coastal eco-socio-economic systems at the regional and district management levels, the local spatial level is characterized by the absence of explicit geopolitical, geo-economic, and other long-term sustainability factors. In this regard, it is possible to consider three factors as components [1]: natural-environmental, economic, and social. Each of these factors is determined by a set of indicators, the values of which are calculated on the basis of statistical or expert-criterion approaches. The methods for calculating the indicators are given in [1] and are based on the following principles.

1. The indicators are presented in dimensionless form by calculating the transition from the absolute values of the indicators.

2. The indicators take values from −1 to +1 (maximum negative and maximum positive degree of impact of the considered parameter on the system, respectively), which will allow smoothing strongly prevailing indicators during the assessment of the sustainability factor.

3. Indicators derived by applying the expert-criterion approach are minimally characterized by a subjective expert opinion and are based on clear parametric and spatial indicators.

4. When calculating a single sustainability factor and integral indicator, indicators are considered without using weight functions [1, 12, 13, 17]. Their introduction will lead to ambiguity in assessing the importance of each indicator due to the artificial prevalence or underestimation of any eco-socio-economic direction.

5. Within a single sustainability factor, indicators do not depend (no cross impact) on each other.

On the basis of these principles, sets of 8 indicators have been created for each considered factor of the coastal eco-socio-economic system sustainability. Methodologies for calculating statistical indicators are given in [1], and the primary sources of expert-criterion indicators [1)] are [14, 15, 37–41].

The comprehensive integral index of the local coastal eco-socio-economic system sustainability is calculated as the average of all indicators and allows the development of an assessment scale of sustainability classes. At the same time, the calculation of integral indicators as a set of individual indicators does not use any weight functions, thus avoiding ambiguity while assessing the importance of each indicator [1, 17].

Indicator calculation algorithms for assessing the sustainability of local coastal eco-socio-economic systems

Indicators of natural-environmental sustainability

Indicator of geomorphological sustainability of coasts

The indicator values are calculated using the method of expert-criterion assessment based on the expert assessment of the local coastal eco-socio-economic system typification by five gradations: from rocky and fjord coasts with very little abrasion (1 point) to fine-sand beaches, including sandy sediments, salt marshes, deltas, etc. (5 points), according to the formula

$$I_G = \frac{\sum_{i=1}^{5}\left(T_i \cdot \frac{p_i}{100}\right) - 1}{2} + 1, \quad (1)$$

where T_i is an assessment of the gradation of the i-th type of coast, an integer within 1...5; p_i is the percentage of the i-th type of coast length of the total coast length, %.

Coast retreat indicator

The indicator is calculated by the formula (1) using the criterion assessment method based on the assessment (according to remote sensing data) of accumulation or retreat of coasts of the local coastal eco-socio-economic system typified by five gradations: from coast accumulation over 2 m/year (1 point) to coast retreat over 2 m/year (5 points).

Coast instability (abrasion) indicator

The indicator values are calculated using the criterion assessment method based on the ratio of the length of falling abrasion coasts of the local coastal eco-socio-economic system to the total length of its coastline, according to the formula

$$I_{AS} = 1 - 2\frac{L_{Us}}{L_C}, \quad (2)$$

where L_{Us} is the length of abrasion coasts, km; L_C is the total length of the studied section of coast, km.

Fortified coastline indicator

The indicator is calculated using the criterion assessment method based on the ratio of the length of the fortified coastline of the local coastal eco-economic system to the total length of its coastline, according to the formula

$$I_{FC} = 2\frac{L_{FC}}{L_C} - 1, \qquad (3)$$

where L_{FC} is the length of the coast with a positive score for the parameter in question, km.

Indicator of uncontaminated parts of coastline

The indicator values are calculated using the formula (3) according to the criterion assessment method and based on the ratio of the length of uncontaminated parts of the coastline of the local coastal eco-socio-economic system to the total length of its coastline.

Natural hazard intensity indicator

The indicator is calculated using the criterion assessment method and includes the following set of parameters:

1) frequency of storms with wind speeds exceeding 15 m/s, by five gradations from < 5 % (1 point) to > 12 % (5 points);

2) height of waves of 3% exceedance probability, by five gradations from < 1 m (1 point) to > 4 m (5 points);

3) tidal heights, by five gradations from < 0.3 m (1 point) to > 2 m (5 points).

The calculation formula is as follows

$$I_{GS} = \frac{1}{2} + \frac{\sum_{i=1}^{5}(W_i \cdot p_i) + \sum_{i=1}^{5}(Wa_i \cdot p_i) + \sum_{i=1}^{5}(Ti_i \cdot p_i)}{6}, \qquad (4)$$

where the assessment of the gradation of the i-th coastal type is determined by the following parameters: W_i – by the 1st parameter, an integer within 1...5; W_{ai} – by the 2nd parameter, an integer within 1...5; T_{ii} – by the 3d parameter, an integer within 1...5.

The value for each characteristic is calculated based on the percentage ratio of the types of coastline of the local eco-socio-economic system to the respective assessment to the total length of its coastline.

Protected areas (PA) indicator

The indicator values are calculated based on the deviation degree of the PA area present in a local coastal municipality from the total PA area present on the RF territory (as a territory of a higher spatial level), with the normalization per area unit, according to the formula

$$I_{PA} = \begin{cases} \dfrac{PA_L/S_L}{PA_F/S_F} - 1 & \text{if } \dfrac{PA_L/S_L}{PA_F/S_F} \le 2, \\ 1 & \text{if } \dfrac{PA_L/S_L}{PA_F/S_F} > 2, \end{cases} \qquad (5)$$

where PA_L is the value of the parameter for a municipality; PA_F is the value of the parameter for the RF as a whole; S_L is the value of the normalizing index for a municipality; S_F is the value of the normalizing index for the RF as a whole.

Indicator of solid municipal waste removal

The indicator is calculated using the formula (5) based on the degree of deviation of the value of solid waste removal from sources located in the local coastal municipality from the total value of solid waste removal from sources located in the RF (as a territory of a higher spatial level), normalized per unit of population.

Indicators of the economic sustainability

Indicator of the recreational attractiveness of the coastal system

The indicator values are calculated using the formula (1) according to the method of expert-criterion assessment based on the expert assessment of the local coastal eco-socio-economic system typification by five gradations: from a very high degree of recreational attractiveness (1 point) to its absence (5 points).

Indicator of anthropogenic hazards intensity

The indicator values are calculated using the formula (1) according to the method of expert-criterion assessment and based on the expert assessment of the local coastal eco-socio-economic system type by five gradations: from the actual absence of anthropogenic hazards for the coastal territory (1 point) to an absolutely anthropogenic coastal territory (5 points).

Transport infrastructure development indicator

The indicator values are calculated using the formula (5) based on the degree of deviation of the length of hard-surface roads on the territory of a local coastal municipality from the length of hard-surface roads located in the territory of the RF (as a territory of a higher spatial level), normalized per area unit.

Budget revenue indicator

The indicator is calculated by the formula (5) based on the deviation degree of the local budget revenues of a local coastal municipality from the total local budget revenues of all local municipalities located on the territory of the RF (as a territory of a higher spatial level), normalized per unit of population.

Investment indicator

The indicator values are calculated using the formula (5) based on the deviation degree of the investment value in fixed capital of the local coastal municipality from the total investment value in fixed capital for all local municipalities located on the territory of the RF (as a territory of a higher spatial level), normalized per unit of population.

Tourism potential indicator

The indicator values are calculated based on two parameters (the number of rooms in collective accommodation facilities (e. g. hotels, hostels, apartments; parameter 1) and the number of collective accommodation facilities (parameter 2)) according to the formula

$$I_{TP} = \frac{1}{2}\left(\frac{P1_L / S_L}{P1_F / S_F} + \frac{P2_L / S_L}{P2_F / S_F} \right) - 1, \quad (6)$$

where $P1_L$ is the value of parameter 1 for the municipality; $P1_F$ is the value of parameter 1 for the RF; $P2_L$ is the value of parameter 2 for the studied coastal municipality; $P2_F$ is the value of parameter 2 for the RF.

The calculation uses the method for calculating the deviation of the value of each parameter of the local coastal municipality from the total value of the parameter for all local municipalities located on the territory of the RF (as a territory of a higher spatial level), normalized per unit of population.

Indicator of subsidies from the RF budgets

The indicator values are calculated based on the degree of deviation of subsidy amount to the budget of the local coastal municipality from the federal budget of the RF from the total subsidy amount to the budgets of all local municipalities of the RF from the federal budget, normalized per budget amount unit, according to the formula

$$I_{PA} = \begin{cases} 1 - \dfrac{PA_L / S_L}{PA_F / S_F} & \text{if } \dfrac{PA_L / S_L}{PA_F / S_F} \le 2, \\ -1 & \text{if } \dfrac{PA_L / S_L}{PA_F / S_F} > 2. \end{cases}$$

Indicator of port cargo turnover

The indicator values are calculated based on the degree of deviation of the cargo turnover of ports located on the territory of a local coastal municipality from the maximum cargo turnover of ports located on the territory of one municipality of the RF, according to the formula

$$I_{HT} = 2\frac{H_L}{H_{\max} - 1},$$

where H_L is the cargo turnover amount of ports located on the territory of a municipality, million tons; H_{max} is the maximum cargo turnover amount of ports located on the territory of one RF municipality, million tons.

Indicators of social sustainability factor

Indicator of socio-economic importance

The indicator values are calculated using the method of expert-criterion assessment, based on the presence of certain types of facilities on the territory of the local coastal municipality. The calculation includes the following set of parameters:

– settlements, by five gradations: from their absence (1 point) to the presence of a metropolis (5 points);

– cultural heritage sites, by two gradations: their absence (1 point) and presence (5 points);

– roads, by five gradations: from their absence (1 point) to federal highways (5 points);

– railway network, by two gradations: their absence (1 point) and presence (5 points);

– type of land use, by five gradations: from the impossibility of economic land use due to the terrain nature (1 point) to the presence of large anthropogenic objects, e. g. enterprises, port complexes, etc. (5 points);

– protected areas (PA), by five grades: from their absence (1 point) to a UNESCO natural monument (5 points).

The calculation formula is as follows

$$I_{SEI} = \frac{S_S + S_{CH} + S_{HW} + S_{RW} + S_{LU} + S_{PA}}{12} - \frac{3}{2},$$

where S_S – assessment based on the settlement type, an integer within 1...5; S_{CH} – assessment based on the cultural heritage type, an integer within 1...5; S_{HW} – assessment based on the road type rating, an integer within 1...5; S_{RW} – assessment based on the railway type, an integer within 1...5; S_{LU} – assessment based on the land use type, an integer within 1...5; S_{PA} – assessment based on protected area type, units.

In case there are several objects of different gradations when considering a single parameter, the one highest value counts.

Indicator of measures taken to improve the sustainability of the coastal system

The indicator values are calculated using the method of expert-criterion assessment and based on the expert assessment of the quantity and quality of measures implemented on the territory of the local coastal municipality to increase the sustainability and preservation of the coastal system, by five gradations: from a high degree of concern and number of measures (1 point) to absence of measures and concern about implementation thereof (5 points). The indicator value is calculated for the municipality as a whole.

Indicator of the natural landscape disturbance level and the need for landscape restoration and maintenance

The indicator values are calculated for coastal areas of the local coastal municipality using the method of expert-criterion assessment. The calculation includes the following set of parameters:

1) the natural coastal landscape disturbance level due to anthropogenic activities, by five gradations: from the absence of any disturbance (1 point) to complete anthropogenic transformation of the landscape (5 points);

2) the degree of need (possibility and importance) for restoration of the natural coastal landscape, by five grades: from no need (possibility and

importance) for landscape restoration (1 point) to an obligation of landscape restoration, including through creation of PAs and cessation of economic activities (5 points).

The calculation formula is as follows

$$I_{CL} = \frac{\sum_{i=1}^{5}(V_i \cdot p_i) + \sum_{i=1}^{5}(R_i \cdot p_i)}{4} + \frac{1}{2},$$

where V_i is the gradation assessment of the i-th coast type by the 1st parameter, an integer within 1...5; R_i is the gradation assessment of the *i*-th coast type by the 2nd parameter, an integer within 1...5.

Indicator of the presence of an area development plan

The indicator is calculated using the method of expert-criterion assessment based on the expert assessment, which considers how much the territorial development plan of a local coastal municipality takes into account the peculiarities of the coastal system, its sustainable development and conservation of coastal landscapes by five gradations: from the availability of a separate section in the territorial development plan related to sustainable development of the coastal system and a road map for implementing this section of the plan (1 point) to the absence of the plan itself (5 points). The indicator value is calculated for the municipality as a whole.

Indicator of housing conditions

The indicator values are calculated according to the formula (5) based on the degree of deviation of the area of commissioned residential houses located on the territory of the local coastal municipality from the total area of those located on the territory of the RF (as the territory of a higher spatial level), normalized per unit of population.

Indicator of social infrastructure facility availability for the population

The indicator is calculated by the formula (6) using two parameters:

1) the number of comprehensive education organizations (parameter 1);

2) the number of healthcare organizations (parameter 2).

The calculation uses the method of calculating the deviation of the value of each parameter of a local coastal municipality from the total value of the parameter for all local municipalities located on the territory of the RF (as the territory of a higher spatial level), with normalization per unit of population.

Indicator of population growth

The indicator is calculated using the following formula

$$I_{PG} = \begin{cases} \frac{B_L}{B_F} - \frac{Mor_L}{Mor_F} & \text{if } \left(\frac{B_L}{B_F} - \frac{Mor_L}{Mor_F}\right) \le 1, \\ 1 & \text{if } \left(\frac{B_L}{B_F} - \frac{Mor_L}{Mor_F}\right) > 1, \end{cases}$$

where B_L is the fertility rate for the municipality, ‰; B_F is the fertility rate for the RF, ‰; Mor_L is the mortality rate for the municipality, ‰; Mor_F is the mortality rate for the RF, ‰.

The calculation uses the methodology of calculating the deviation of the values of each parameter for a local coastal municipality from the value of the parameter for the RF (as a territory of a higher spatial level) as a whole.

Indicator of the population migration balance value

The indicator values are calculated according to the formula as an average of the values obtained:

1) by the deviation degree of the migration gain/outflow value for the local coastal municipality from the parameter value for the RF (as the territory of a higher spatial level);

2) by the deviation degree of migration gain/outflow values for the local coastal municipality from its extreme values for the whole set of local municipalities of the Krasnodar Krai.

$$I_M = \begin{cases} \dfrac{M_L - M_{L\min}}{M_{L\max} - M_{L\min}} & \text{if} \quad \dfrac{M_L/H_L}{M_F/H_F} > 2, \\ \dfrac{M_L - M_{L\min}}{M_{L\max} - M_{L\min}} - 1 & \text{if} \quad \dfrac{M_L/H_L}{M_F/H_F} < 0, \\ \dfrac{1}{2} \cdot \left(\dfrac{M_L/H_L}{M_F/H_F} + \dfrac{M_L - M_{L\min}}{M_{L\max} - M_{L\min}} \right) - \dfrac{1}{2} & \text{if} \quad 0 \le \dfrac{M_L/H_L}{M_F/H_F} \le 2, \end{cases}$$

where M_L – migration gain/outflow for the municipality, people; M_F – migration gain/outflow for the Russian Federation, people; $M_{L\min}$ – minimum value of migration gain/outflow for the entire population of municipalities in the region, people; $M_{L\max}$ – maximum value of migration gain/outflow for the entire population of municipalities in the region, people.

Criterion-statistical assessment of the sustainability of the Black Sea local coastal eco-socio-economic systems

The resulting system of criterion-statistical assessment of the sustainability of local coastal eco-socio-economic systems is approved for local municipalities, which are part of the district municipalities of the Krasnodar Krai located at the Black Sea. A total of 18 local coastal systems were thus considered, including:

– eight local municipalities in the Temryuksky District (Temryuk urban settlement and rural settlements: Golubitskaya, Akhtanizovskaya, Fontalovskaya, Zaporozhskaya, Sennoy, Taman, Novotaman);

– the resort city of Anapa;

– the city of Novorossiysk;

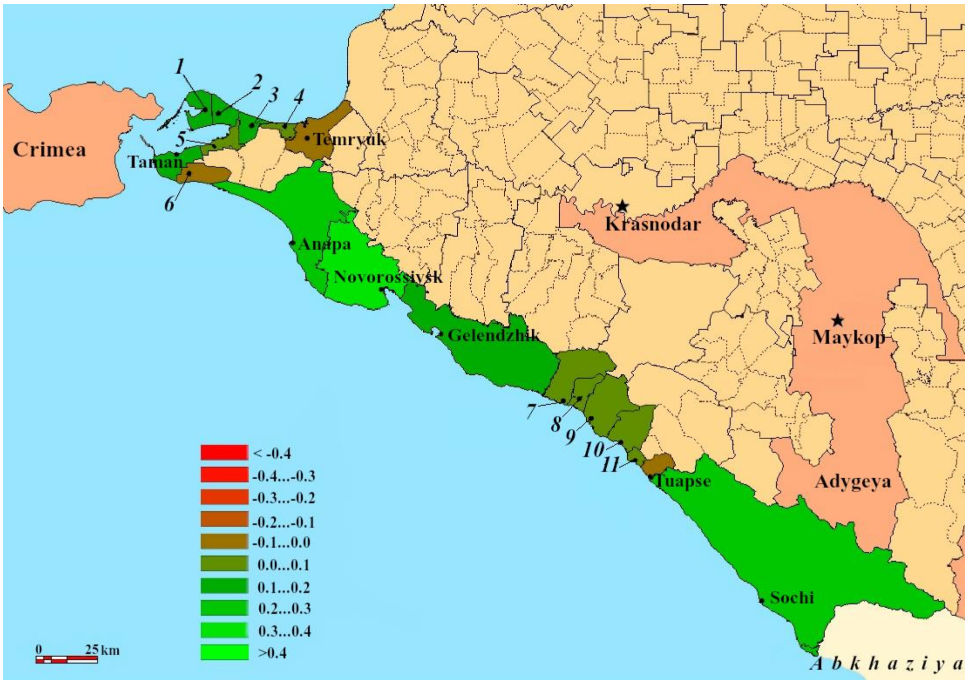
– the resort city of Gelendzhik;

– six local municipalities of the Tuapse District (urban settlements: Dzhubga, Novomikhaylovskoe, Tuapse; rural settlements: Tenginka, Nebug, Shepsi);

– the resort city of Sochi.

As baseline data, the authors used statistical information from open sources and administrations of coastal municipalities of district and local management levels for 2019 as well as data from satellite remote sensing and field research conducted as part of the above projects. The scale for assessment of the sustainability of coastal eco-socio-economic systems by factor and comprehensive index consists of 10 gradations: from −0.4 and below (critical unsustainability) to 0.4 and above (significant sustainability, favourable situation).

Based on the totality of all factors and the comprehensive index of sustainability in 2019, of all local coastal eco-socio-economic systems of the Black Sea coast of the Krasnodar Krai the most sustainable is the city of Novorossiysk (the value of the comprehensive index of sustainability is 0.34), which is associated with fairly high values of all indices (see table, figure). Next are the resort cities of Anapa and Sochi with index values of 0.24 and 0.22, respectively.



Comprehensive integral index of the stability of local Black Sea coastal eco-socio-economic systems of the Krasnodar Krai, 2019 (*1* – Zaporozhskaya; *2* – Fontalovskaya; *3* – Akhtanizovskaya; *4* – Golubitskaya; *5* – Sennoy; *6* – Tamansky; *7* – Dzhubga; *8* – Tenginka; *9* – Novomikhaylovskoe; *10* – Nebug; *11* – Shepsi)

Factors and comprehensive integral index of the sustainability estimation for the Black Sea local coastal eco-socio-economic systems (local municipalities) of the Krasnodar Krai

Local municipality	Natural-ecological factor	Economic factor	Social factor	Integral sustain-ability index
Temryuk US	0.04	–0.03	–0.11	–0.03
Golubitskaya RS	–0.16	0.11	0.12	0.02
Ahktanizovskaya RS	–0.17	0.30	0.17	0.10
Fontalovskaya RS	–0.01	0.11	0.23	0.11
Zaporozhskaya RS	0.11	0.20	0.11	0.14
Sennoy RS	–0.19	0.20	0.11	0.04
Taman RS	–0.05	0.36	0.06	0.12
Novotaman RS	–0.12	–0.07	0.07	–0.04
Anapa Resort City	–0.06	0.18	0.61	0.24
Novorossiysk City	0.24	0.52	0.27	0.34
Gelendzhik Resort City	0.03	0.28	0.11	0.14
Dzhubga MS	0.00	0.06	0.06	0.04
Tenginka RS	–0.07	0.11	–0.02	0.01
Novomikhaylovskoe US	0.05	0.16	0.04	0.09
Nebug RS	0.03	0.13	0.06	0.07
Tuapse US	0.28	0.26	–0.27	0.09
Shepsi RS	–0.16	0.06	0.01	–0.03
Sochi Resort CIty	0.14	0.18	0.36	0.22

Note: US – urban settlement; RS – rural settlement.

Conclusion

As a result of the performed work, the authors present a criterion-statistical approach to integrated assessment of the sustainability of local coastal eco-socio-economic systems based on the indicator approach. Use of aggregate indicators for three sustainability factors (natural-environmental, economic, social) makes it possible to obtain quantitative assessments of the sustainability by individual factors and a comprehensive integral index of sustainability of a local coastal eco-socio-economic system. The considered approach allows performing:

– comprehensive analysis of the sustainability of a local coastal eco-socio-economic system with the identification of sustainability and unsustainability factors;

– assessment of the sustainability of local coastal systems and an appropriate spatial analysis with the identification of stable (key) and unstable local coastal systems as territorial units of the local level of governance.

The criterion-statistical approach to assessing the sustainability of coastal systems is approved in 18 local coastal municipalities of the districts of the Black Sea coast of the Krasnodar Krai. As a result, it is shown that the most sustainable of the local coastal systems is the city of Novorossiysk with the value of the complex sustainability index of 0.34, which is associated with failrly high index values for all sustainability factors. The local coastal systems of Temryuk (Temryuk urban settlement and Novotaman rural settlement) and Tuapse (Shepsi rural settlement) districts are the least sustainable, with the main negative contribution to the sustainability assessment for these coastal systems being the natural and environmental factor. In general, the local coastal systems of the Black Sea coast of the Krasnodar Krai have positive values of the comprehensive sustainability index, with the main contribution being made by the high tourism potential, transport infrastructure development level, stable socio-demographic situation and high degree of natural and environmental sustainability. This approach is universal and can be used in other coastal regions of the RF to assess the sustainability of local coastal eco-socio-economic systems. In the future, when implementing the *Coastal eco-socio-economic systems of Krasnodar Krai* GIS, this approach will enable spatial territory planning and forecasting of sustainable development of coastal eco-socio-economic systems at all governance levels (regional, district, and local) taking into account medium- and long-term natural, ecological and socio-economic dynamics of variability to improve the efficiency of environmental management decisions in the marine coastal zone.

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Submitted 10.07.2021; accepted after review 11.08.2021;
revised 4.02.2022; published 25.03.2022

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