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КОНЦЕПТУАЛЬНІ ЗАСАДИ ВИКОРИСТАННЯ ГІС-ТЕХНОЛОГІЙ ДЛЯ ДОСЛІДЖЕНЬ ПРИБЕРЕЖНИХ ЕКОСИСТЕМ АЗОВО-ЧОРНОМОРСЬКОГО БАСЕЙНУ У МЕЖАХ БЛАКИТНОГО ЗРОСТАННЯ

Актуальність: У статті розглянуто питання щодо можливості застосування сучасних ГІС-технологій для досліджень прибережних екосистем Азово-Чорноморського басейну у межах блакитного зростання. Сьогодні ГІС-технології значно полегшують дослідження впливу природних і антропогенних факторів на природне середовище. За останні десятиліття розвиток цих технологій значно зріс. Тепер їх можна використовувати як окремий і самостійний інструмент для досліджень у різних сферах виробництва. На основі результатів, отриманих на базі ГІС-технологій, можна робити наукові висновки або створювати і реалізовувати управлінські рішення для підтримки сталого або резилььєнтного розвитку стану довкілля в умовах значного екологічного тиску. Також проводити економічну, екологічну, соціальну оцінку наслідків антропогенного та природного впливу на морські та прибережні екосистеми та екосистему суші.

Мета та завдання: Метою дослідження було наукове обґрунтування можливостей використання сучасних ГІС-технологій щодо сталого розвитку прибережної екосистеми Азово-Чорноморського басейну в рамках блакитного зростання.

Матеріали та методи: Дослідження здійснювались на методах картографування прибережної смуги за класифікацією екологічних параметрів на основі даних Геологічної служби США (USGS). Екологічна прибережна класифікація (ECU) була розроблена Геологічною службою США (USGS) у співпраці з Esri та Мережею спостереження за морським біорізноманіттям (MBON). Ці дані були розроблені в рамках ініціативи Групи зі спостереження за Землею (GEO) під назвою «Екосистеми GEO» (GEO ECO) і пов’язані із завданням GEO ECO з розробки глобальних даних про прибережні екосистеми.

Результати: У статті описано стан прибережної смуги морів України за класифікацією екологічних параметрів на основі даних Геологічної служби США (USGS). Було зазначено, що екологічний стан узбережжя класифікується за п’ятьма параметрами океану, двома параметрами суші та трьома параметрами узбережжя. Результати досліджень показали, що екологічна обстановка прибережних смуг морів України в цілому відповідає другому, третьому, шостому та п’ятнадцятому класам за екологічною береговою класифікацією.

Висновки: На підставі отриманих результатів показано, що метод класифікації прибережних смуг, розглянутий у цій статті на основі даних Геологічної служби США (USGS), може слугувати потужним інструментом у процесі управління прибережними зонами Азово-Чорноморського басейну. Встановлено, що ГІС-технології на сучасному етапі розвитку мають дуже великий потенціал для вивчення прибережних екосистем Азово-Чорноморського басейну в рамках блакитного зростання.

Ключові слова: природні ресурси, прибережні екосистеми, ГІС-технології, сталий розвиток, блакитне зростання, управління, екологічна прибережна класифікація, інновації, Українське Причорномор’я, Українське Приазов’я.

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CONCEPTUAL FOUNDATIONS FOR THE USE OF GIS TECHNOLOGIES FOR THE STUDY OF COASTAL ECOSYSTEMS OF THE AZOV-BLACK SEA BASIN IN THE FRAMEWORK OF BLUE GROWTH

Topicality. The paper discusses the possibility of using modern GIS technologies for studying coastal ecosystems of the Azov-Black Sea basin within the framework of blue growth. Today, GIS technologies greatly facilitate the study of the impact of natural and anthropogenic factors on the natural environment. The development of these technologies has increased greatly in recent decades. Now they can be used as a separate and independent tool for research in various areas of production. Based on the results obtained on the basis of GIS technologies, it is possible to draw scientific conclusions or create and implement management decisions to maintain sustainable or resilient development of the state of the environment under significant environmental pressure. Also conduct an economic, environmental, social assessment of the consequences of anthropogenic and natural impacts on marine and coastal ecosystems and the terrestrial ecosystem.

Aim and tasks. Scientific substantiation of the possibilities of using modern GIS technologies regarding the sustainable development of the coastal ecosystem of the Azov-Black Sea basin within the framework of blue growth was the aim of the study.

Materials and Methods. The studies were based on coastal mapping methods. The classification of environmental parameters based on United States Geological Survey (USGS) data was the initial information. The ecological coastal classification (Ecological Coastal Units (ECU)) was developed by the US Geological Survey (USGS) in collaboration with Esri and the Marine Biodiversity Observation Network (MBON). These data were developed as part of a Group on Earth Observation (GEO) initiative called GEO Ecosystems (GEO ECO). They are linked to the GEO ECO task of developing global data on coastal ecosystems.

Research results. The state of the coastal strip of the seas of Ukraine according to the classification of environmental parameters based on data from the United States Geological Survey (USGS) was described in this paper. It was stated that the ecological status of coastlines is classified into five ocean parameters, two land parameters and three coastal parameters. The research results showed that the ecological situation of the coastal strips of the seas of Ukraine generally corresponds to the second, third, sixth and fifteenth classes according to the ecological coastal classification.

Conclusion. It is presented that the coastal strip classification method discussed in this paper based on US Geological Survey (USGS) data can serve as a very powerful tool in the process of managing coastal zones of the Azov-Black Sea basin. It has been established that GIS technologies at the current stage of development have very great potential for studying coastal ecosystems of the Azov-Black Sea basin within the framework of blue growth.

Keywords: natural resources, coastal ecosystems, GIS technologies, sustainable development, blue growth, management, ecological coastal classification, innovations, Ukrainian Black Sea region, Ukrainian Azov region.

Problem statement and its connection with important scientific and practical tasks. Land is a unique resource for any country on Earth. The volume of this resource is limited. This underlines its comprehensive value to society. This resource is a fundamental source of livelihood, valued for its benefits to people above and below the earth's surface. Land is a strategic socio-economic asset, especially in poor societies where both survival and prosperity are still largely dependent on control and access to land resources. (Tretiak et al., 2021).

Environmental safety is the main prerequisite for the sustainable development of any region. It is directly related to the need to maintain the optimal level of natural resource potential and the necessary quality of the environment. Environmental security is also related to environmental conflicts (Petrushenko & Voroshylko, 2015). This concept cannot be implemented without the formation of an effective economic mechanism in the region. This mechanism must meet the requirements of optimal use of natural resources, on the one hand, and the requirements of nature protection, on the other. Also, an effective economic mechanism is the basis for sustainable investment (Petrushenko, Shevchenko, Burkynskyi, & Khumarova, 2019).

This can be achieved only through the joint efforts of local authorities, scientists, specialists, entrepreneurs and the general public of all countries located in the Black Sea region (Zerkalov, 2012).

The need to preserve the natural features of the coastal strip of the Azov-Black Sea basin, compliance with safety requirements and the unique role of this strip in the economic development of coastal countries are of particular importance.

Irrational use of the resources of the coastal strip of the sea, in particular and first of all the use of the coastal territory (territorial resource), non-compliance with scientifically based management approaches lead to a decrease in the economic potential of the region, as well as to the degradation of coastal ecosystems, loss of biodiversity, deterioration of the environment. Solving complex economic-ecological and related
social problems requires a comprehensive, integrated approach. On the one hand, these approaches take into account the interests of the socio-economic development of the territory of the coastal strip of the sea, and on the other hand, the damage caused to the surrounding natural environment is minimized (Komorin, Pavlenko, Matsokin, Kotelyhko, & Malovana, 2022).

**Analysis of recent publications on the problem.** Blue growth is a multi-faceted, multi-sectoral direction, designed to facilitate the fastest possible transition of the economy of the Ukrainian Black Sea region, which is focused on the priority of production interests to a sustainable blue economy (Petrushenko, Burkynskyi, Shevchenko, & Baranchenko, 2021). Common aspects of the blue growth goals are the effective fight against negative climate change (Petrushenko, 2023).

It is known (Kulikov et al., 2021) that marine abrasion in the coastal zone of the seas contributes to the destruction of the shores and leads to changes in the coastline. The authors (Shuisky, Vykhovanetz, & Pankratenkova, 2019) indicate that in recent years, significant anthropogenic influence has been observed in the coastal regions of the Danube, North-Western and Dnipro-Karkinits regions on the Black Sea and North-Azov region on the Sea of Azov. Among the main types of anthropogenic intervention in the nature of the coastal zone of the seas, the authors (Shuisky et al., 2019) single out direct extraction of sediments from beaches, bars, barriers from the underwater slope. They draw attention to the fact that the coastal part of the Black Sea Lowland is composed of clayey and weak rocky carbonate rocks of the Neogene-Anthropogen period. Sediments are often transported from the surface of single-sloped beaches by truck for the construction of residential buildings, cottages, recreation centers, roads, etc. Especially a lot of drifts (sand, gravel, pebbles) is removed from accumulative relief forms (barriers, bars, terraces, etc.). The authors (Shuisky et al., 2019) note that together with the top layer of sand that is removed, plants, animals, nutrient solutions are physically irrevocably dying en masse, and the natural structure of the beach layer is disappearing. The drifts are also removed from the underwater slope - from the reliefs of banks, ancient sand forms, large covering spots. Unique physical-geographic systems that occur only on sandy accumulative forms of the coastal zone, with an unusual amount of elements and components, with individual paths of development, with a very intense interaction of the structural components of the structure, suffer the most.

The paper (Tambovtsev & Makieieva, 2020) states that the length of the coastline with the development of abrasion within the AR Crimea is 822 km (Black and Azov seas), Mykolaiivska – 17.8 km, Odeska – 86.0 km and Khersonska – 128.0 km regions (Black sea) and about 340 km on the Sea of Azov – Donetska (69.7 km) and Zaporizka regions (270.0 km including estuaries). 611 km of the coast are protected by engineering structures.

In order to effectively protect the shores from abrasion, it is necessary to have a clear idea of the causes of erosion, and only then can you choose an effective method of protection. It is especially difficult to protect sandy shores from erosion. All structures of passive protection on sandy shores, even those built on a strong foundation, are washed away, overturned and drowned in sand drifts over several years. On pebbly shores, breakwater walls are more durable, but need to be repaired due to their bombardment with pebbles. (Karpenko, 2009).

The authors (Tambovtsev & Makieieva, 2020) state that solving the problems associated with the activation of exogenous geological processes, strengthening the shores in order to prevent the further escalation of the ecological disaster, overcoming the consequences of a dangerous ecological situation, solving the problems of protecting and preserving valuable natural and healing resources and the recreational potential of the region is possible only if integrated approach at the state level with the involvement of local level capabilities.

It should be noted that the principles of state management of water fund lands are: sustainable development of a combination of basin and administrative-territorial management methods, separation of protection functions and functions of economic water use. The unified system of management bodies that ensure the implementation of state policy in the field of water fund land use and protection is formed by (Tretiak & Dorosh, 2006):

- Cabinet of Ministers of Ukraine;
- Ministry of Environmental Protection and Natural Resources of Ukraine;
- State Agency of Land Resources of Ukraine;
- State Agency of Water Resources of Ukraine;
- State Agency of Forest Resources of Ukraine;
- State Geology and Subsoil Service of Ukraine;
- Regional state administrations;
- Executive committees of district, city,
small town, village councils.

Today, an improved data management system is the basis for making decisions in the field of sustainable land use, taking into account the specifics of the development of the blue economy (Kaliraj, Chandrasekar, Ramachandran, Srinivas, & Saravanan, 2017; Boucquey, St Martin, Fairbanks, Campbell, & Wise, 2019). One of the main components of this system is remote sensing of the Earth. It enriches coastal science with data, in particular to improve the accuracy and increase the detail of modern GIS technologies. This, in turn, provides grounds for ensuring prompt decision-making regarding the sustainable development of marine and coastal areas (Vitousek et al., 2023).

**Allocation of previously unsolved parts of the general problem.** To date, the issue of a universal method or methodology for conducting detailed research and monitoring of water or land objects has not yet been fully resolved. Scientists are constantly improving these methods and techniques. One part of the scientific community is inclined to conduct research based on in-situ measurements, another uses remote sensing information in research, and a third combines and integrates both in-situ measurements and remote sensing data. However, all these areas of research have a great sense in their development.

**Formulation of research objectives (problem statement).** The purpose of the study is to substantiate the possibilities of using modern GIS technologies in relation to the sustainable development of the coastal strip ecosystem of the Azov-Black Sea basin within the limits of blue growth.

**Materials and Methods.** The studies were based on the methods of mapping the coastal strip according to the classification of environmental parameters based on the data of the United States Geological Survey (USGS).

**An outline of the main results and their justification.** Today, GIS technologies greatly facilitate research on the impact of natural and anthropogenic factors on the natural environment. In recent decades, the development of GIS technologies has grown so much that today they can act as a separate and independent tool for research in various fields of production. Based on the results obtained on the basis of GIS technologies, it is possible to draw scientific conclusions or create and implement management decisions regarding the maintenance of sustainable or resilient development of the state of the environment under a significant ecological load on it, in particular, to carry out an economic, ecological, social assessment of the consequences of anthropogenic and natural impact on marine and coastal ecosystem and terrestrial ecosystem.

During the last two decades, global information on the state of the coasts of the entire globe has been obtained with the help of remote sensing technologies and satellite images. This made it possible to integrate and generalize the available information to compile a comprehensive picture of the state of coastal ecosystems and assess their relative importance from the point of view of ecological, economic and social characteristics (Martinez et al., 2007).

It is known that the negative effects on the state of coastal and beach zones are not limited to anthropogenic influence. Natural processes, which usually have an accumulative or abrasive nature, also have a significant impact on the state of the coastal strip. The most important such processes can be distinguished, for example: atmospheric (hurricanes, tornadoes, heavy rainfall), hydrological (due to the action of waves during storms or powerful surf, corresponding water level fluctuations, strong river floods, etc.) and tectonic (earthquakes). But, as our analytical examination of modern scientific bibliographic sources and scientific publications shows, the research of domestic scientists, for example, Professor Yu.D. Shuisky (Shuisky et al., 2019; Shuisky, Vykhovanetz, & Murkalov, 2023), Professor M.A. Berlinskyi (Sahaidak, & Berlynskyi, 2021), etc. are of particular interest regarding the state of the marine coastal zone within Ukraine under the influence of anthropogenic (technogenic) factors. This may indicate that the anthropogenic impact on the coastal zones of the Azov-Black Sea region is very significant, and scientific interest in this impact significantly outweighs research on natural processes that affect the state of coastal zones.

In our opinion, this can be explained by the fact that the natural processes that affect the state of the coastal zones of the seas of Ukraine are more or less well studied and today it is believed that they can be predicted, forecasted and modeled. As a result, it can be assumed that the direction of research into the current state of the coastal protective strip of seas, sea bays and estuaries is mainly characterized by the study of anthropogenic influence on these areas of the earth's surface. This indicates that, nevertheless, the consequences of human activity have a very large impact on the state of the coastal ecosystem on a global scale, in particular in the Azov-Black Sea region.

Today, a new set of resources describing the main characteristics of the coastline has already appeared and is available to everyone. The
ecological coastal classification (Ecological Coastal Units (ECU)) was developed by the US Geological Survey (USGS) in collaboration with ESRI and the Marine Biodiversity Observation Network (MBON). These data were developed as part of a Group on Earth Observation (GEO) initiative called GEO Ecosystems (GEO ECO). They are linked to the GEO ECO task of developing global data on coastal ecosystems (VanGraafeiland, 2021). In Fig. 1 shows the distribution of 16 globally similar ecological coastal classes (ECUs) across the globe.

![Fig. 1. Classification of ecological conditions of coastal strips around the globe (each of the 16 ecological coastal classes corresponds to a certain class color (ECUs))](image)

Source: based on (VanGraafeiland, 2021)

This data allows you to visualize and isolate any part of the coastline on Earth, with the exception of Antarctica (Sryberko & Stepanova, 2023). The initial data are 4 million coastal segments of 1 km or less, each assigned a value from ten parameters of environmental conditions representing adjacent ocean, adjacent land, and shoreline.

Four million coastal segments are classified into 81,000 Coastal Segment Classes (CSUs) using the Coastal and Marine Ecosystem Classification Standard (CMECS) (Marine and Coastal Spatial Data Subcommittee, 2012). Each individual class (CSU) is a segment with a unique combination of classes of values of ten environmental variables. The four million segments were also grouped into a set of 16 global shoreline classes that are similar in aggregate environmental parameters described by ten variables (VanGraafeiland, 2021; Sayre et al., 2021a).

The developed 10 parameters belonging to the coastal segments describe the overall ecological situation of the coastal strip. The values of these parameters are taken from various data sources and refer to the midpoints of the coastal segment.

Shown in Fig. 2 ten parameters make up the ecological conditions of the coastal environment (VanGraafeiland, 2021):

- 5 parameters of the ocean;
- 2 parameters of land;
- 3 parameters of the coastline.

Each midpoint of the segment (Fig. 2) is assigned the value of each of the 10 parameters. The paper (Sayre, 2021) states that five ocean parameters are used to characterize the average over many years of coastal water conditions. The hydrophysical characteristics of the marine environment are an integrated measure of temperature, salinity and dissolved oxygen regimes, each with its own CMECS categories (Marine and Coastal Spatial Data Subcommittee, 2012). The underlying data for this metric was based on data derived from global marine ecological units (Ecological Marine Units, 2018; Sayre et al., 2017), based on long-term averaged data from the NOAA World Ocean Atlas (NOAA, 2023). Let us give as an example the limits of values that characterize a certain gradation of hydrophysical parameters based on the CMECS classification standard of coastal and marine ecosystems (Marine and Coastal Spatial Data Subcommittee, 2012) (table 1).
Fig. 2. A set of 10 parameters to describe the aggregate environmental conditions encountered by coastal segments

Source: (VanGraafeiland, 2021)

Table 1. Ranges of values characterizing the distribution by categories of hydrophysical parameters of the marine environment based on the standard (CMECS)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Category</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The temperature of the waters of the marine environment, °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frozen/Superchilled</td>
<td>≤ 0</td>
</tr>
<tr>
<td></td>
<td>Very Cold</td>
<td>0 to &lt; 5</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>5 to &lt; 10</td>
</tr>
<tr>
<td></td>
<td>Cool</td>
<td>10 to &lt; 15</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>15 to &lt; 20</td>
</tr>
<tr>
<td></td>
<td>Warm</td>
<td>20 to &lt; 25</td>
</tr>
<tr>
<td></td>
<td>Very Warm</td>
<td>25 to &lt; 30</td>
</tr>
<tr>
<td></td>
<td>Hot</td>
<td>30 to &lt; 35</td>
</tr>
<tr>
<td></td>
<td>Very Hot</td>
<td>≥ 35</td>
</tr>
<tr>
<td></td>
<td>Salinity of waters of the marine environment, ‰</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oligohaline i</td>
<td>≤ 5</td>
</tr>
<tr>
<td></td>
<td>Mesohaline</td>
<td>5 to &lt; 18</td>
</tr>
<tr>
<td></td>
<td>Lower Polyhaline</td>
<td>18 to &lt; 25</td>
</tr>
<tr>
<td></td>
<td>Upper Polyhaline</td>
<td>25 to &lt; 30</td>
</tr>
<tr>
<td></td>
<td>Euhaline</td>
<td>30 to &lt; 40</td>
</tr>
<tr>
<td></td>
<td>Hyperhaline</td>
<td>≥ 40</td>
</tr>
<tr>
<td></td>
<td>The concentration of oxygen dissolved in the water of the marine environment, mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anoxic</td>
<td>0 to &lt; 0,1</td>
</tr>
<tr>
<td></td>
<td>Severely Hypoxic</td>
<td>0,1 to &lt; 2</td>
</tr>
<tr>
<td></td>
<td>Hypoxic</td>
<td>2 to &lt; 4</td>
</tr>
<tr>
<td></td>
<td>Oxic</td>
<td>4 to &lt; 8</td>
</tr>
<tr>
<td></td>
<td>Highly Oxic</td>
<td>8 to &lt; 12</td>
</tr>
<tr>
<td></td>
<td>Very Oxic</td>
<td>≥ 12</td>
</tr>
</tbody>
</table>

Source: developed based on (Marine and Coastal Spatial Data Subcommittee, 2012)

Land characteristics are factors of biotic distribution (Bailey, 2009; Gagné et al, 2020). The initial data of multi-year average air temperature and precipitation were the data of World Climate Regions (Sayre et al., 2020) obtained from the climatic databases WorldClim v.2.0 (Fick &
Data from the Global Lithological Map were also used to describe the relative susceptibility to erosion of the underlying lithological formations of the coastline (Global Lithological Map, 2023; Hartmann & Moosdorf, 2012) and index of erosion activity (Moosdorf, Cohen, & von Hagke, 2018). To characterize the coastline itself, three parameters were determined that have a special impact on coastal ecology: sinuosity, slope profile, and river outflow index. Sinuosity affects terrestrial (e.g. coastal drifts) and aquatic (e.g. energy and wave action) processes (Bartley, Buddemeier, & Bennett, 2001; Nyberg & Howell, 2016). The slope profile perpendicular to the shoreline affects wave energy and impact (John, Brew, & Cottle, 2017). River outflow affects the nature of sediment drifts, turbidity and salinity.

In most cases (seven out of ten characteristics), the parameters were derived from a global bitmap layer constructed for each characteristic. Then, the value of the raster cell, the central point of which was closer to the middle of the 1-kilometer segment, was referred to the middle point of the segment. To profile the land slope, a 200-meter perpendicular extending 100 meters landward and 100 meters seaward from the midpoint of each segment was created, and the elevation values at both ends of the perpendicular were used to calculate the slope. A 10-km stretch of coastline (10 segments) was used for sinuosity, and the roughness index (RI) was calculated as the ratio of the length of the actual curved coastline to the length of the straight line connecting the two ends of the segment. An index value (RI) was then assigned to the midpoints of the 10 segments.

For the river outflow index, it was necessary to determine where rivers (~160,000) cross the global vector of the coastline and calculate the amount of river runoff into the marine environment. The index represents the volumes of water discharged into river mouths and the distribution of these waters in the marine environment, statistically modeled using a kernel density function. The authors (Sayre et al., 2021a) modeled the average annual precipitation in catchment basins with a spatial resolution of 1 km and assumed that this flow is approximated. Assumptions included the following: first, rainfall is uniform throughout the basin and second, water flow is equal to rainfall. Water volume values were normalized using a dimensionless river flow index ranging from zero to one using a minimum-maximum scaling method and then grouped by impact level: low, medium, and high impact. The river outflow index characterizes a simple relative measure of the river's influence along the coastline (Sayre et al., 2021b).

On the time scale, most of the values are long-term average annual values from the data archive: hydrophysical characteristics of the marine environment – 57 years (1956–2013), chlorophyll values – 24 years (1997–2020), tidal range values – 20 years (1994–2014), wave height value – 30 years (1979–2009), turbidity characteristics – 17 years (2002–2019), climate state characteristics – 30 years (1970–2000), characteristics of river flow influence – 30 years (1970–2000). The other parameters (erosivity, sinuosity, and slope profile) are more stable characteristics of the shoreline and were not obtained from the time series data (Sayre et al., 2021a). The performed classification stage led to the development of CSU classes, defined as any segment with a unique set of class labels for 10 parameters (Fig. 2) (VanGraafeiland, 2021).

The data described above (ECU) are available in ArcGIS Living Atlas (VanGraafeiland, 2021 of the World as an online vector layer representing 1 km long shoreline segments, and as an ArcGIS Pro package (The Esri Oceans, 2023) that can be downloaded and used for computer visualization and analysis (Sayre et al., 2021a).

In order to visualize the ecological state of the coastal strips of the seas of Ukraine, we have built a map (Fig. 3) of the distribution of global classes of coastal strips (CSUs) of the seas of Ukraine with the help of data from the US Geological Survey (USGS) (VanGraafeiland, 2021).

As can be seen from Fig. 3, the ecological situation of the coastal strips of the seas of Ukraine generally corresponds to the second, third and sixth classes in relation to the ecological coastal classification (ECU). According to the ecological coastal classification (ECU), the coastal strips of the sea belong to the second class – Mykolaii, Donetsk regions, a large part of Kherson and Zaporizhzhya regions. Also, the western part of Crimea in the waters of the Sea of Azov and the south-western part of Crimea in the area of the Karkinit Bay of the Black Sea. In general, this class corresponds to the parameters of the marine environment, which characterizes the waters of this area as cold, mesohaline and hypoxic, with a moderate content of chlorophyll, a microtidal area with low wave energy and moderate turbidity. On the land side, this class is characterized by a cool, moderate and dry climate and low erosion.
The coastal strip itself is characterized by a gentle slope with a moderate river outflow.

The third class (ECU) includes the coastlines of the western and eastern parts of Crimea in the Black Sea water area, a small section of the Crimean coast in the southern part of the Kerch Strait in the water area of the Sea of Azov, a section of the coast of Lake Dzharylgach and the continental coastline of Dzharylgach Bay near the Skadovsk city in the Black Sea (Fig. 3). Class three characterizes a coastline with sloping and straight shores, low erosion, warm, temperate and dry climate, moderate river outflow, microtidal or intertidal area with low wave energy, marine waters polyhaline, oxic and cold, transparent with low to moderate chlorophyll content.

Most of the coastline in the southern part of Crimea in the section from the Alupka city to the Sudak city corresponds to the sixth class (ECU). The sixth class also includes a section of the coast in the Zaporizhzhya region in the area between Obitochna spit and the Berdyansk city in the Sea of Azov. Thus, according to the classification (ECU), the parameters of the marine environment characterize the waters of this area as cold, polyhaline and oxic with low chlorophyll content, the areas are tidal with low wave energy and moderate turbidity. On the land side, the regions are characterized by a warm, moderate and dry climate and moderate erosion. The coastal strip itself is characterized as a straight line with a sloping slope and a moderate river outflow.

The only part of the coastline that belongs to the fifteenth class is the coast of Obitochna spit in the Sea of Azov in the Zaporizhzhia region. This class (ECU) characterizes the coast with a sloping and winding coast, low erosion, cool, temperate and dry climate, moderate river outflow, tidal area with low wave energy, the water parameters of the marine environment are characterized as mesohaline, oxygenated and cold, transparent with high chlorophyll.

Thus, based on the above, it can be stated that the detailed information obtained from the data of GIS technologies can be integrated to create management decisions regarding the sustainable development of the coastal ecosystems of the seas of Ukraine.

Conclusions and perspectives of further research. Based on the obtained results, it can be concluded that the method of coastal strip classification (CSUs) considered in this article based on the data of the US Geological Survey (USGS) can serve as a very important tool in the process of managing the coastal zones of the Azov-Black Sea basin. If this tool is integrated, for example, into numerical or simulation modeling of coastal zone development processes under the influence of anthropogenic or natural factors, then there is an opportunity to calculate and take into account the risks that these factors pose to the coastal strip. Based on the results of such modeling, it is possible to conduct economic, ecological, and social assessments of the current state of coastal strips, which will serve as a basis for decision-making regarding the management of coastal strips of the Azov-Black Sea basin.

Thus, this indicates that modern GIS...
technologies are a very important auxiliary tool in the adoption and implementation of management decisions regarding the sustainable or resilient development of the coastlines of the seas of Ukraine.

GIS technologies at the current stage of development have very great potential for studying coastal ecosystems of the Azov-Black Sea basin within the framework of blue growth.

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