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### GEOINFORMATION SUPPORT FOR COASTAL CLIMATE HAZARD ASSESSMENT IN THE EU INTERREG NEXT MOREADAPTBSB PROJECT

**M. Broshkov**

Doctor of Veterinary Sciences, Professor  
ORCID: <https://orcid.org/0000-0002-9917-7257>  
Odesa State Agrarian University  
99 Kanatna St., Odesa, 65039, Ukraine

**T. Neboha**

PhD of Economic Sciences, Senior Researcher  
ORCID: <https://orcid.org/0000-0002-5025-7299>  
Odesa State Agrarian University  
99 Kanatna St., Odesa, 65039, Ukraine

**D. Bulysheva**

PhD of Economic Sciences, Associate Professor  
ORCID: <https://orcid.org/0000-0003-2907-9413>  
Odesa State Agrarian University  
99 Kanatna St., Odesa, 65039, Ukraine

**A. Maiev**

PhD of Public Administration  
ORCID: <https://orcid.org/0000-0001-9333-2933>  
Odesa State Agrarian University  
99 Kanatna St., Odesa, 65039, Ukraine

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**Abstract.** The article summarizes the results of a study carried out within the framework of the international project “Less vulnerability, more adaptability – pilot remote sensing assisted restoration of green spaces in coastal and urban areas within the Black Sea region” (MoreAdaptBSB). The aim of the study was to develop and test a comprehensive approach to geoinformation support for assessing the climate vulnerability of coastal and urban ecosystems of the Ukrainian Black Sea region. The methodological framework of the study was based on geoinformation analysis, remote sensing, spatial modelling, and field validation methods implemented in accordance with the three-component vulnerability model. At the first stage, a structured array of geospatial layers covering climatic, environmental, geomorphological, socio-economic, and infrastructural parameters was developed. The main data sources included open-access satellite platforms Copernicus and Landsat, state registers, and official geospatial databases. At the second stage, field validation of the developed vulnerability models was conducted using a standardized checklist and a four-point indicator assessment scale. Field surveys covered 150 locations within the Odesa region. The results obtained confirmed the overall reliability of the remote sensing-based models and made it possible to identify local degradation zones not represented in open-access data sources. It was established that aquatic ecosystems, particularly estuaries and small rivers, are the most vulnerable due to the combination of high climate-related exposure and low adaptive capacity. The practical significance of the study lies in the possibility of applying the developed approach to regional climate adaptation planning, environmental risk management, and the integration of Ukraine into European spatial monitoring systems. The scientific novelty of the study consists in the testing of a comprehensive approach combining geoinformation modelling and field validation under conditions of limited access to official data during martial law.

**Key words:** climate vulnerability assessment; geographic information systems (GIS); remote sensing; field validation; Black Sea region; Environmental Vulnerability Index (EVI); climate change adaptation; coastal ecosystems; geospatial data; MoreAdaptBSB.

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**Problem statement**

The Black Sea region is characterized by the interaction of several interrelated climate risks, including the degradation of coastal ecosystems, increasing aridity, erosion processes, disruption of water balance, and urbanization pressure. Covering approximately 160 thousand km<sup>2</sup>, which accounts for

nearly one quarter of the territory of Ukraine, the Black Sea region represents a strategically important agro-industrial, logistical, and socio-ecological system with exceptionally challenging conditions for adaptation planning [1].

Effective adaptation to climate hazards is impossible without a reliable, structured, and spatially referenced

information base. Therefore, within the framework of Activity 1.1 “Joint Development of Remote-Sensing Based Methodology for Assessment of the Resilience and Vulnerability of Coastal and Urban Areas to Climate Change Related Hazards”, implemented under the international project “Less vulnerability, more adaptability – pilot remote sensing assisted restoration of green spaces in coastal and urban areas within the Black Sea region” (BSB00479), funded by the European Union within the Interreg VI-B NEXT Black Sea Basin Programme (hereinafter – MoreAdaptBSB), a two-stage study was conducted. The study included the development of geospatial, climatic, and analytical datasets, followed by field validation of the resulting cartographic vulnerability models.

The relevance of this study is determined by several factors. First, there is a significant lack of comprehensive GIS-compatible spatial data for the Black Sea coastal region, as the fragmented nature of cartographic coverage and the heterogeneity of geospatial information complicate the systematic assessment of environmental risks. Moreover, over the last decade, climate change has become one of the most pressing issues in global economics and policy due to the limited adaptive capacity of countries to cope with extreme climate-related events, such as floods, droughts, and other hazards capable of causing social and economic instability [2]. Second, the martial law introduced in Ukraine on 24 February 2022 has restricted access to a number of official statistical and topographic sources, thereby necessitating the development of methodological approaches for working with open-access satellite data under conditions of information constraints. Third, there is a lack of standardized methodologies for the field verification of remote vulnerability assessments adapted to the conditions of coastal ecosystems of the Black Sea Basin and aligned with European Union requirements. Finally, the effective participation of Ukraine in transboundary climate risk management mechanisms requires the availability of a unified vulnerability assessment system comparable with European approaches and internationally recognized within the framework of contemporary climate adaptation practices [3].

Among the key transboundary threats affecting the Black Sea coastal region are sea level rise, droughts, landslides, desertification, floods, biodiversity loss, soil degradation, urban heat accumulation, and disruption of water balance. These phenomena are complex and interconnected in nature, significantly affecting both ecosystem conditions and the living environment of the population, as well as the potential for transboundary cooperation. The problem becomes particularly acute in the context of post-war regional recovery, where infrastructure destruction and environmental degradation are superimposed on long-term climate-related stresses.

Therefore, the development of methodological approaches to the formation of geoinformation support for climate vulnerability assessment, as well as their practical implementation within the framework of an EU-funded international project, constitutes a scientifically grounded and practically significant task

directly related to Ukraine’s adaptation to climate change and its integration into European mechanisms for environmental risk monitoring and management.

**The aim of the article** is to summarize the approaches to the development of geoinformation support for climate vulnerability assessment and the results of their field validation obtained within the framework of the MoreAdaptBSB project.

#### **Analysis of recent research and publications**

The issue of assessing the climate vulnerability of coastal and urban areas using remote sensing and GIS-based analysis has undergone substantial development in international scientific literature over the past 7–10 years. A review of these studies makes it possible to identify the current state of approaches addressing tasks closely related to the objectives of the MoreAdaptBSB project.

The integration of remote sensing methods, GIS technologies, and multi-criteria decision analysis for the identification of climate-vulnerable zones in coastal areas has become an established approach in contemporary assessments. This process generally includes the collection and processing of climatic data, the development of impact assessment models, and the selection of adaptation systems. Such a three-stage structure corresponds to the logic of Activity 1.1 of the MoreAdaptBSB project – from the development of geospatial databases to the field validation of the obtained results [4].

For the Black Sea coastal zone, a representative example is the 2025 study based on the Romanian Black Sea coast, in which a quantitative assessment tool was developed to evaluate the cumulative impact of hydrogeomorphological factors and anthropogenic pressures on the vulnerability of coastal areas to erosion. This approach may subsequently serve as a basis for transboundary comparison and harmonized regional assessments [5].

The combination of optical and radar (SAR) satellite data for monitoring shoreline changes along the Black Sea coast between 2016 and 2023 demonstrated that more than 35 km<sup>2</sup> of the coastal strip underwent transformations, of which 68 % corresponded to land accretion and 32 % to shoreline retreat. Natural changes were predominantly recorded near deltas and estuarine systems, particularly within the Dnipro–Bug Estuary and in the areas between the Dnipro estuary and the Karkinit Bay. This information is directly relevant to the target area of the MoreAdaptBSB project [6].

Analysis of Black Sea level dynamics based on satellite altimetry data for the period 1993–2020 confirms the nonlinearity of its temporal changes and the significant spatial variability across the sea basin. This complicates the application of generalized predictive models and necessitates regionally differentiated approaches to risk zone mapping, such as those implemented within the framework of the MoreAdaptBSB project [7].

A study assessing the vulnerability of the Thracian Peninsula (Türkiye) to sea level rise using a digital elevation model and the Coastal Vulnerability Index (CVI) demonstrated that coastal wetlands, densely

populated urbanized areas, and coastal tourism facilities are expected to be the most vulnerable within the 2020–2050 time horizon. A similar typology of vulnerable areas is also characteristic of the Ukrainian Black Sea region, particularly the Odesa and Kherson regions [8].

A broader methodological framework is provided by the approach of the Intergovernmental Panel on Climate Change (IPCC), presented in the Sixth Assessment Report [3]. According to this approach, vulnerability is considered as a function of three components: exposure, sensitivity, and adaptive capacity. This three-component model forms the methodological basis of the Technical Manual of the MoreAdaptBSB project and the corresponding field assessment checklist [9]. A similar structure is embedded in the European Union Technical Guidance on Climate-Proofing of Infrastructure for 2021–2027 [10] as well as in the ISO 14091:2021 standard, which establishes guidelines for climate change vulnerability, impacts, and risk assessment [11].

For Ukraine, the assessment of climate change impacts on economic sectors was carried out within another EU-funded project, in which GIS tools were applied for the spatial mapping of climate-related risks. This study represents the closest national analogue to the research activities conducted within the framework of the MoreAdaptBSB project [12].

At the same time, the analysis of recent literature reveals several unresolved or insufficiently explored issues addressed in this article. In particular, the field validation of climate vulnerability models remains poorly represented in Ukrainian scientific research.

*First*, methodologies for developing a unified set of geospatial layers covering several adjacent regions of Ukraine remain insufficiently tested. Such datasets should simultaneously incorporate climatic, environmental, socio-economic, geomorphological, and infrastructural parameters in formats compatible with European Union requirements.

*Second*, field validation of climate vulnerability models is still inadequately represented in national studies, particularly through the application of standardized checklists aligned with EU methodologies. Most existing studies are limited to remote sensing approaches without ground-based validation.

*Third*, the specific conditions associated with the wartime environment – including restricted access to official cartographic and statistical sources, as well as the presence of temporarily occupied and damaged territories – have not been adequately incorporated into vulnerability assessment frameworks for the Black Sea Basin region.

Therefore, the results of this study expand methodological approaches to the development of geoinformation support for climate vulnerability assessment of coastal areas and demonstrate the possibilities for their practical application under the conditions of the Ukrainian Black Sea region. In particular, the study proposes a comprehensive approach, tested within the framework of the MoreAdaptBSB project, for assessing the climate vulnerability of coastal ecosystems under conditions of limited availability of official data.

Table 1 – Characteristics of the Main Geospatial Data Sources Used in the MoreAdaptBSB Project (Activity 1.1) for the Ukrainian Black Sea Region

Type of data	Source	Format / Platform	Timeliness
Climate data (temperature, precipitation, projections to 2050/2100)	Copernicus Climate Change Service (C3S), TerraClimate/ CPC Global Unified Temperature	NetCDF, .shp	2021–2024
Land use and land cover	Copernicus Land Service (CORINE Land Cover)	GeoTIFF, .shp	2018–2020
Flood and inundation risk zones	EU Flood Directive / INSPIRE, DAVR of Ukraine	.shp	2022–2023
Geomorphological hazards (landslides, karst processes)	State Service of Geology and Subsoil of Ukraine, OpenStreetMap	.shp	2021–2024
Administrative-territorial boundaries	State Service of Ukraine for Geodesy, Cartography and Cadastre (official publication.)/ GADM	.shp	2022
Emerald Network (Natura 2000 equivalent)	Council of Europe Ministry of Environmental Protection and Natural Resources of Ukraine, Regional statistical yearbooks	.shp	2022
Socio-economic indicators	State Statistics Service of Ukraine (as of 01 January 2022)	.xlsx / .shp	2022
Environmental Vulnerability Index (EVI)	Via Pontica Foundation (based on provided geospatial layers)	.shp, .tif	2024–2025
Regional climate projections (SSP5-8.5 scenario)	CMIP6 (WorldClim v2, CHELSA)	GeoTIFF	Projection
Infrastructure data	Open Street Map/ GeoportalUA/ Google Maps and Google Earth	.shp	2022

### Statement of the problem and its solution

The aim of this study was to develop and test a comprehensive approach to geoinformation support for assessing the climate vulnerability of coastal and urban ecosystems. The approach includes the development of structured geospatial data arrays and their subsequent field verification, implemented within the framework of the EU-funded international MoreAdaptBSB project.

In accordance with the stated aim, the following tasks were addressed: the development of unified geoinformation layers by thematic categories in formats compatible with the requirements of the INSPIRE framework [13]; the interpretation of approaches to the field validation of the obtained cartographic vulnerability models; the implementation of field surveys using a standardized checklist based on the three-component vulnerability model; and the comparison of remote assessment results with ground observations in order to determine the correspondence between the developed models and the actual state of ecosystems.

#### Stage 1. Development of Geoinformation Layers.

At the first stage, the selection, processing, verification, and structuring of spatial data required for the development of an integrated vulnerability model were carried out. The work was conducted in accordance with the Technical Guidance of the project provided by the lead partner – the Via Pontica Foundation (Bulgaria).

All layers were developed on the basis of open-access sources, including the Copernicus (Sentinel) and Landsat (NASA/USGS) satellite platforms, state registers, official geospatial databases, and up-to-date cartographic materials. The data were structured in formats compatible with major GIS systems and suitable for integration into national and international spatial data platforms. Under the conditions of martial law, some official sources were temporarily inaccessible, which determined the priority use of remote methods for obtaining spatial information and the corresponding documentation of limitations within the metadata.

The resulting dataset covered the following thematic categories of geospatial data: climatic parameters and regional climate projections; land use and land cover; flood and inundation risk zones; geomorphological hazards (landslides, karst processes, loess soils, and erosion susceptibility); administrative-territorial boundaries; protected and buffer zones (the Emerald Network and protected area sites); hydrographic networks (water bodies, watercourses, and estuaries); socio-economic indicators and population density; transport and engineering infrastructure; and contamination of soils, surface and groundwater resources, and atmospheric air.

Particular attention was paid to the development of layers reflecting the spatial differentiation of potential vulnerability to climate hazards and enabling the modelling of coastal zone changes. Based on the provided layers, the project partner, the Via Pontica Foundation, developed the Environmental Vulnerability

Index (EVI) map, NDVI change maps, and a map of projected temperature changes under the SSP5-8.5 scenario for the 2041–2060 time horizon. These products served as the baseline data for the second stage of the study.

#### Stage 2. Methodological Framework for Field Validation.

Field validation constitutes an integral component of contemporary environmental mapping, enabling the comparison of GIS-based analysis and remote sensing results with the actual condition of natural objects and infrastructural elements in the field. The methodological approach to field validation was based on the three-component vulnerability model of the Intergovernmental Panel on Climate Change (exposure, sensitivity, and adaptive capacity), which is applied within the framework of the EU Climate Adaptation Framework and the ISO 14091:2021 standard.

*Exposure* characterizes the degree to which an ecosystem or object is subjected to climate-related hazards. For coastal regions, the principal factors include sea level rise, coastal erosion, inundation, landslides, droughts, prolonged heat waves, water scarcity, and wind-related impacts.

*Sensitivity* reflects the intrinsic properties of an ecosystem, including soil type and condition, vegetation cover density, biodiversity level, geomorphological structure, and characteristics of the built environment. At the same time, actual field conditions often differ from cartographic and statistical sources, which determines the necessity of ground-based verification.

*Adaptive capacity* characterizes the ability of an ecosystem or territory to withstand changes, recover, and reduce risk in the long-term perspective. It encompasses natural self-recovery mechanisms, the availability of management and planning documents, infrastructural protection measures, monitoring systems, and the level of community involvement.

Each indicator was assessed using a standardized four-point scale (1 – no or minimal threat/high adaptive capacity; 4 – critically expressed impact/very low adaptive capacity). Survey points were selected based on prior GIS analysis of the EVI map and ecosystem typology. Alongside direct visual field inspections, the following methods were applied: analysis of satellite imagery, topographic and soil maps, surveys of local community representatives, consultations with local experts, and review of institutional data sources. A total of 150 field surveys were conducted across all administrative districts of the Odesa region, which served as the pilot area for this stage of the project.

#### Results of Field Validation

The distribution of the studied ecosystems according to vulnerability levels is presented in Table 2.

Among the eight locations classified as having the very high vulnerability, four belong to aquatic ecosystems, two to forestry areas, one to agricultural land, and one to road infrastructure. A detailed summary of critically vulnerable objects is provided in Table 3.

Table 2– Results of Field Validation of Ecosystem Vulnerability Assessment in the Odesa Region (November 2025, n = 150)

Vulnerability level	Score range	Number of points	Share (%)	Dominant ecosystem types
Low	34–66	112	74,7	Agricultural land (stable condition), forest plantations, transport infrastructure in satisfactory condition
Moderate	67–99	30	20,0	Degraded agricultural land, overloaded water bodies and some sections of infrastructure
Very high	≥ 100	8	5,3	Aquatic ecosystems (estuaries, small rivers), forest plantations showing signs of degradation, infrastructure and agricultural areas in critical condition
Total	–	150	100,0	–

Table 3 – Characteristics of Objects with Very High Vulnerability Level According to the Three-Component Model

Ecosystem type	Object	Exposure	Sensitivity	Adaptive capacity
Water	Kuyalnyk Estuary (Odesa city)	Highly pronounced (drought, reduced inflow, heat waves)	Moderate to high (vegetation die-off, reduced biodiversity)	Very low (lack of reliable water sources and buffer zones)
Water	Dniester Estuary (Roksolany village)	Highly pronounced (floods, droughts, decline in groundwater levels)	Moderate to high (degradation of coastal vegetation)	Very low
Water	Lake Yalpuh – Lake Kugurlui (Nova Nekrasivka village)	Highly pronounced (lack of water exchange, heat waves)	High (reed fires, loss of biodiversity)	Very low
Water	Small river with pond, Dalnyk forest area	Highly pronounced	Moderate	Very low
Forest	Ravine forest, upper Kuyalnyk Estuary (Novokubanka village)	Highly pronounced (drought, frost, damaged infrastructure)	High (tree dieback, soil fertility decline)	Very low (no adaptation plans, no protected status)
Forest	Artificial plantations, Molodizhne village	Highly pronounced	High	Very low
Agricultural	Field, Rozalivka village (border with Moldova)	Highly pronounced (floods, droughts, frost damage)	Moderate to high (declining soil fertility)	Very low (no crop rotation, no buffer strips, no adaptation plan)
Infrastructure	Ovidiopolska Street, Molodizhne village	Highly pronounced (erosion, extreme events)	High (active erosion, soil compaction, road surface damage)	Very low (no buffer strips, no adaptation plan)



Figure 1 –Visualization of the Objects with Very High Vulnerability Level across the Odesa Region

Field surveys generally confirmed the reliability of the vulnerability cartographic models developed by the project partner based on the provided geospatial data. At the same time, local zones of degradation were identified that were not fully represented in the analytical datasets, including new hotspots of landscape transformation, technogenically altered areas, and expansion of coastal development. Surveys of local communities enabled further refinement of the seasonal patterns of hazard occurrence, documentation of hydrological changes, and acquisition of information on emerging anthropogenic pressures that were not captured in open-access sources.

### Conclusions

Based on the results of the study conducted within the framework of the MoreAdaptBSB project, the following conclusions were formulated.

1. The two-stage approach developed within the project – comprising the creation of a structured geospatial dataset and the subsequent field validation of the resulting models – is methodologically sound and reproducible. It is aligned with the requirements of the INSPIRE framework, the ISO 14091:2021 standard, and the technical requirements of EU climate-resilient infrastructure programmes, thereby ensuring its compatibility with transboundary risk assessment mechanisms.

2. The development of a unified set of geospatial layers in open, machine-readable formats made it

possible, for the first time, to ensure systematic and spatially referenced coverage of the Black Sea region with thematic data on climatic, environmental, socio-economic, geomorphological, and infrastructural parameters. These datasets were subsequently used by the project partner for the development of an integrated Environmental Vulnerability Index (EVI) model. Experience gained under conditions of limited access to official data sources during martial law demonstrated that open satellite platforms (Copernicus, Landsat) and statistical datasets provide a sufficient level of detail for regional vulnerability assessments.

3. Field validation of 150 survey points within the Odesa region confirmed the overall consistency of the remote sensing-based model with the actual state of ecosystems: 74.7 % of surveyed sites were classified as having low vulnerability, 20.0 % as moderate, and 5.3 % as very high. Critically vulnerable areas were primarily associated with aquatic ecosystems (estuaries and small rivers), which combine maximum exposure to climate impacts with a complete absence of adaptive mechanisms. At the same time, field observations revealed local degradation zones not captured in remote datasets, further confirming the necessity of ground-based verification as an essential component of the methodology.

4. The three-component model (exposure – sensitivity – adaptive capacity) and the standardized four-point scale for indicator assessment were operationalized as a practical field survey instrument.

The developed unified interpretation scales for each indicator make it possible to reproduce assessments by independent groups of experts and to compare data across different regions and participating countries of the programme.

5. EU funding provided within the framework of the Interreg NEXT Black Sea Basin Programme ensured access to advanced methodological frameworks and enabled their adaptation to the conditions of the specific region. The obtained results create opportunities for

integrating the Ukrainian Black Sea region into pan-European information and analytical platforms for climate risk management and provide a foundation for the development of relevant regional adaptation plans.

Prospects for further research include the expansion of field verification to other regions; the development of a methodology for calibrating the remote sensing-based model; the creation of a transboundary tool for data access; as well as the investigation of vulnerability dynamics of critical objects.

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#### ГЕОІНФОРМАЦІЙНЕ ЗАБЕЗПЕЧЕННЯ ОЦІНЮВАННЯ КЛІМАТИЧНИХ НЕБЕЗПЕК ПРИБЕРЕЖНИХ ТЕРИТОРІЙ У ПРОЄКТІ ЄС INTERREG NEXT MOREADAPTBSB

##### М. М. Брошков

доктор ветеринарних наук, професор  
ORCID: <https://orcid.org/0000-0002-9917-7257>  
Одеський державний аграрний університет  
вул. Канатна, 99, м. Одеса, 65039, Україна

##### Т. В. Небога

кандидат економічних наук, старший науковий співробітник  
ORCID: <https://orcid.org/0000-0002-5025-7299>  
Одеський державний аграрний університет  
вул. Канатна, 99, м. Одеса, 65039, Україна

##### Д. В. Булишева

кандидат економічних наук, доцент  
ORCID: <https://orcid.org/0000-0003-2907-9413>  
Одеський державний аграрний університет  
вул. Канатна, 99, м. Одеса, 65039, Україна

##### А. П. Масв

кандидат наук з державного управління, доцент  
ORCID: <https://orcid.org/0000-0001-9333-2933>  
Одеський державний аграрний університет  
вул. Канатна, 99, м. Одеса, 65039, Україна  
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**Анотація.** У статті узагальнено результати дослідження, виконаного в межах міжнародного проєкту “Менше вразливості, більше адаптивності – пілотне дистанційне зондування задля відновлення зелених зон у прибережних та міських територіях Чорноморського регіону” (MoreAdaptBSB). Метою дослідження стала розробка та апробація комплексного підходу до геоінформаційного забезпечення оцінки кліматичної вразливості прибережних і міських екосистем Причорноморського регіону України. Методологічною основою дослідження стали методи геоінформаційного аналізу, дистанційного зондування Землі, просторового моделювання та польової верифікації, реалізовані відповідно до трикомпонентної моделі вразливості. На першому етапі сформовано структурований масив геопросторових шарів, що охоплює кліматичні, екологічні, геоморфологічні, соціально-економічні та інфраструктурні параметри. Джерелами даних стали відкриті супутникові платформи Copernicus і Landsat, державні реєстри та офіційні геопросторові бази. На другому етапі проведено польову верифікацію побудованих моделей вразливості із застосуванням стандартизованого чекліста та чотирибальної шкали оцінювання індикаторів. Польові обстеження охопили 150 точок у межах Одеської області. Результати підтвердили загальну достовірність дистанційних моделей та дозволили виявити локальні зони деградації, не відображені у відкритих джерелах. Встановлено, що найбільш вразливими є водні екосистеми, зокрема лимани та малі річки, для яких характерне поєднання високого кліматичного впливу та низької адаптивної здатності. Практична цінність дослідження полягає у можливості застосування розробленого підходу для регіонального планування адаптації до зміни клімату, управління екологічними ризиками та інтеграції України до європейських систем просторового моніторингу. Наукова новизна полягає в апробації комплексного підходу до поєднання геоінформаційного моделювання та польової верифікації в умовах обмеженого доступу до офіційних даних під час воєнного стану.

**Ключові слова:** оцінка кліматичної вразливості, геоінформаційні системи (ГІС), дистанційне зондування Землі, польова верифікація, Причорноморський регіон, індекс екологічної вразливості (EVI), адаптація до зміни клімату, прибережні екосистеми, геопросторові дані, MoreAdaptBSB.

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