Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 47 Issue 5 September 2026 pp. 1024-1030
DOI: http://doi.org/10.22438/jeb/47/5/MRN-5860

J. Environ. Biol., 2026

Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

The phenomena of the wetland landscapes of the Colchic Lowland (Georgia) and their sustainable development challenges

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Received: 11 August 2025 **Revised:** 14 October 2025 **Accepted:** 27 May 2026

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Abstract

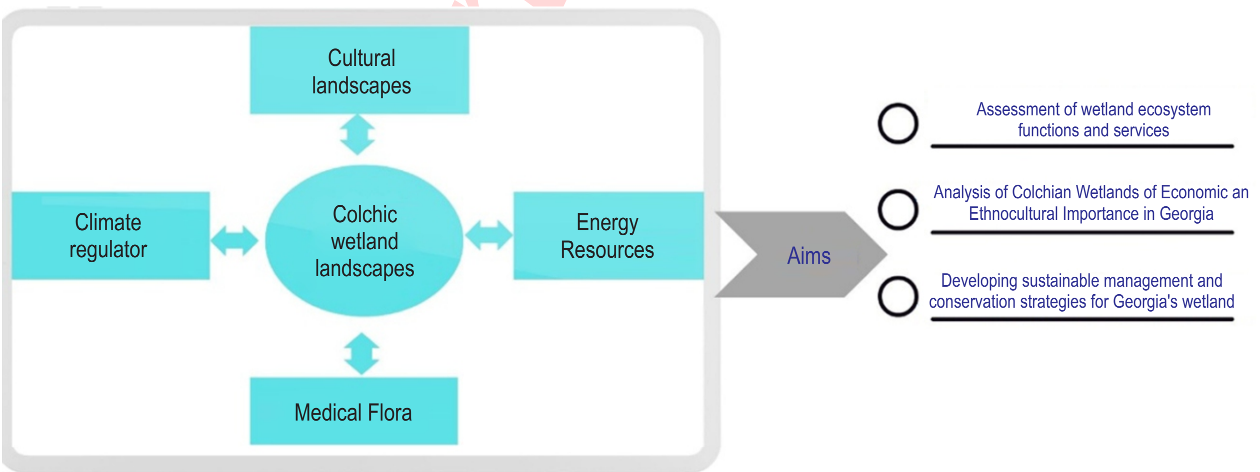
Aim: Comprehensive assessment of the Kolkheti wetlands inorder to study the development of these territories according to the principles of sustainable development.

Methodology: An integrative approach and method were used during the research, which combined the analysis of geographical, ecological, economic and ethnocultural data. The research included an assessment of historical and contemporary agriculture, supplemented by field research data: area, vegetation cover, hydrological conditions, ecosystem. Relevant literature review.

Results: Kolkheti wetlands have a crucial ecological function, maintain biodiversity and are distinguished by the abundance of medicinal plant species. The creation of the Kolkheti National Park improved the conservation status of the mentioned landscape, however, the surrounding territories are still experiencing pressure from human activity and infrastructure development.

Interpretation: This study highlights the role of geographical sciences in the assessment, conservation and management of this landscape. This territory has economic, cultural and ecological importance for the sustainable development of the region. Therefore, its analysis and assessment with integrative approaches are essential for future planning and forecasting.

Key words: Biodiversity, landscape, Kolkheti wetlands, Sustainable development



How to cite: Elizbarashvili, N., M. Gurgenidze, L. Bubashvili and D. Svanadze: The phenomena of the wetland landscapes of the Colchic Lowland (Georgia) and their sustainable development challenges. *J. Environ. Biol.,* **47,** 1024-1030 (2026).

Introduction

The landscapes of the Colchis Lowland represent one of the most ecologically vulnerable and economically interesting regions of the country. Wetlands play a crucial role in maintaining ecological balance, regulating hydrological networks, and supporting biological diversity. These landscapes also contribute to human well-being by providing ecosystem servicesrelated to environmental health and natural resource sustainability (Ramesh *et al.,* 2015). Despite several comprehensive studies conducted in the late 20th century, including the collective monograph The Colchic Lowland: Scientific Prerequisites for Development, significant gaps remain in understanding the current geoecological condition of these wetlands under changing environmental and land-use pressures. Previous studies have provided a multidisciplinary description of the physical-geographical structure, land use patterns, and resource potential of the Colchic wetlands (Elizbarashvili, 2010; Elizbarashvili *et al.,* 2024).

However, since the establishment of Kolkheti National Park and its designation as a Ramsar site, the functional role of these landscapes has substantially changed. Economic activities such as peat extraction, hunting, and intensive fishing are now restricted, while conservation and ecotourism have become dominant forms of land use (Ramsar Convention Secretariat, 2025). At the same time, large-scale infrastructure development in adjacent areas continue to influence the hydrological regimes, ecosystem stability and landscape connectivity. This article aims to assess the current geoecological state of the wetland landscapes of the Colchic Lowland and to identify key factors that should be considered in ecologically oriented territorial planning. The study focuses on three main objectives: to analyze natural and climatic conditions shaping wetland dynamics; to evaluate human impacts, including land use and infrastructure development and to examine the ecological and socio-cultural significance of wetland vegetation, with particular emphasis on medicinal plant species.

Special attention is given to the spatial distribution, bioecological characteristics, and traditional use of medicinal plants typical of Colchic wetlands, as these represent an important link between ecosystem functioning and local ethnocultural practices. Several wetland plant species possess documented medicinal properties and have been used in traditional medicine (Zhao *et al.,* 2016; Chaves *et al.,* 2019; Konyar and Gül, 2013). The wetlands are also analyzed as relict ecosystems of subtropical origin, preserving elements formed during earlier geological periods and serving as critical habitats for migratory bird species along the Black Sea flyway. The research is based on field measurements and landscape surveys, including data on precipitation, vegetation structure, wetland area, and ecosystem functions, combined with cartographic analysis and interpretation of satellite imagery. These data were used to identify zones of high ecological vulnerability and to formulate recommendations for sustainable land-use planning and conservation management.

Materials and Methods

The methodological framework of the study is based on the principles of geographical analysis and synthesis, which are widely applied in landscape and geoecological research. According to this approach, the assessment of the geographical environment was conducted through the evaluation of several key parameters, including the current condition of landscapes, their natural potential, sustainability, and socio-economic functions (Elizbarashvili *et al.,* 2024; Mitsch and Gosselink, 2015). Particular attention was given to the characteristics of environmental transformation, the forms and spatial scale of natural and anthropogenic impacts, and the interdependence between different geographical components of the landscape system. Such an integrated geoecological approach allows the identification of functional relationships between climate, hydrology, vegetation, and human activities within wetland ecosystems (Latsiou *et al.,* 2021). The study combined field observations, landscape surveys, and cartographic analysis, including the interpretation of spatial data and satellite imagery, which enabled the evaluation of wetland structure, ecological functions, and environmental vulnerability. This integrated methodological approach provides a scientific basis for landscape assessment and environmentally oriented territorial planning. In the analysis of landscapes and wetland ecosystems, particular attention was paid to their current condition (structure and functioning), the forms and scales of natural and anthropogenic impacts, natural potential, and overall sustainability (Elizbarashvili *et al.,* 2024; Mitsch and Gosselink, 2015).

The condition of landscapes, the conflicts between natural and anthropogenic factors, and the sustainability of specific areas were assessed through geo-ecological analysis and synthesis combined with landscape planning approaches (Sayadyan *et al.,* 2009). The main objective of the geo-ecological investigation was to identify the complex interactions between natural systems and human society and their spatial and temporal variability, including the characteristics of territorial organization, the ecological condition of landscape and ecosystem components, and their interactions. Special attention was also given to the ecological culture and environmental practices of local communities. Field measurements constituted an essential component of the study. Observations were carried out at representative wetland sites to record key parameters, including vegetation cover and density, peat layer thickness, hydrological characteristics, wetland area, and other ecological indicators. These empirical data provided a basis for evaluating ecosystem functioning, supporting landscape planning, and developing sustainable management practices.

Field surveys constituted a key component of the study. Observations were conducted at representative wetland sites within the Colchic Lowland. During fieldwork, the following parameters were recorded: vegetation composition, cover and density, peat layer thickness, hydrological characteristics (surface water presence and moisture conditions), wetland area and visible signs of natural or anthropogenic disturbance. These measurements provided empirical data for assessing ecosystem condition and landscape stability. The collected field data were used to characterize the functional state of wetland ecosystems and to support landscape-ecological evaluation and planning. The condition of wetland landscapes, the intensity of natural and anthropogenic impacts, and ecosystem sustainability were assessed through geo-ecological analysis and synthesis. Spatial analysis was applied to identify patterns of landscape structure and environmental pressure. Based on the integrated analysis of field observations and landscape characteristics, the wetland ecosystems were evaluated in terms of their ecological functioning, resilience, and role in regional sustainable development.

Results and Discussion

The final results are based on the analysis of the ecological, structural, biodiversity, and hydrological functions of the Kolkheti wetlands. The conclusions highlight the geoecological patterns of the distribution of the Kolkheti Lowland wetlands, ecosystem functioning, natural resource potential, and their relationship to sustainable development and human well-being.

Geoecological characteristics of the Kolkheti Lowland wetland landscapes: The Kolkheti wetlands are located in the Western Georgia, between the Kolkheti Lowland and the sea coast. The total area of the wetlands is relatively small (approximately 2000 km^2). These wetlands are of international importance and have been protected by the Ramsar Convention since 1977. The formation of the Colchian lowlands is influenced by various factors such as sloping relief, humid subtropical climatic conditions with high precipitation(Dunestian index: 2.2), a dense hydrographic and geological past, which was created by Quaternary strata and the retreat of the sea (Elizbarashvili *et al.,* 2024; Mitsch and Gosselink, 2015). The flora of Colchian is represented by various relict and endemic species. The combination of peatlands, forests with evergreen undergrowth and grassy shrub ecosystems is the characteristic of the Northern Hemisphere, both boreal and subtropical. zones. This clearly indicates the unique ecological significance of this territory. The flora of the Colchic National Park is exceptionally rich.

A total of 324 plant species have been recorded within its territory, 24 of which are included in the IUCN Global Red List of Threatened Species. The park also contains species listed in the Georgian Red List, such as Hartwiss oak (*Quercus hartwissiana*), wych elm (*Ulmus glabra*), Caucasian zelkova (*Zelkova carpinifolia*), and Colchic boxwood (*Buxus colchica*). In addition, three species protected under the Bern Convention occur in the area: water clover (*Marsilea quadrifolia*), floating fern (*Salvinia natans*), and dwarf bulrush (*Typha minima*). The region is also home to four endemic species — the Colchic boxwood (*Buxus colchica*), the Caucasian endemic *Rhynchospora caucasica,* the Colchic water lily (*Nymphaea colchica*), and the peatland goldenrod (*Solidago turfosa*).

The territory is characterized by an ongoing process of tectonic subsidence (4–6 mm per year), which has resulted in the secondary waterlogging of wetlands that were previously drained and exploited by humans during the first half of the 20th century. The largest part of the Colchic wetland landscape lies within the Colchic National Park, established in 1999 to protect and preserve wetland ecosystems of international importance. The park features several observation towers that allow visitors to observe more than 100 species of migratory birds. On July 26, 2021, the Colchic National Park was inscribed on the UNESCO World Natural Heritage List. As a result of field investigations, two main types of wetland landscapes were identified within the Colchic Lowland: Accumulative lowland landscapes with alder forests, oak–hornbeam forests, and peat moss wetlands.

Accumulative lowland landscapes with peat (*Sphagnum*) moss wetlands. The wetland landscapes are separated from the sea by a dune belt, attaining a height up to 5 m. The total area of these landscapes is approximately 2,090 km^2, which accounts 3% of the territory of Georgia. The formation of these landscapes is associated with several environmental factors, including altitude, relief forms, geological structure, climate and vegetation cover. The landscapes presented within the Colchic peatlands differ from one another in several parameters, the most important of which are site elevation, total annual precipitation, seasonal distribution of precipitation, and aridity index. These parameters largely determine the formation of vegetation cover in Colchic peatland landscapes, which, in some cases, is dominated by forest vegetation, while in other cases it is represented solely by herbaceous vegetation. The geographical and geoecological characteristics of Colchian peat landscapes are summarized in Table 1.

The ecology of wetland landscape is primarily determined by two key processes: water exchange and peat formation. On the one hand, water in wetlands is in constant motion, influenced by groundwater inflow and outflow as well as by evaporation. On the other hand, the gradual decomposition of organic matter leads to the formation of a peat layer, which must exceed 30 cm in thickness to classify the area as a true peatland. If these processes occur with lower intensity, the area is considered periodically flooded or swampy rather than a fully developed wetland. The wetlands of the Colchic Lowland belong to the hydromorphic and subhydromorphic types of flat lowland landscapes, represented by alder forests, peat moss and sedge vegetation. Their total area accounts for about 3% of Georgia's territory. A total of 21 individual wetlands have been identified in the region, most of which are small and fragmented. Only three — Gagidi, Chaladidi and Pechora-Paliastomi — exceed 100 km^2 in area. Interestingly, the average water depth in most wetlands ranges between 1 and 1.5 m, which creates favorable conditions for their gradual overgrowth and silting. In the area where the wetlands are distributed, the amount of precipitation exceeds evaporation by a factor of 2.4. This ratio becomes particularly pronounced during winter months, due to high cloud cover and relatively low temperatures. The diversity of vegetation found within the

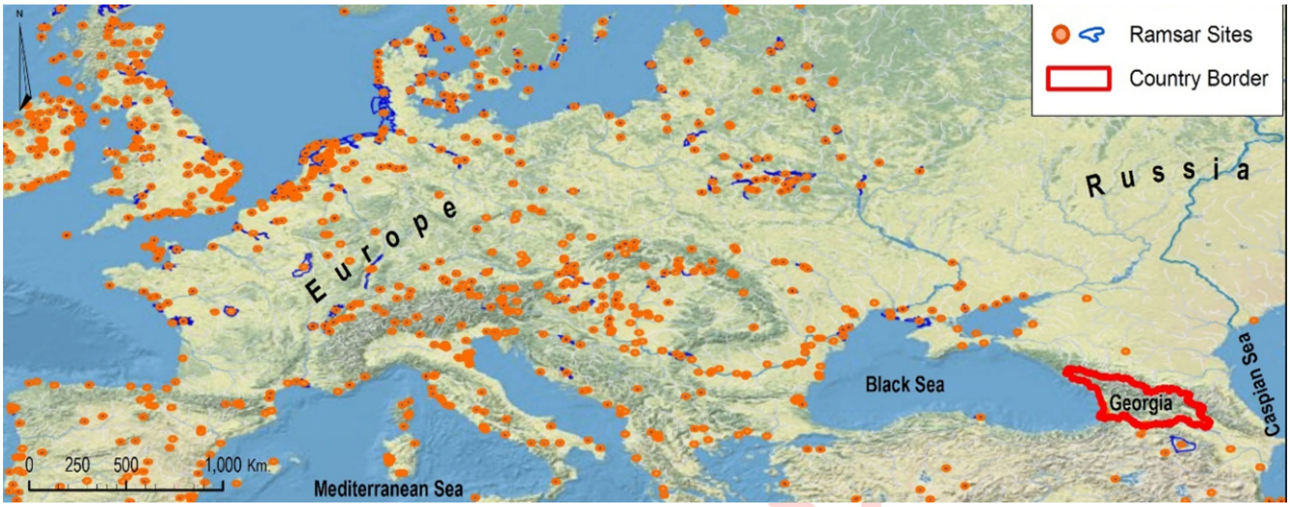


Fig. 1: Location of the Colchis Wetlands within the Ramsar Sites of Georgia (source: Ramsar Convention Secretariat).

Fig. 2: Spatial Distribution of the Colchic Wetland (Hygrophilous) Landscapes (schematic representation; not to scale).

wetlands reflects the natural uniqueness and ecological richness of the Colchic Wetlands, serving as an important prerequisite for the development of scientific and educational tourism.

The analysis demonstrates that the Colchic wetland function as significant carbon sink and hydrological regulator, reducing nutrient loads and contributing to climate stabilization at the regional scale. The ecological importance of wetlands is immense as they play a vital role in mitigating the greenhouse effect, and are often compared to forests — the so-called "lungs of the Earth." In addition, wetlands serve as a favorable environment for moisture accumulation and natural water filtration, and many important rivers originate from these ecosystems. In most countries, wetlands are protected by the state. The most common forms of wetland protection are national parks and nature reserves. Both types are represented in Georgia —in the form of a national park on the Colchic Plain and five reserves on the Javakheti Volcanic Plateau. These areas preserve the habitats and refuges of migratory birds. In both the Colchic and Javakheti wetlands, millions of birds from hundreds of species of the temperate and arctic zones rest during migration to southern regions. For this reason, both areas have been designated as Ramsar Sites. The Colchic National Park was established specifically to protect and conserve the wetland ecosystems of international importance. These ecosystems represent not only a vital component of Georgia's natural heritage, but also an integral

Table 1: Geographical and Geo-ecological Characteristics of Colchic Peatland Landscapes

Geographical location	Landscape	Landscape type and climatic parameters
	Accumulation lowland landscapes with alder stands, oak–hornbeam forests, and peat moss wetlands.	Area: 2,000 km^2 Elevation: 1–30 m above sea level Relief form: Accumulative plain Geological structure: Quaternary sedimentary deposits Climate: Humid subtropical Precipitation: 1400–2000 mm Maximum precipitation: December–January Average summer (July) air temperature: 23.0 °C Average winter (January) air temperature: 5.8 °C Aridity index: 1.9 Vegetation: alder, hornbeam, oak, marsh grasses, shrubs
	Accumulation lowland landscapes with peat moss wetlands	Area: 90 km^2 Elevation: 1–10 m above sea level Relief form: Accumulative plain Geological structure: Quaternary sedimentary deposits Climate: Humid subtropical Precipitation: 2000–2100 mm Maximum precipitation: August–September Average summer (July) air temperature: 22.5 °C Average air temperature in winter (January): 6.0 °C; Aridity index: 2.3 Vegetation: swamp grassland (Sphagnum moss)

part of global biodiversity conservation efforts, underlining their significance within the framework of international environmental protection. The Colchic wetlands represent a relict of ancient tropical wetland ecosystems that have survived from earlier geological epochs under changing climatic and geo-morphological conditions. These landscapes preserve elements of flora and ecological structures that once characterized tropical zones millions of years ago, making them a living testimony to the evolutionary history of the Earth's ecosystems.

In addition, the Colchic wetlands host vegetation typical of both temperate and subtropical wetland zones. They encompass a wide variety of ecosystems, including bogs, riparian (floodplain) forests, coastal dune belts and submerged aquatic vegetation (Elizbarashvili, Kupatadze and Gurgenidze, 2024, p. 4). On assessing the resource potential, it was found that the peat reserves on the Colchic Lowland reach approximately 8 billion m^3, which indicates the economic importance of the swamps. Historically, there are no examples of large-scale consumption of this resource. Peat can be used for various purposes: organic fertilizer, protein-vitamin concentrate, cattle feed, in the chemical industry, etc. There are also oil and gas deposits in this area, which makes it one of the most promising regions for the extraction of energy resources in the South Caucasus. The Colchic wetlands also represent an important and attractive recreational destination. With the development of a targeted tourism infrastructure, they could become a major center for educational and scientific tourism. Moreover, the wetlands are situated amidst a cluster of recreational sites and cultural landmarks. In their vicinity lie several significant archaeological and historical monuments (Archaeopolis, Martvili Monastery Complex, Khobi Monastery, Tsaishi Church, etc.), renowned thermal springs (Tskaltubo, Menji, Tsaishi, Skuri, Nakalakevi, Lebarde, Khobi, etc.), and seaside resorts (Ureki, Kobuleti, Anaklia, etc.), all of which enhance the region's recreational potential.Nowadays, the Rioni River is almost not used for transportation, but in the future, its inclusion in tourist activities may prove interesting and successful. According to climate forecasts, the Kolkheti wetlands are not threatened by intense changes related to climate change in the next century. Therefore, it is possible that the region will retain its high potential for the development of agricultural activities.

In terms of the impact on human health, the Kolkheti wetland landscapes have a dual effect: on the one hand, properly managed ecosystems contribute to water purification and reduce the risk of diseases, but on the other hand, unmanaged areas can increase the potential for vector-borne diseases. The history of malaria in the Kolkheti region confirms this duality, but today, epidemiological threats have been minimized due to monitoring.

Wetlands have both direct and indirect effects on human health. This depends on the management and condition of ecosystems. The positive impact of these landscapes on human health is manifested in several ways: wetlands play the role of natural filtration, their water purification ability ensures the absorption of various chemical and organic pollutants from the freshwater systems. As a result, the concentration of heavy metals and other pollutants decreases, which significantly reduces the risk of diseases associated with water pollution (Mitsch and Gosselink, 2015). In addition, wetlands contribute to the regulation of the atmospheric oxygen balance and storage of carbon combustion products, which has a positive effect on the overall state of human health. When properly managed, wetlands can also help prevent the spread of infectious diseases. Effective drainage and water circulation systems can reduce populations of harmful insects that act as vectors for viral and parasitic diseases (WHO, 2004; Reisen, 2010). Beyond physical health, wetlands also promote psychological and emotional well-being. As natural recreational spaces, they help reduce stress, restore emotional balance, and improve the overall mental health (Ramesh *et al.,* 2015).

Wetlands also play a crucial role in climate change mitigation. By sequestering significant amounts of atmospheric carbon, they help slow global warming. This climate stabilization, in turn, mitigates long-term global health risks. However, when mismanaged, wetlands can also pose negative health impacts. Stagnant, unmanaged wetlands often become breeding grounds for disease-carrying insects. For instance, standing water provides favorable conditions for mosquitoes transmitting malaria, dengue fever, leishmaniasis, and the West Nile virus (Reisen, 2010). Additionally, the accumulation of toxic substances in wetlands—due to agricultural runoff or industrial waste—can increase the risk of chronic illnesses if such contaminants enter the food chain (WHO, 2004). Improper drainage may further lead to reduced biodiversity and soil degradation, ultimately affecting the quality of drinking water and agricultural productivity.

In Georgia, wetland ecosystems warrant special attention in this regard. Historically, for example, malaria was widespread in the Colchis Plain, but today, due to consistent control and monitoring efforts, the problem has been virtually eliminated (Elizbarashvili, 2010). At the same time, Georgian wetlands represent a valuable resource for balneological and recreational tourism. The wetlands of Colchis host a diverse array of plants with medicinal properties, many of which have long been used in traditional medicine. Among them, *Marsilea quadrifolia* stands out for its antimicrobial, anti-inflammatory and cardioprotective effects—properties confirmed by ethnopharmacological studies (Zhao *et al.,* 2016; Elizbarashvili *et al.,* 2024). This species is abundant in the hydrophilic environments characteristic of the Colchic wetlands, contributing to both biodiversity conservation and well-being of local populations.

Salvinia natans, another notable species, possesses diuretic and antimicrobial properties traditionally applied in the treatment of genitourinary conditions (Chaves *et al.,* 2019). Likewise, *Typha minima* (small bulrush), which thrives in wetlands and moist habitats, is valued for its wound-healing and anti-inflammatory properties (KonyarandGül, 2013). The endemic *Buxus colchica* (Colchian boxwood) is particularly significant in the Colchic wetlands, where it has been traditionally used as an analgesic and antimicrobial agent. Its unique phytochemical composition suggests substantial potential for future pharmacological research and applications.

Overall, the medicinal flora of the Colchic wetlands represents an invaluable natural pharmacy, underscoring the importance of protecting these ecosystems not only for their ecological functions but also for their ethnobotanical and pharmacological value. Nevertheless, comprehensive phytochemical and pharmacological studies of these species remain limited—necessitating further scientific research to validate traditional knowledge and discover new bioactive substances.

Swamp formation in the Colchic Lowland reflects both natural geomorphological processes and increasing anthropogenic pressures. Our study indicate that prolonged flooding, limited water turnover, and low evaporation rates remain primary drivers of wetland persistence. These findings are consistent with established models of wetland development in temperate lowland regions (Mitschand Gosselink, 2015). However, the present study demonstrates that anthropogenic factors have significantly intensified natural swamp formation processes. Vegetation degradation within reservoir catchments has accelerated soil erosion, increasing sediment and organic matter input into the aquatic systems. Similar processes have been documented in European riparian landscapes, where land-use change has altered hydrological balance and sediment flux (Skoulikidis *et al.,* 2007; Petropoulos *et al.,* 2013). A particularly significant result of our analysis concerns the ongoing tectonic subsidence in the Kolkheti region, reaching 4–6.5 mm annually near Poti. Historically, sediment deposition from the Rioni River compensated for this subsidence. Our findings suggest that the reduction of seasonal sediment input in recent decades has disrupted this natural equilibrium, increasing the vulnerability of wetland systems. Comparable interactions between subsidence and sediment supply have been observed in other deltaic and coastal wetland systems (Syvitski *et al.,* 2009).

The integrated landscape-based approach applied in this study confirms that wetland evolution is determined by the interaction of geological structure, relief, climate, hydrology, vegetation, and socio-economic activity. This multidimensional framework corresponds to contemporary European methodologies in wetland and landscape assessment, which emphasize structural and functional analysis for sustainable planning (EEA, 2025). In this context, the principles of the European Landscape Convention (Florence, 2000) provide an important conceptual foundation. This study supports the Convention's definition of landscape as a product of natural and human interaction and highlight the necessity of integrated management strategies aimed at restoring structural and functional balance in wetland ecosystems.

Acknowledgments

During the preparation of this article, we made use of archival and research materials from the Department of Geography at Tbilisi State University, for which we express our sincere gratitude to the department's academic staff.This research was supported by the Shota Rustaveli National Science Foundation of Georgia (SRNSFG), grant number FR-24-5800. We also wish to extend our appreciation to Prof. Zviad Kvitsiani of the Institute of History and Assoc. Prof. Shamil Shetekauri of the Department of Biology at Tbilisi State University, whose valuable consultations and materials on the ethnocultural and ecological aspects of the Kolkheti wetlands greatly contributed to the comprehensive preparation of this study.

Authors' contribution: N. Elizbarashvili: Conceptualization, Methodology development, writing Materials and Methods, and Analysis of geo-ecological characteristics; **M. Gurgenidze:** Data collection, Ecological and economic analysis, drafting the section on natural, ecological, economic and ethnocultural phenomena; **L. Bubashvili:** Literature review, Ethnogeographical analysis, Writing the section on Wetland landscape as an ethnogeographical Phenomenon, manuscript editing; **D. Svanadze:** Involved in field measurements, analyzed the data, and compiled the cartographic samples.

Funding: This research was supported by the Shota Rustaveli National Science Foundation of Georgia (SRNSFG), grant number FR-24-5800

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: This study did not involve human participants or animals, and therefore did not require ethical approval.

Conflict of interest: The authors declare that is there is no conflict of interest.

Data availability: The datasets used and/or analyzed during the current study are available from the Corresponding author on reasonable request.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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