

Research Article

Assessment of carbon sequestration and hazardous chemical storage in reed habitats of the Danube Delta Biosphere Reserve's fluvio-marine sector

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Abstract

The Danube Delta, a dynamic alluvial plain, serves as a substantial carbon sink due to its extensive stands of reeds, specifically *Phragmites australis*. This study quantifies carbon storage across five distinct reedbed types based on substrate characteristics, using biomass assessment, soil carbon analysis, and GIS-based spatial mapping. Results show that reeds on salinized organic soils (S-Pa) have the highest carbon storage capacity (8.595 t/ha C), while those on gleyic soils (S-F) have the lowest storage levels (0.463 t/ha C). Furthermore, an analysis of heavy metal contamination (Cr, Ni, Pb, Zn) over 5 years revealed concentrations below regulatory thresholds, with a declining trend. The analysis indicates that reeds have notable potential for pollutant sequestration, particularly in aquatic vegetation and soil. These findings highlight the crucial role of deltaic wetland ecosystems in carbon sequestration and contaminant retention, underscoring the need for sustainable management strategies.

Key words: Carbon sequestration, Danube Delta, GIS analysis, heavy metals, reed biomass, wetland ecosystems

Introduction

A significant global concern is environmental pollution, which is influenced by greenhouse gas emissions, commonly referred to as the carbon footprint. In this context, the present study aims to identify the carbon storage potential in the estuarine habitats of the fluvio-marine Danube Delta. This is carried out by sampling and analyzing representative samples.

A comprehensive review of the existing literature on reed ecology reveals that different management methods exert variable effects, contingent upon substrate characteristics, testing methodologies, and geographical and genetic variations within the reed population (Engloner 2009).

In general, reed products are regarded as environmentally friendly because reed habitats are renewable and can grow rapidly without requiring extensive resources such as fertilizers or pesticides. However, their associated carbon footprint should be assessed holistically, taking into account factors such as harvesting and processing, transportation from the harvesting site to a production facility, and the lifetime of the reed product, which collectively can influence the total carbon footprint.

In the Danube Delta Biosphere Reserve, pure or nearly pure stands of *Phragmites australis* are found in floodplains such as the Somova-Parcheș, Șon-tea-Furtuna, Gorgova-Uzlina, Matîța-Merhei, Roșu-Puiu, and Razim–Sinoe lake complexes (Covaliov et al. 2023).

Grazing management has been observed to result in a decrease in reed biomass production (Covaliov et al. 2023). To prevent nutrient depletion and a negative soil carbon balance, it is advisable to refrain from harvesting the entire reed area every year, instead reducing harvesting to once every 2 years. Greenhouse gas savings are one of the key sustainability criteria outlined in the Renewable Energy Directive (Netherlands Standardization Institute 2015).

Wetlands comprise 2–6% of the global land area, and their carbon storage capacity significantly contributes to the terrestrial ecosystem, accounting for 12–20% of the total carbon stored on land (Jones et al. 2022). This vital role of wetlands in carbon storage is directly linked to greenhouse gas emissions and the broader issue of climate change.

The hydrogeomorphic type of the wetland exerts a substantial influence on the carbon storage capacity of these ecosystems. The primary factor hindering the sequestration of carbon in wetlands is the bioavailability of the underlying substrate, which is contingent on the composition and type of vegetation present. The specific vegetation is a crucial factor in determining the carbon sequestration capacity (Kayranli et al. 2010; Villa et al. 2018; Lolu et al. 2019). Most of these wetlands are also peatlands with histosols (organic soils).

Wetlands with *Phragmites australis* act as a reservoir for greenhouse gases by photosynthetically assimilating carbon dioxide (CO_2) from the atmosphere and sequestering organic matter produced in the soil.

However, wetlands also act as a source of greenhouse gases through the emission of methane (CH_4), produced by sediments, into the atmosphere (Brix et al. 2001). The production and emission of CH_4 in wetlands involve complex physiological processes of plants and microorganisms that are linked to climatic factors. The interaction of these processes with heterogeneous environments gives rise to substantial variations in CH_4 fluxes (Cao et al. 1998). Wetlands represent the most substantial natural source of CH_4 to the atmosphere, accounting for approximately 20% of annual global emissions. Of the total amount emitted, northern areas contribute 34%, temperate areas 5%, and tropical areas 60%.

Wetlands likely constitute the most substantial natural source of CH_4 to the atmosphere, accounting for approximately 20% of the current global annual emissions (Wang et al. 1996). Of the total CH_4 emissions, northern wetlands contribute 34%, temperate wetlands 5%, and tropical systems 60%.

Wetlands have also been found to emit nitrous oxide, a colorless gas with a sweet odor that supports combustion by acting as an oxidizing agent (N_2O). However, nitrous oxide is a minor source and is mainly related to drainage and grazing.

Materials and methods

Study area

The Danube Delta is a relatively young geographic formation influenced by both coastal and riverine processes, including sea level variation, sea currents, tides, and waves, as well as sediment deposition and water flow. Morphologically, it is classified as an alluvial plain in continuous formation, with low hypsometry and varying elevation differences of approximately 16 m. The delta consists of three primary river branches—Sfântu Gheorghe, Sulina, and Chilia—accompanied by fluvial levees, marine ridges, and depressions. Marine ridges, oriented transversely along the coast, have elevations ranging from 2 to 13 m, while depressions can extend 1 to 3 m below sea level. Predeltaic terrains, such as the Chiliei Plain and remnants of the Bugeac Plains, contribute to the region's geomorphology (Romanescu 1999; Gâștescu et al. 2006).

The Danube Delta is divided into two major subdivisions: the western fluvial delta and the eastern fluvio-marine delta, separated by the Jibreni-Letea-Ceaurulia-Caraorman-Crasnicol-Perisor ridge. The fluvial delta predominantly consists of alluvial deposits, whereas marine sands characterize the fluvio-marine delta. The Razim–Sinoie lake complex, originating from Halmyris Bay, represents a morphogenetic unit shaped by interactions among fluvial, fluvio-marine, and marine sediments. Sandstone formations and blocked lagoons are prevalent, alongside extensive dune formations in the Letea, Caraorman, and Sărăturile areas (Gâștescu et al. 2006; Romanescu 2013).

The location map of the study area (Fig. 1) was created using GIS methods, employing both vector spatial layers and a Web Map Service (WMS) for the raster base map, covering both terrestrial elements and the bathymetry of the Black Sea.

The fluvio-marine sector of the Danube Delta Biosphere Reserve serves as a critical wetland with high potential for carbon sequestration. Soil organic carbon dynamics are influenced by both natural processes and anthropogenic activities, which in turn impact greenhouse gas emissions. Reedbeds (Fig. 2) play a significant role in carbon storage, with carbon cycling occurring through photosynthesis, respiration, organic matter decomposition, and biomass accumulation.

Carbon storage methodology in reed habitats

The quantification of carbon stored in reed habitats follows a systematic approach that involves assessing biomass, analyzing carbon content, and evaluating soil carbon.

Assessment of reed biomass

The carbon content of reed biomass was determined through laboratory analysis according to the Dumas method (Dumas 1831). Samples were dried, ground into a fine powder, and analyzed using dry combustion techniques, with the carbon content expressed as a percentage of the dry weight. Rhizome biomass was estimated using soil coring techniques and biomass estimation equations.

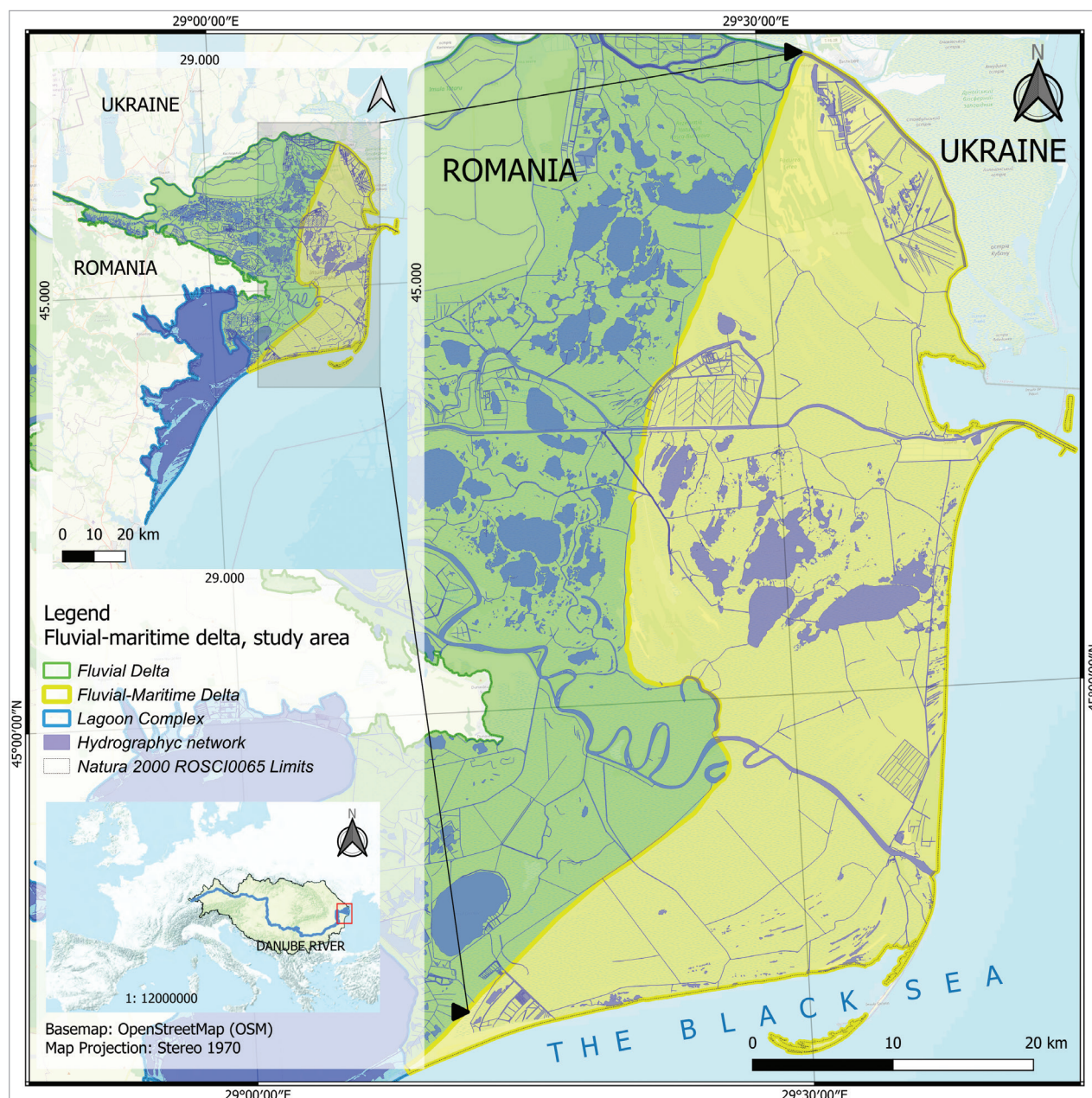


Figure 1. Map of study area—fluvio-marine area within the Danube Delta Biosphere Reserve.

Soil carbon analysis

Soil carbon storage was assessed through systematic soil sampling at varying depths. Samples were analyzed for organic carbon content using the Walkley–Black procedure (Walkley and Black 1934) (wet oxidation and dosage titration) and the Dumas method (dry combustion).

Quantification of highly hazardous chemical compounds

To assess hazardous chemical compounds in the study area, a 5-year dataset (2019–2023) was analyzed. The study focused on five heavy metals: chromium (Cr), nickel (Ni), lead (Pb), zinc (Zn), and cadmium (Cd). Annual average concentrations (mg/kg) were considered for evaluating contamination levels. Heavy



Figure 2. Drone photos of the research landscape within the Danube Delta Biosphere Reserve (Photo credit: Cristian Trifanov).

metal accumulation was examined in both abiotic (soil and sediment) and biotic (aquatic vegetation) environments within the Roșu–Puiu lacustrine complex. Sediment samples were analyzed under the Water Framework Directive (Directive 2000/60/EC), as transposed into national regulations by Order No. 161/2006 of the Ministry of Environment and Water Management. According to table 8B of this directive, sediment quality was assessed in the $<63\ \mu\text{m}$ fraction to determine ecological status.

The analysis of metal content was carried out using an ICP-MS Elan DRC-e inductively coupled plasma mass spectrometer.

Results and discussion

Suitability of substrate types in the fluvio-marine delta area for carbon storage

The assessment of substrate and reed vegetation in the fluvio-marine area concerning carbon storage and hazardous chemicals requires a multidisciplinary approach that integrates knowledge of sedimentation processes and the biogeochemical cycle.

Ecosystems accumulate organic matter over time, which is buried and preserved in the sediment, contributing to carbon sequestration.

The fluvio-marine area of the Danube Delta Biosphere Reserve is a wetland with a high potential for carbon sequestration, acting as a carbon reservoir and mitigating increased greenhouse gas emissions from the atmosphere.

In addition to histosols, the most common soil types in the Danube Delta, reedbeds play a particularly important role in carbon storage. Soil organic carbon is dynamic, and human impacts on soil can make it a direct source of greenhouse gas emissions. Most soil carbon is available to vegetation from humus and organic residues in the soil.

Carbon inputs occur through photosynthesis, while outputs occur through respiration, the decomposition of organic matter, fires, or harvesting. The input of organic matter into the soil is crucial for replenishing or increasing soil carbon stocks.

Quantifying the carbon stored by substrate type in the fluvio-marine delta

Histosols, which are rich in undisturbed organic matter, are the most important contributors to carbon storage. Histosols play a crucial role in the global carbon cycle by storing substantial amounts of carbon in the form of organic matter. If these soils are disturbed or degraded, there is a risk that the carbon stored within them will be released into the atmosphere as greenhouse gases, particularly carbon dioxide and methane. Sustainable management of soils, especially histosols, can therefore contribute to reducing greenhouse gas emissions. In contrast, predominantly mineral soils that are low in organic matter play a negligible role in carbon storage (Livanov et al. 2023).

The estuarine habitats of the fluvio-marine delta are based on organic and/or mineral substrates. The most common organic substrates are peaty histosols or gley soils. The most common mineral substrates are gley soils and psamosols.

The period between 1960 and 1980 is considered the most intensive reed harvesting activity in the Danube Delta. Rudescu et al. (1965) classified the reed areas into four groups, each comprising 10 biotopes. Subsequently, Chifu et al. (1993) identified seven types of reeds, each with seven subtypes, suitable for harvesting.

In addition, Hanganu (2002) identified nine reed ecotypes, 5 of which are suitable for harvesting. Our review of research over the last 8 years (2002–2010) includes information on the main economically exploited resource, the reed, categorized into five reed ecotypes (Hanganu 2013).

In the process of vegetation mapping, taking into account various criteria such as biometric characteristics and substrate type, monodominant reeds potentially suitable for harvesting were divided into five categories of reed ecosystems:

- Reed on gleyic soils (S-F);
- Reed on peaty or peaty gleyic soils (S-Ft);
- Reed on compact peat on organic hemic soils (S-Ps);
- Reed on psamo- soils (S-N);
- Reed on organic saline soils (S-Pa).

The reed identified in the field, classified into one of these types according to its biometric characteristics and accompanying flora, exhibits close

productivity values, which facilitates field studies. The characteristics of each reedbed type are described in detail below (Covaliov et al. 2023).

The type of reedbeds on gleyic soils (S-F) has an average cover of 90% with *Phragmites australis*. It includes species such as *Cladium mariscus*, *Mentha arvensis*, *Scutellaria galericulata*, and *Galium palustre*. The average density of the reed stands is 57 individuals/m², with an average height of 2.9 m, an average diameter of 1.10 cm, and an average biomass of 1.66 kg dry substance (d.s.)/m².

The reed type on peaty or peaty gleyic soils (S-Ft) has an average cover of 80% with *Phragmites australis*. It includes species such as *Symphytum officinale*, *Schoenoplectus lacustris*, *Solanum dulcamara*, *Lycopus europaeus*, and *Lythrum salicaria*. The average density of the reed populations is 52 individuals/m², with an average height of 2.7 m, an average diameter of 0.97 cm, and an average biomass of 2.05 kg d.s./m².

The reed type of compact flat reed on humic organic soils (S-Ps) has an average cover of 80% with *Phragmites australis*. It includes species such as *Mentha aquatica*, *Senecio paludosus*, and *Rorippa amphibia*. The average density of the reed phytopopulations is 43 individuals/m², with an average height of 2.35 m, an average diameter of 1.2 cm, and an average biomass of 1.14 kg d.s./m².

The reed type on psamosoils (S-N) has an average cover of 90% with *Phragmites australis*. It includes species such as *Calystegia sepium*, *Lysimachia vulgaris*, *Alisma plantago-aquatica*, and *Ranunculus lingua*. The average density of the reed phytopopulations is 73 individuals/m², with an average height of 2.51 m, an average diameter of 0.95 cm, and an average biomass of 2.30 kg d.s./m².

The reed type on salinized organic soils (S-Pa) is characterized by an average reed stem density of 135 individuals/m², an average stem height of 2.2 m, an average stem diameter of 0.8 cm, and a total biomass of 2.3 kg d.s./m², where reed stems represent 65% of the total biomass.

The distribution of the five types of reeds in the Danube Delta Biosphere Reserve area is shown in Fig. 3.

The results of the GIS analysis for the areas occupied by the five types of harvestable reed are presented in Table 1.

It can be observed that in the fluvio-marine area of the Danube Delta Biosphere Reserve, the compact reed type on hemic organic soils (S-Ps) dominates—40%—followed in approximately equal proportions by reed types on salinized organic soils (S-Pa) (29%) and psamosoils (S-N) (23%).

A lower percentage of reed type is found on gleyic soils (S-F). These aspects are represented graphically in Fig. 4.

Table 1. Results of the analysis of the harvestable reed species and the amount of carbon stored in the fluvio-marine area of the Danube Delta Biosphere Reserve.

Reed type	Code	Surface (ha)	Average biomass [kg d.s./m ²]	Average biomass [kg d.s.]
Reed on gleyic soils	S-F	642.8	1.66	1067
Reed on peaty or peaty gleyic soils	S-Ft	1635.5	2.05	3352.77
Reed on psamosoils	S-N	6675.0	2.3	15352.50
Reed on compact reed on organic hemic soils	S-Ps	11920.1	1.14	13589
Reed on salinized organic soils	S-Pa	8604.5	2.3	19790.35
TOTAL		29477.9		53151.62

*d.s. – dry matter.

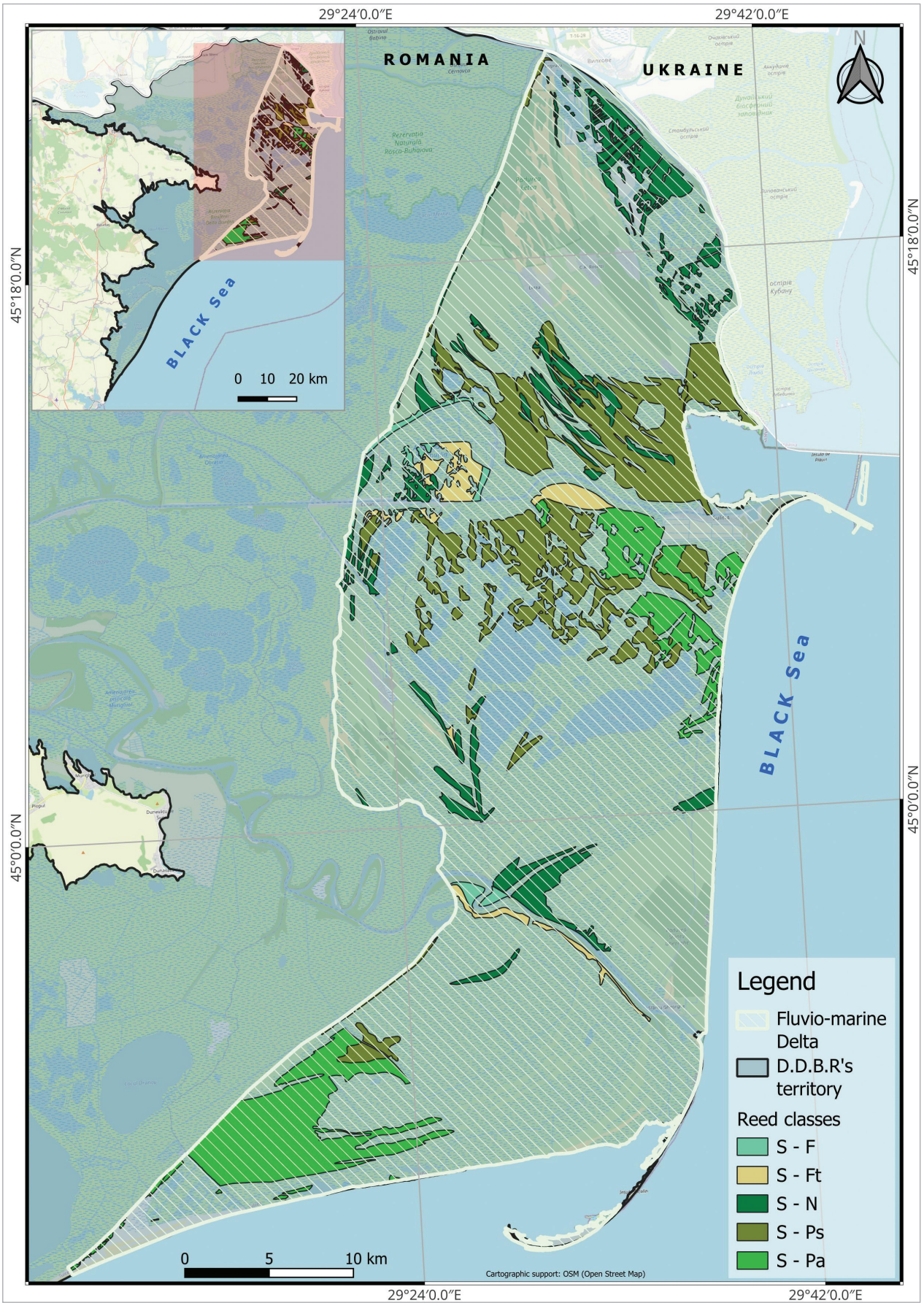


Figure 3. Map of the distribution of the five types of reeds within the fluvio-marine area of the Danube Delta Biosphere Reserve.

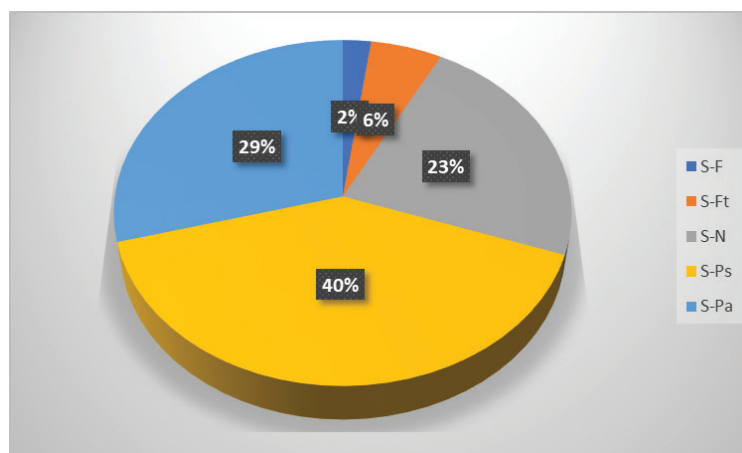


Figure 4. Proportion of the land cover by the five types of harvestable reed in the fluvio-marine area of the Danube Delta Biosphere Reserve: (S-F) – reeds on gleyic soils; (S-Ft) – reeds on peaty or peaty gleyic soils; (S-Ps) – reeds on compact peat on organic hemic soils; (S-N) – reeds on psamosoils; (S-Pa) – reeds on salinized organic soils.

According to the research carried out during the studies for the estimation of the harvestable potential of the reedbeds in the RBDD area, the average biomass of the reedbed resource during the period 2002–2023 was quantified, and the average biomass values (kg d.s./m²) for each type of reedbed were determined, as shown in Table 1. Based on this information, the average biomass per reed type and the total biomass were calculated, totaling 53.151 tons of dry matter.

An analysis of the obtained results (Table 1; Fig. 3) revealed a significant variation in the amount of biomass (t/ha) for *Phragmites australis* in the fluvio-marine area of the Danube Delta Biosphere Reserve, ranging from 1.067 t/ha to 19.790 t/ha, depending on the category of reedbeds and the substrate on which it develops.

The maximum recorded value for the species was 19.790 t/ha mean dry biomass for reeds grown on salinized organic soils (S-Pa). Analogous mean dry biomass values were documented for reedbeds on hemic organic soils (S-Ps) (13.589 t/ha) and psamosoils (S-N) (15.353 t/ha). In comparison, the lowest values (1.067 t/ha) were observed for reedbeds on gleyic soils (S-F).

Concerning stored carbon, each type of reed was analyzed, taking into account the substrate on which it develops. To quantify the total amount of carbon in the fluvio-marine area of the Danube Delta Biosphere Reserve, the carbon concentration values were considered representative for each type of reed. According to the average amount of biomass, the following results were obtained (Table 2).

Table 2. Results of the amount of carbon stored in the fluvio-marine area of the Danube Delta Biosphere Reserve on different types of reedbeds.

Reed type		Total surface in the fluvio-marine delta (ha)	Average biomass [t/ha]	Stored carbon [t/ha]
Reed on gleyic soils	S-F	29478	1.067	0.463
Reed on peaty or peaty gleyic soils	S-Ft		3.353	1.456
Reed on psamo-soils	S-N		15.353	6.668
Reed on compact reed on organic hemic soils	S-Ps		13.589	5.902
Reed on salinized organic soils	S-Pa		19.790	8.595
TOTAL stored carbon in fluvio marine delta (ha)				23.084

The maximum carbon content of 8.595 t/ha C was calculated for reedbeds developed on histosols (S-Pa). High carbon storage values in this soil category are frequently reported in other studies and are attributed to the slow accumulation of organic matter. However, when these soils are disturbed or degraded, there is a risk of releasing stored carbon into the atmosphere as greenhouse gases, primarily carbon dioxide and methane.

The minimum carbon content was recorded for reedbeds growing on gleyic soils (S-F), with a value of 0.463 t/ha C. A disadvantage of reedbeds is the presence of a water layer that stagnates at the soil surface or in lower layers, affecting organic matter decomposition and carbon sequestration. Anaerobic conditions in flooded soil layers slow the decomposition process, leading to methane emissions. Consequently, while these ecosystems can sequester carbon in reed biomass, they may also release greenhouse gases such as methane, potentially offsetting the benefits of carbon sequestration in some instances.

The average carbon content stored in *Phragmites australis* in our study was 4.617 t/ha C, with an average dry biomass of 10.63 t/ha. The mean carbon content of *Phragmites australis* biomass, as determined from the analyzed samples, was 43%.

Our results align with data from a similar study on carbon storage in *Phragmites australis* in Macquarie Marshes, a floodplain in the Murray–Darling Basin, Australia. That study highlighted that from a total dry biomass of 2.760 kg/m² recorded in the Willancorah marshland, an estimated 1.190 g/m² of carbon was stored (Whitaker et al. 2015).

By correlating the results of carbon storage in the analyzed reedbeds with the characteristics of the two soil types (histosols and gleyic soils), which provided extreme sequestration conditions, it was found that both types of reedbeds contribute to carbon storage. However, soil-specific conditions and the area's flood regime can influence the amount of carbon stored and the potential for greenhouse gas emissions.

Quantification of highly hazardous chemical compounds in the fluvio-marine delta

The prolonged introduction of highly hazardous chemical compounds into the complex ecosystems of the Danube Delta results in their accumulation within primary storage compartments, such as soil and sediment, or their transfer into biotic compartments within the ecosystem. These compounds eventually re-enter the abiotic environment through the decomposition of organic matter originating from the biotic compartments. Soils and sediments in the Danube Delta serve as the principal repositories for heavy metals, absorbing these pollutants directly from the water through sedimentation processes. The contamination of aquatic ecosystems with heavy metals is primarily associated with industrial, urban, and agricultural sources. Additionally, hydrological events significantly contribute to the increased influx of these substances.

The analysis of chromium (Cr) concentrations in sediment samples collected from the Roșu–Puiu aquatic complex (Fig. 5) revealed relatively minor variations. The recorded values ranged from an average of 9.202 mg/kg in 2020 to 6.796 mg/kg in the same year, suggesting overall stability in concentration trends.

Regarding lead (Pb) concentrations, annual mean values over the 5-year monitoring period fluctuated between 3.996 mg/kg and 6.571 mg/kg (Fig. 6). The maximum permissible concentration of 85 mg/kg was not exceeded at any point during the study, and a general decline in lead concentrations was observed.

Nickel (Ni) concentrations (Fig. 7) exhibited more significant variability over the study period, ranging from an average of 7.014 mg/kg in 2023 to a peak of 18.204 mg/kg in 2020. Despite these fluctuations, all recorded values remained below the regulatory threshold of 35 mg/kg for the entire period from 2019 to 2023.

Zinc (Zn) concentrations (Fig. 8) varied from 8.308 mg/kg in 2023 to 24.853 mg/kg in 2020. A decreasing trend in Zn concentrations was observed, with all values remaining below the established quality standard of 150 mg/kg.

Overall, the annual mean concentrations of the four heavy metals analyzed—chromium, nickel, lead, and zinc—did not surpass the established environmental quality standards (100 mg/kg for chromium, 35 mg/kg for nickel, 85 mg/kg for lead, and 150 mg/kg for zinc) throughout the study.

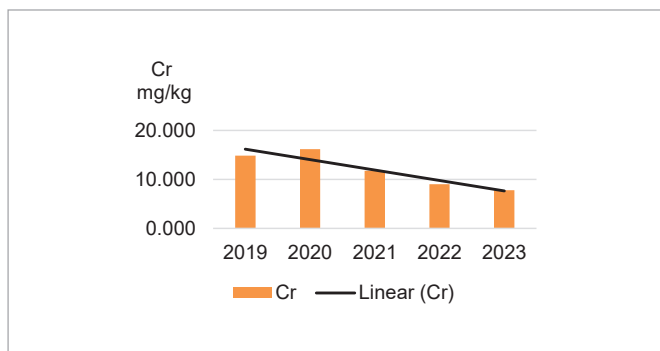


Figure 5. Multi-annual dynamics of average chromium concentrations in sediment samples.

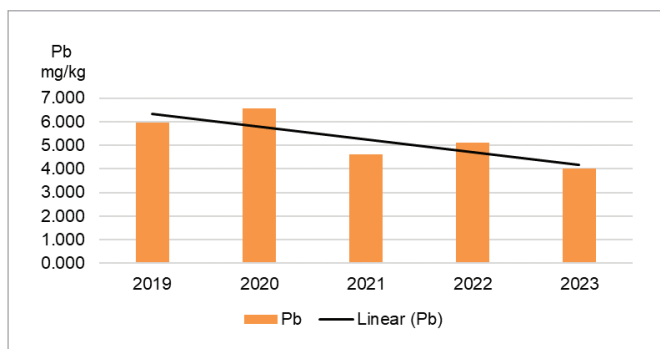


Figure 6. Multi-annual dynamics of average lead concentrations in sediment samples.

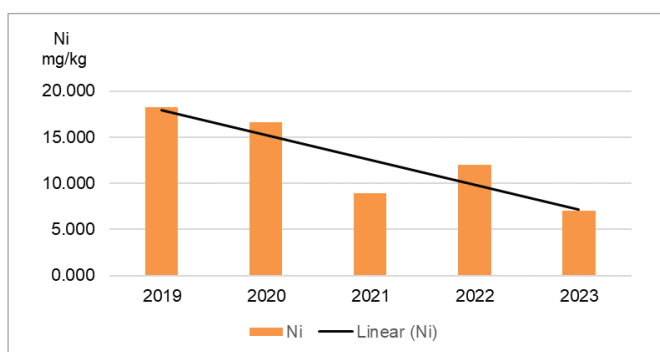


Figure 7. Multi-annual dynamics of average nickel concentrations in sediment samples.

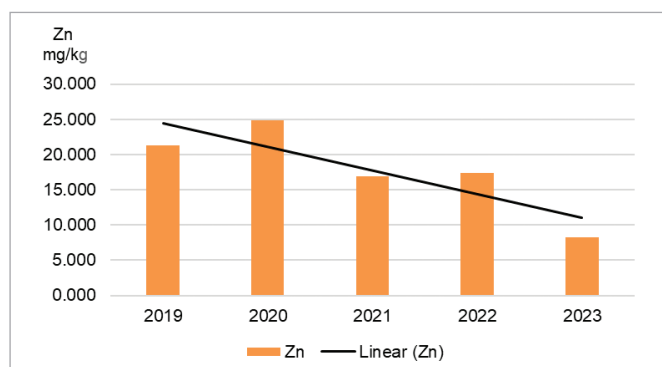


Figure 8. Multi-annual dynamics of average zinc concentrations in sediment samples.

Storage potential of reed habitats in the fluvio-marine Danube Delta for highly hazardous chemical compounds

In deltaic ecosystems, aquatic macrophytes, particularly reeds (*Phragmites australis*), exhibit favorable characteristics for accumulating chemical pollutants such as heavy metals. This ability is primarily attributed to their stationary nature and continuous exposure to contamination. As rooted species, they absorb metals both through their roots and rhizomes, capturing metal ions and sequestering various pollutants within their tissues.

The annual accumulation of rhizomes and roots within the substrate contributes to the formation of a thick layer of decomposing or peat-forming organic matter, effectively trapping these highly hazardous chemical compounds.

Analyzing the accumulation levels of highly toxic compounds in reed samples collected from the fluvio-marine area of the Danube Delta Biosphere Reserve (Figs 9–12), a decreasing trend in contaminant levels was observed over the period from 2019 to 2023.

Chromium concentrations (Fig. 9) in the analyzed vegetation samples ranged from 3.318 mg/kg in 2021 to a peak of 8.552 mg/kg in 2020. The reported values for *Phragmites australis* in the monitored area remained below the toxicity threshold of 63 mg/kg, above which a decline in macrophyte growth rate has been documented (Guilizzoni 1991).

For lead, the highest recorded concentration was 6.018 mg/kg in 2020, while the lowest concentration, 3.396 mg/kg, was detected in 2023 (Fig. 10).

Nickel exhibited higher concentration levels in 2019 and 2022, reaching a maximum of 8.816 mg/kg. The lowest concentrations of this element were recorded in 2019 and 2023, with minimum values of 5.023 mg/kg and 4.308 mg/kg, respectively (Fig. 11).

The highest accumulations were observed for zinc concentrations (Fig. 12), with values reaching up to 12.214 mg/kg in 2021. The minimum recorded value was 8.336 mg/kg in 2023.

Analyzing the accumulation levels of heavy metals in aquatic vegetation from the fluvio-marine area, in most cases, the concentrations of these pollutants showed a significant decreasing trend, which strongly correlates with the values obtained for bottom sediment. The data indicate that aquatic macrophytes with well-developed root systems extract most elements primarily from sediment.

Among the four studied metals, zinc consistently showed the highest concentrations in all samples from all sampling points. However, a distinction must

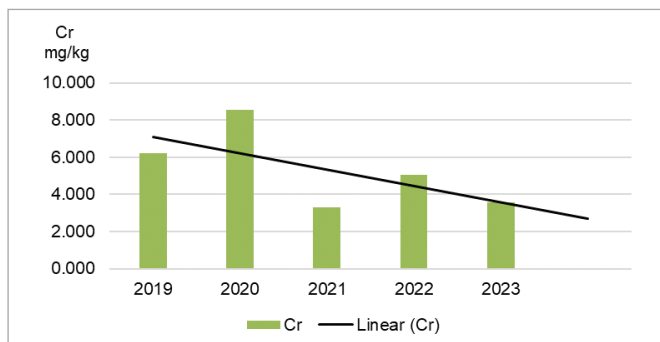


Figure 9. Multi-annual variation trend of chromium in aquatic vegetation samples (*Phragmites australis*).

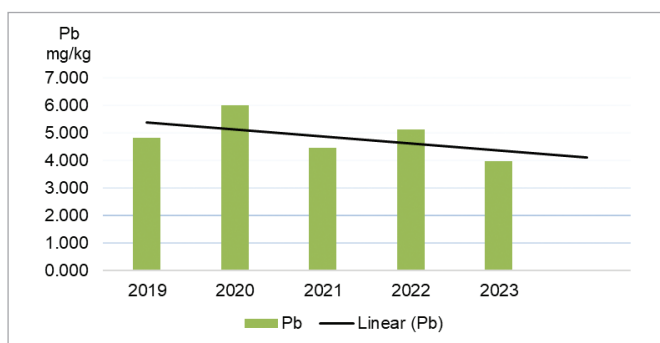


Figure 10. Multi-annual variation trend of lead in aquatic vegetation samples (*Phragmites australis*).

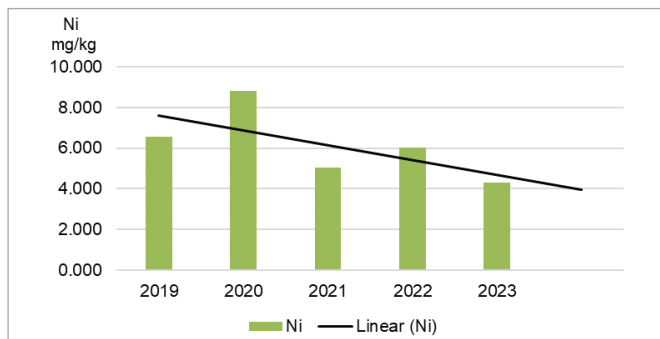


Figure 11. Multi-annual variation trend of nickel in aquatic vegetation samples (*Phragmites australis*).

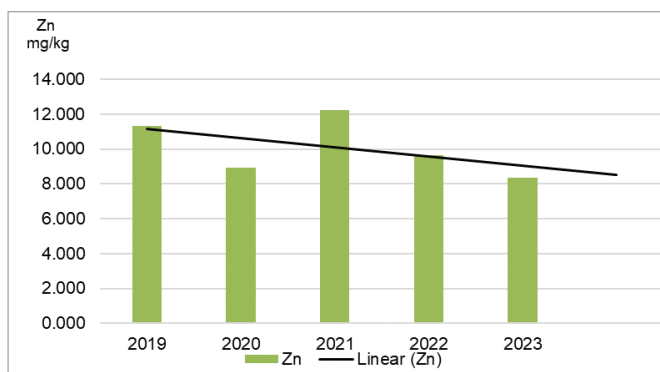


Figure 12. Multi-annual variation trend of zinc in aquatic vegetation samples (*Phragmites australis*).

be made between localized accumulation due to physiological requirements (as seen in Zn) and seemingly uncontrolled accumulation (as observed in Ni or Cr).

Regarding the dynamics of heavy metal concentrations in *Phragmites australis*, non-essential metals (Pb, Ni) exhibited more significant variation compared to essential metals (Zn). This variability reflects the potential of different species to serve as bioindicators in monitoring heavy metal pollution.

Conclusion

The Danube Delta's vegetation is likely to change due to human impact and climate change. A potential strategy to enhance the Danube Delta's stored carbon concentration involves restoring drained areas currently used for agriculture. Given that carbon sequestration in the soil is regarded as a pivotal approach to reducing greenhouse gas emissions into the atmosphere, effective management of agricultural practices affecting carbon storage is imperative. Implementing such management or restoration measures would contribute to a reduction in greenhouse gas emissions.

Furthermore, the role of reed-covered areas in storing carbon is crucial for peat formation in wetlands and the preservation of organic soils—the vegetation and sediments in the studied area serve as reservoirs for storing chemical contaminants. The higher values recorded at some sampling points can be attributed to the remobilization of these elements from the bottom sediment, both during flood periods and in low-water periods when boat wakes displace large amounts of sediment.

A comparison of the 5-year monitoring period (2019–2023) reveals relatively minor annual variations, with fluctuations remaining within relatively low limits. These variations are influenced by changes in the Danube's water levels, which include higher flow rates and increased current speeds. These conditions displace the mobile sediment layer and resuspend particles in suspension. The average carbon content of the *Phragmites australis* biomass, as determined in the samples, was 43.433%.

The objective of this research has been achieved, and future research will focus on quantifying the amounts of carbon and highly hazardous chemical compounds stored in the reed habitats of the fluvial delta.

Additional information

Conflict of interest

The authors have declared that no competing interests exist. The funders had no role in the design of the study, the collection, analysis, or interpretation of data, the writing of the manuscript, or the decision to publish the results.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

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Author contributions

Evaluation of data and manuscript writing: Iasemin Suliman, Mihai Doroftei, Silviu Covaliov, Iuliana-Mihaela Tudor; Analysis of all samples: Oliver Livanov, Silviu Covaliov, Adrian Burada, Cristina Despina, Petre-Bogdan Gheorghe, Nicoleta Matei, Daniela Seceleanu-Odor, Dragoş Balaican, Matei Simionov; Map creation: Cristian Trifanov, Marian Mierlă, Orhan Ibram; Supervision of the study: Marian Tudor.

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Data availability

All of the data that support the findings of this study are available in the main text.

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