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SPATIAL DISTRIBUTION OF TOTAL ORGANIC MATTER IN RECENT SEDIMENTS OF DANUBE DELTA LAKES (GORGOVA-UZLINA HYDROGRAPHIC UNIT)

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Abstract

Organic matter plays a crucial role in maintaining lake health and trophic balance. It mainly originates from autochthonous sources like phytoplankton, microorganisms, and macrophytes, as well as allochthonous inputs from the surrounding terrestrial ecosystem. Understanding the origin of organic matter is important for assessing ecosystem quality and trends in lake evolution. This study uses the Loss of Ignition method to estimate the distribution, sources, and quantity of total organic matter (TOM %) in lakes of the Gorgova-Uzlina hydrographic unit in the Danube Delta, Romania. Results indicate that TOM concentrations (15-30%) in surface sediments primarily originate from in-situ lacustrine production, with minor contributions from upstream terrestrial inputs. Accomplished analysis revealed recent organo-sedimentary accumulations based on lithological components (TOM %, carbonates - CAR %, and minerogenic fraction - SIL %). The organic matter in these sediments may reflect both natural processes and anthropogenic impacts, emphasizing the need for monitoring to understand the dynamics and vulnerability of the delta ecosystem and perform conservation efforts.

Key words*: areal distribution, lacustrine ecosystems, LOI method, surface sediments, total organic matter.*

INTRODUCTION

Delta shallow lakes, which are formed at the mouths of rivers, are vital ecosystems that support a rich diversity of flora and fauna while also providing significant key ecosystem services (Verpoorter et al., 2014; Laignel et al., 2023). These lakes are highly dynamic systems, shaped by sediment deposition, hydrological flow, and anthropogenic influences. However, one of the critical issues facing delta lakes is the phenomenon of clogging or siltation, wherein excessive sediment accumulation results in a reduction of water quality, decreased oxygen levels, and altered habitat conditions for aquatic species (Walton et al., 2024; How et al., 2024; Wang et al., 2024). The process of siltation in delta lakes is primarily driven by the deposition of fine sediments, such as silt and clay, which can accumulate at the lakebed due to changes in flow velocity, river damming, land-use changes, and climate variability (Zhang et al., 2022; Wang et al., 2024). Siltation not only affects the sedimentary structure of the lakebed but also contributes to the loss of biodiversity and can significantly alter the hydrodynamics of the lake (Ho & Goethals, 2019; Tammeorg et al., 2024). Additionally, autochthonous aquatic vegetation contributes to the clogging of deltaic lakes. Aquatic vegetation plays a vital role in the ecological health of wetlands (Sun et al., 2023), providing habitat for various aquatic animal species and contributing to water quality by stabilizing sediments. However, excessive growth of aquatic vegetation can lead to challenges (Tan et al., 2020), particularly, dealing with clogging water channels and reducing flow, ultimately accumulating organic matter and sediments. Studies have shown that several plant species may exacerbate these issues by rapidly colonizing large areas of delta lakes, forming dense mats that could restrict water movement or create other impediments to the overall health of aquatic ecosystems (Oteman et al., 2021; Schneider et al., 2024). The overabundance of these plants is often a result of nutrient-rich conditions in the water, frequently fueled by agricultural runoffs and industrial discharges. The Danube Delta, one of Europe's largest and most biodiverse wetlands, plays a key role in regulating water quality, supporting wildlife, and providing livelihoods for local communities. The delta, which spans across Romania and Ukraine, consists of a complex network of lakes, channels, and marshes (Gâștescu & Știucă, 2008). However, over the past several decades, deltaic aquatic ecosystems have been increasingly susceptible to being impacted by the phenomenon of clogging or siltation (Tiron Duțu et al., 2022). Siltation refers to the accumulation of fine sediments, such as silt and clay, that degrade water quality and ecosystem health and obstruct various connecting channels or other deltaic aquatic systems (Constantinescu et al., 2023). This process is primarily driven by changes in riverine sediment load, hydrological modifications, and anthropogenic activities, including damming the Danube River upstream. The Danube Delta's lakes are particularly vulnerable to siltation due to the reduced sediment transport caused by upstream river regulation via the construction of dams or diversions and altered flow patterns (Panin & Jipa, 2002; Duțu et al., 2022). As sediments accumulate, they can clog channels, reducing water flow, oxygen levels, and habitat quality for aquatic species such as fish, birds, and invertebrates (Năstase et al., 2022). This study intends to investigate the responses of several selected middle Danube Delta floodplain lakes to natural siltation or clogging by studying the main lithological components dissemination in lakebed sediment samples. The selected lakes with relatively different hydrological conditions, situated in the same catchment area *(i.e., Rusca-Gorgova-Uzlina* Hydrographic Unit), include hydrologically connected lakes such as *Uzlina, Isacova, Durnoliatca, Bleziuc-Pojarnia* and *Pojarnia*, as well as relatively hydrologically isolated lakes, namely *Cuzmințul Mare, Cuzmințul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăț* and *Potcoava de Sud*. Even though the natural processes of siltation and organic deposit accumulations are characteristic of the Danube Delta aquatic ecosystems, the intensification of processes from the last periods demands special attention. Given the importance of these lakes for biodiversity and human activities, understanding the processes and consequences of siltation/clogging is essential for effectively conserving and managing Danube Delta's aquatic ecosystems.

MATERIALS AND METHODS

Study area

This investigation was realized at the *Rusca-Gorgova-Uzlina* Hydrographic Unit (Figure 1), the Danube Delta, Romania. The unit is included in the fluvial western area of the Danube Delta, being delimited by the *Sulina* (north) and the *Sf. Gheorghe* (south) branches, and east of the *Letea-Caraorman* Spit (Panin et al., 2016). In the southern part, this hydrographic unit is represented by lakes such as *Uzlina, Isacova, Durnoliatca, Isăcel, Pojarnia, Bleziuc-Pojarnia* etc. Then, the northern part consists of the *Gorgova* lake and other satellite lakes such as *Gorgovăț, Cuzmințul Mare, Cuzmințul Lat, Rotund, Rădăcinos, Potcoava de Sud*. The southern part is separated from the northern part by the *Litcov Canal*. The freshwater input in the southern part of the *Rusca-Gorgova-Uzlina* Hydrographic Unit is assured mainly by the *Sf. Gheorghe* Branch via *Uzlina Canal*, including several connecting channels between lakes and streams (*i.e.*, *Perivolovca Stream*). Contrarily, the northern part has an inconstant water supply, through the *Old Danube River Meander via Litcov Canal* and other connecting channels between lakes. The chosen sampling sites for this study portray a notable example of the potential environmental impact of both mineral and/or organic recent sediment accumulations yielded by the allochthonous sources from the Danube River flowing alluvial input and streams, or due to the local autochthonous sources.

Field sampling and data analysis

The lakebed sediment samples, and field data collection (including field observations and measurements) were performed at the R/V "Istros" belonging to the National Institute for Research and Development of Marine Geology and Geoecology-GeoEcoMar, Romania. The field surveys were carried out during two distinct hydrological periods of the Danube River's flow: *low-water level* (06-13 September 2024) and *high-water level* (21-28 October 2024). In the low-water period, the Danube River's water level height (cm) registered at the

Tulcea hydrometric station was the lowest level, *i.e.,* 70.25 cm *versus* 180-200 cm normal reference quota, whilst the maximum value was measured in October 2024, *i.e.,* 205.12 cm versus the above-mentioned reference quota. Sediment samples were collected at a depth of ~25 cm using a Van Veen grab sampler. The macroscopic description of the sedimentary material was made *in situ*, such as the structure, texture, main litho-clastic elements (clay, mud, silt, sand, gravel etc.), and bioclastic components (detritus, shells, other organic fragments), color, odor etc. Then, the samples were transferred to sterile plastic recipients maintained at a constant temperature (4°C) and shipped to the specific laboratory for analysis.

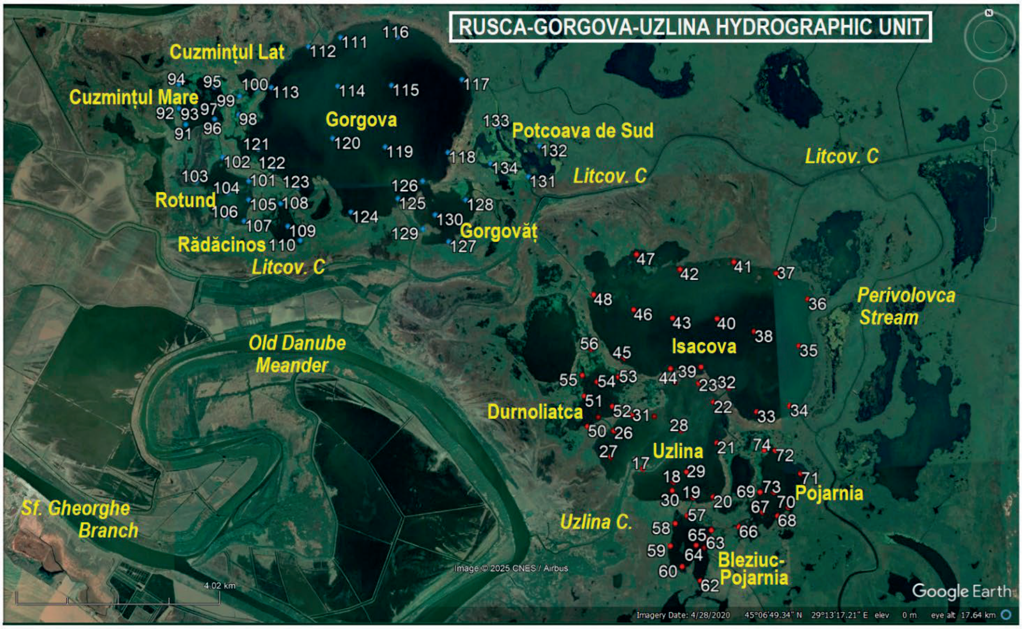

Figure 1. Location of the perimeters investigated. Red dots mark the sampling sites during the low-water periods; Blue dots mark the sampling sites during the high-water periods
(Base Map Source: https://www.google.com/maps)

A percentage quantitative analysis standard technique for the review of the main lithological components was used. In the preparatory phase, the sediments were probed for their moisture content (%) by the Loss On Drying (LOD) method, using a laboratory heater (Universal Memmert Oven) at 105°C temperature (Smith & Mullins, 2000; ASTM-D221). Subsequently, the percentage proportion of the main lithological components was performed in line with the LOI (Loss of Ignition) method. The sediment samples were subjected to sequential heating to distinguish the organic matter (TOM %), carbonates (CAR %), and siliciclastic fraction (SIL %) constituents. The loss in mass by combustion at 550°C was attributed to total organic matter content (Dean, 1974; Bengtsson & Enell, 1986). The total organic matter content was related to a standard classification (Perrin, 1974; Tate, 1987; Van der Veer, 2006), that allows the grouping of *organic matter-rich sediments (≥ 15-30% organic matter)* and *mineral-rich sediments (≤ 15-30% organic matter)*. The loss in mass by calcination at 950-1000°C was related to the total carbonate content (Digerfeldt et al., 2000; www.geog.cam.ac.uk). The total carbonate content was correlated with the well-known sedimentary systematization (Emelyanov & Shimkus, 1986), presenting: *non-carbonated sediments (*$CaCO_3 \leq 10\%$*)*, *low calcareous sediments (*$10\% < CaCO_3 \leq 30\%$*)* and *calcareous sediments (*$30\% < CaCO_3 \leq 50\%$*)*. Finally, the remaining residual sediment mass after calcination was associated with the siliciclastic fraction content. The obtained

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results were assessed as percentages of the TOM %, CAR % and SIL % content from the total sample mass by weight loss procedure. The spatial distribution of the data points has been plotted by the Surfer software package (Golden Software Inc., 2010, Golden, CO, USA) using the kriging method of gridding.

RESULTS AND DISCUSSIONS

The sites represent a good example of environmental exposure to different types of recent sedimentary depositional environments of allochthonous or autochthonous origins. The extent to which the allochthonous or autochthonous source may have a potential impact on the sedimentary depositional environment is mainly determined by the alluvial input contribution brought by the Danube River, and subsequently, is given by the processes that take place in the catchment area *i.e.,* small and shallow reservoirs, the fluvial-dynamic conditions, and the hydrogeochemical background susceptibility to siltation/clogging. In the present study, the main lithological components (*i.e.,* TOM %, CAR %, SIL %) were used as proxy indicators to reflect changes in sediment composition resulting from allochthonous or autochthonous sources. Generally, the freshwater/marine sediments, (porous, soft, or lithified) are composed of three main components, *i.e.,* organic matter, carbonate, and siliciclastics, representing their solid fraction (Ricken, 1993). The lithological analysis of the aquatic sediments in the Danube Delta is important for several reasons, as these data help to gain insight into the processes of formation and evolution of the Danube Delta, as well as to manage natural resources and protect the environment. Among the main reasons for which lithological analysis (*e.g.,* organic matter, carbonates and siliciclastic fraction) is important, the following are specified:

• ***Understanding sedimentary processes***: the lithological analysis facilitates the identification of the sources of sediments and deciphering how they are transported and deposited in the Danube Delta. The composition of the sediments (*e.g.,* organic matter content, carbonates and siliciclastic fraction) can provide information about the environment of transport and deposition of sedimentary particles (the sedimentary environment of the fluvial zone, the marine zone and the transition zone between them).

• ***Study of the evolution of the Danube Delta***: the Danube Delta is a dynamic system being in a constantly changing status. Lithological analysis of sediments allows the reconstruction of the history of geological processes and the geomorphological evolution of the delta, helping to gain an overview of the formation of various habitat types (lakes surrounded by dense reed beds, adjacent channels, reeds formations etc.) and how they have evolved;

• ***Biodiversity and habitat assessment***: Danube Delta sediments, especially those containing organic matter (e.g., plant and animal remnants), are fundamental for supporting biodiversity in the Danube Delta ecosystems. Organic matter in sediments influences substrate fertility and nutrient availability, which affects aquatic and terrestrial ecosystems. Knowledge of the distribution of organic matter in sediments can help assess the state of ecosystems in the Danube Delta;

• ***Impact of climate change***: the lithological analysis can provide information on the impact of climate change on the delta. For example, changes in the ratio of siliciclastic to carbonate fractions may indicate changes in the hydrological regime or water level, which are consequently influenced by climatic factors.

• ***Natural resource management***: the Danube Delta is an important area for fishing, tourism, and agriculture, and sediment analysis can help assess the natural resources of the region. For example, carbonate sedimentation can be an indicator of the potential for the formation of fertile soils, while the analysis of siliciclastic material can contribute to the identification and assessment of natural resources, which represent both ecological and economic value.

• ***Pollution and conservation studies***: sediment analysis can identify contaminants in the Danube Delta ecosystems, such as heavy metals or toxic substances from industrial or agricultural activities. Therefore, lithological analysis may contribute to the assessment of pollution risks and the development of strategies for the conservation of the delta and the protection of biodiversity.

• ***Water management and wetland protection***: the Danube Delta is an important wetland

ecosystem with multiple ecological functions. Lithological analysis may contribute to understanding the interaction between sediments, water and vegetation, essential for the efficient management of water resources and the protection of sensitive habitats. In this study, the percentage concentration of the main lithological components (TOM %, CAR %, SIL %) noticeably ranged between the investigated sampling sites based on their geographical position and lithological content.
The study case situations will be presented below.

The lithological components areal distribution during the low-water period investigation

During the low-water period (September 2024), several lakes in the southern part of the Rusca-Gorgova-Uzlina depression were investigated. Accordingly, lakes such as *Uzlina, Isacova, Durnoliatca, Bleziuc-Pojarnia* and *Pojarnia* (Figure 1) illustrated different patterns of the main lithological components' horizontal distribution. The results are shown in Table 1.

Total organic matter fraction (TOM %). The organic matter of lake sediments is subjected to various sources. Generally, allochthonous sources (terrestrial material) may enter the lake's receiving basin along with plant fragments, eroded sediments, wastewaters, sewages, organic contaminants, and long-range transport associated with the potentially contaminated water of the Danube River. Autochthonous sources are mainly attributed to the primary production of lakes, such as algae, macrophytes, zooplankton, and a mixture of decomposed vegetal and animal organisms. An overall assessment of the investigated sediment samples indicated that the TOM (%) content fractions dominate in most samples, presenting values included in a wide range of variations (34.31% < TOM ≤ 90.24%), of the total weight of the dry residue (Table 1). This distribution trend is evident in most of the lakes investigated. However, the highest values were found in very small, shallow lakes such as *Durnoliatca* (90.24% TOM), *Bleziuc-Pojarnia* (87.66% TOM) and *Pojarnia* (87.65% TOM). These lakes have plenty of underwater vegetation, are characterized by slower hydrodynamic conditions and are less disturbed by the bottom water currents. Regarding the *Uzlina* and *Isacova*, it was noticed that the inlet/outlet parts of the investigated lakes are characterized by relatively decreased TOM % values in the sediments compared to other sectors of the lakes (Figure 2).

Table 1. Results expressed as the percentage concentration (%) of the main lithological components

Location	Tested samples	TOM (%)			CAR (%)			SIL (%)		
		Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
Uzlina	(n=15)	49.40	72.57	65.02	6.51	20.05	12.10	14.53	44.09	22.89
Isacova	(n=16)	34.31	78.37	69.57	1.35	18.16	12.23	8.37	56.00	18.19
Durnoliatca	(n=8)	80.20	90.24	84.66	2.25	11.28	7.06	5.60	11.80	8.29
Bleziuc-Pojarnia	(n=9)	77.94	87.66	83.28	2.99	11.30	6.42	5.91	15.60	10.30
Pojarnia	(n=9)	80.13	87.65	84.02	2.96	12.96	8.69	5.83	10.38	7.29

Total carbonates fraction (CAR %). The presence of carbonates in aquatic environments could be both biogenic (*e.g.,* tests of benthic and pelagic organisms, skeletal parts, shells, and shell debris) and inorganic (*e.g.,* calcite, aragonite) in origin.
The contents of the carbonate fractions identified in the set of tested samples showed a notable surface area variation along the investigated lakes (Table 1). Generally, the range of variation for the CAR % content was relatively lower (2.25% < CAR ≤ 12.96%) in lakes such as *Durnoliatca*, *Bleziuc-Pojarnia* and *Pojarnia*. The other investigated lakes revealed relatively higher ranges of variations, *i.e., Uzlina* (6.51% < CAR ≤ 20.05%) and *Isacova* (1.35% < CAR ≤ 18.16%). The maximum values of the CAR% contents encountered in certain sediment samples (Figure 2) are about to the extent of local or short-range differences in data points, due to the incorporation of shells and shell debris abundance within the sediment matrices.

Siliciclastic fraction (SIL %). The content of siliciclastic fractions in the bottom sediments may be owed to upstream allochthonous fluvial sediment supply (*e.g.,* siliciclastic material, like quartz-rich sand, gravel, and silt, from the surrounding weathered rock, soils, and other materials) or autochthonous sediment supply (*e.g.,* siliciclastic materials such as sand, silt, and clay that are generated or derived locally, within the lake's drainage basin or directly from the surrounding environment by weathering of lake shoreline materials, river inputs from nearby watersheds, suspension and settlement of fine silts and clay, erosion). Broadly, the investigated lakes illustrated lower contents of the siliciclastic fractions (SIL %) (Table 1). The smallest ranges of variation were found in lakes such as *Durnoliatca* (5.60% < SIL ≤ 11.80%), *Bleziuc-Pojarnia* (5.91% < SIL ≤ 15.60%) and *Pojarnia* (5.83% < SIL ≤ 10.38%). Next, *Uzlina* (14.53% < SIL ≤ 44.09%) and *Isacova* (8.37% < SIL ≤ 56%) exposed relatively higher ranges of SIL% variations, especially near the inlets/outlets or connecting channels between the lakes (Figure 2). Generally, a significant inverse correlation was found between the SIL% and TOM% variables.

Conclusively, according to the organic matter (TOM%) and the siliciclastic (SIL%) fraction (calculated from the total dry sediment weight), the following types of mixed sediments were differentiated in the investigated sediment samples from *Uzlina, Isacova, Durnoliatca, Bleziuc-Pojarnia* and *Pojarnia* (Figure 3):

- *the organic-rich sediments*, subsequently followed by the *silica-rich sediments*;
- *organic-rich sediments* (> 15-30% TOM). From the total number of 57 analyzed samples, 12 samples are included in the range of variations with values between 30 and 70% TOM, and the rest of the 45 samples had increased values, more than 70% TOM;
- *silica-rich sediments* (> 15-30% SIL). From the total number of 57 analyzed samples, 52 samples are included in the range of variations with values between 0 and 30% SIL, and the rest of the 5 samples had increased values, between 30 and 70% SIL.

Subsequently, based on the total carbonate content (CAR%) the following types were spotted:

- *non-carbonated sediment* (CAR ≤ 10%). In this regard, from the total number of 57 analyzed sediment samples, 34 samples had lower values of ≤ 10%;
- *slightly carbonated sediments* (10% < CAR ≤ 30%). From this perspective, from the total number of 57 analyzed sediment samples, 23 samples had values included in the 10% < CAR ≤ 30% range interval.

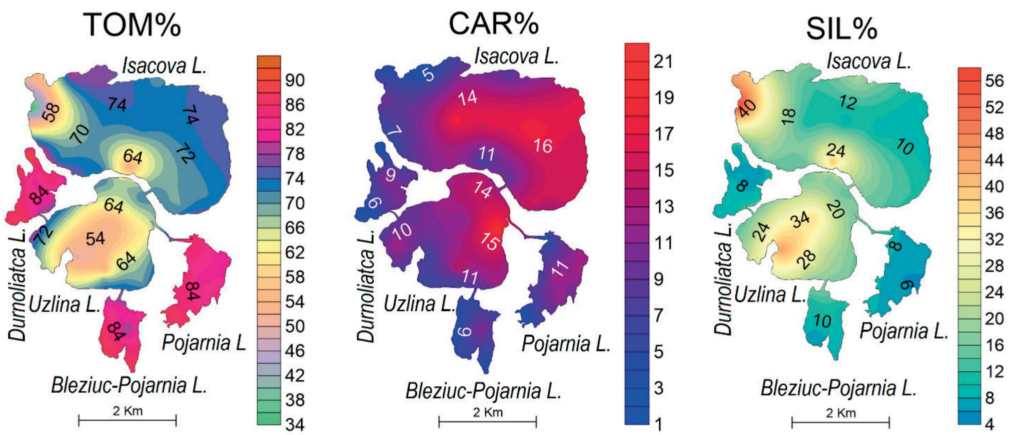

Figure 2. Spatial distribution of TOM, CAR and SIL (%) fractions according to their spatial distribution in the lake sediments of *Uzlina, Isacova, Durnoliatca, Bleziuc-Pojarnia* and *Pojarnia*

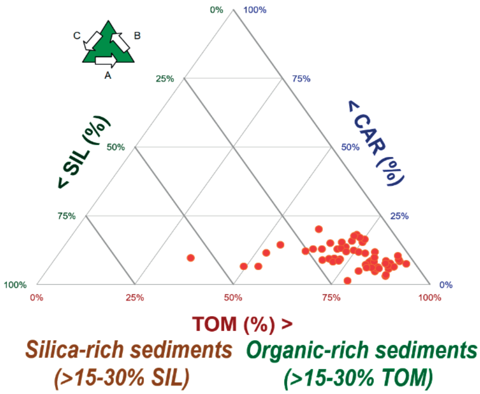

Figure 3. Ternary diagrams showing the percentage distribution (%) of the lithological parameters in the lake sediments of *Uzlina, Isacova, Durnoliatca, Bleziuc-Pojarnia* and *Pojarnia*

The lithological components areal distribution during the high-water period investigation

Within the high-water period (October 2024), several lakes in the northern part of the Rusca-Gorgova-Uzlina depression were surveyed. Therefore, lakes such as *Cuzminţul Mare, Cuzminţul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăţ* and *Potcoava de Sud* (Figure 1) displayed different patterns of the main lithological components' horizontal distribution. The results are shown in Table 2.

Total organic matter fraction (TOM %). Generally, the sediment samples taken from *Cuzminţul Mare, Cuzminţul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăţ* and *Potcoava de Sud* are characterized by a relatively higher organic matter content (TOM %), with values included in a wide range of variations (28.18% < TOM ≤ 89.99%), of the total weight of the dry residue (Table 2). The highest values of TOM% were found in the superficial sediments of the shallow plant-dominated lakes as *Cuzminţul Mare* (89.23% TOM)*, Cuzminţul Lat* (85.03% TOM)*, Rădăcinos* (89.99% TOM) and *Gorgovăţ* (71.11% TOM), but also in certain sectors of the lakes like *Rotund* (85.80% TOM), *Gorgova* (81.93% TOM) and *Potcoava de Sud* (87.90% TOM) (Figure 4). In shallow plant-dominated lakes, the organic matter content is typically higher than larger, deeper lakes due to a combination of factors such as higher biological productivity, better light penetration, greater interaction with surrounding land, and specific physical characteristics that favor organic matter accumulation.

Table 2. Results expressed as the percentage concentration (%) of the main lithological components

Location	Tested samples	TOM (%)			CAR (%)			SIL (%)		
		Min.	Max.	Ave-rage	Min.	Max.	Ave-rage	Min.	Max.	Ave-rage
Cuzminţul Mare	(n=7)	76.50	89.23	84.43	1.46	9.11	4.25	7.61	19.32	11.32
Cuzminţul Lat	(n=3)	71.81	85.03	77.82	4.36	11.61	6.78	10.61	23.80	15.40
Rotund	(n=7)	35.30	85.80	63.02	2.22	14.79	8.69	11.97	56.03	28.29
Rădăcinos	(n=3)	81.76	89.99	84.76	0.89	8.61	5.84	9.12	9.63	9.41
Gorgova	(n=16)	30.89	81.93	62.23	5.60	34.78	12.29	10.48	56.33	25.48
Gorgovăţ	(n=4)	52.34	71.11	63.55	6.77	17.42	11.33	19.13	40.90	25.12
Potcoava de Sud	(n=4)	28.18	87.90	70.02	2.26	12.57	7.28	9.05	59.26	22.70

Total carbonates fraction (CAR %). In general, the contents of the carbonate fractions spotted in the investigated sediment samples did not show a significant surface area variation along the investigated lakes (Table 2), excepting some sectors of the *Gorgova* and *Gorgovăţ* lakes. The range of variation for the CAR% content was relatively lower (0.89% < CAR ≤ 14.79%) in lakes such as *Cuzminţul Mare* (1.46% < CAR ≤ 9.11%)*, Cuzminţul Lat* (4.36% < CAR ≤ 11.61%)*, Rotund* (2.22% < CAR ≤ 14.79%)*, Rădăcinos* (0.89% < CAR ≤ 8.61%) and *Potcoava de Sud* (2.26% < CAR ≤ 12.57%). The other investigated lakes revealed relatively higher ranges of variations, *i.e., Gorgova* (5.60% < CAR ≤ 34.78%) and *Gorgovăţ* (6.77% < CAR ≤ 17.42%) (Figure 4). The maximum values of the CAR % contents identified in some samples are owed to shells and shell debris abundance within the sediment matrices. The provenance of the carbonate content in delta lake sediments comes from a combination of biogenic processes (such as the precipitation of calcium carbonate by aquatic organisms), detrital input (weathering of carbonate rocks in the catchment area), chemical precipitation (from lake water under certain conditions). Each of these sources contributes to the overall carbonate content found in the sediment of delta lakes.

Siliciclastic fraction (SIL %). Mostly, the investigated lakes displayed lower contents of the siliciclastic fractions (SIL %) (Table 2). The smallest ranges of variation were found in lakes such as *Cuzminţul Mare* (7.61% < SIL ≤ 19.32%), *Cuzminţul Lat* (10.61% < SIL ≤ 23.80%) and *Rădăcinos* (9.12% < SIL ≤ 9.63%). Further, lakes as *Rotund* (11.97% < SIL ≤ 56.03%), *Gorgova* (10.48% < SIL ≤ 56.33%), *Gorgovăţ* (19.13% < SIL ≤ 40.90%), and *Potcoava de Sud* (9.05% < SIL ≤ 59.26%) disclosed relatively higher ranges of SIL % variations, especially near the mouth of the connection canals with lakes (Figure 4).

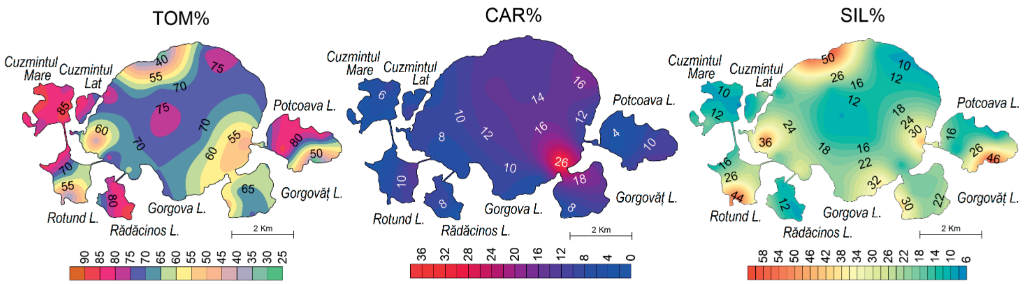

Figure 4. Spatial distribution of TOM, CAR and SIL (%) fractions according to their spatial distribution in the lake sediments of *Cuzminţul Mare, Cuzminţul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăţ* and *Potcoava de Sud*

Near the mouth of the connection canals with delta lakes, there is more siliciclastic fraction content because of the higher energy environment, which allows for the deposition of coarser materials, such as sand and gravel. In contrast, inside the lakes, where water flow is slower, the energy is lower, the finer sediments (such as clay and silt) dominate the sediment composition. The hydrodynamic conditions of the currents near the canal mouth and slower currents inside the lake, largely, determine the grain size distribution and sediment composition in these areas.

Based on the organic matter (TOM %) and the siliciclastic (SIL %) fraction (calculated from the total dry sediment weight), the following types of mixed sediments were differentiated in the investigated sediment samples from *Cuzminţul Mare, Cuzminţul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăţ* and *Potcoava de Sud* (Figure 5):

- *the organic-rich sediments*, subsequently followed by the *silica-rich sediments*;
- *organic-rich sediments* (> 15-30% TOM). From the total number of 45 analyzed samples, 2 samples had values less than 30% TOM, 15 samples were included in the range of variations with values between 30 and 70% TOM, and the rest of the 28 samples had increased values, more than 70% TOM.
- *silica-rich sediments* (> 15-30% SIL). From the total number of 45 analyzed samples, 34 samples are included in the range of variations with values between 0 and 30% SIL, 10 samples had increased values between 30 and 70% SIL, and 1 sample had values more than 70% SIL.

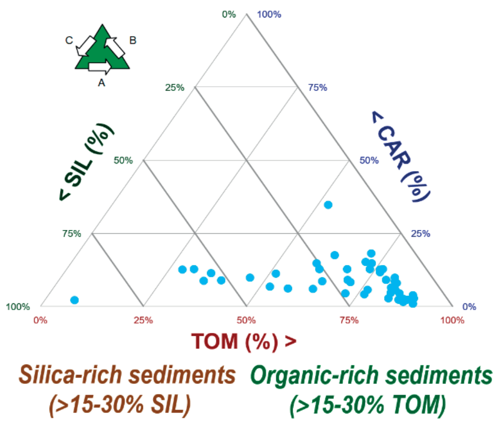

Figure 5. Ternary diagrams showing the percentage distribution (%) of the lithological parameters in the lake sediments of *Cuzminţul Mare, Cuzminţul Lat, Rotund, Rădăcinos, Gorgova, Gorgovăţ* and *Potcoava de Sud*

Subsequently, based on the total carbonate content (CAR %) the following types were spotted:
- *non-carbonated sediment* (CAR ≤ 10%). Accordingly, from the total number of 45 analyzed sediment samples, 29 samples had lower values ≤ 10%;
- *slightly carbonated sediments* (10% < CAR ≤ 30%). Considering this, from the total number of 45 analyzed sediment samples, 15 samples had values included in the 10% < CAR ≤ 30% range interval;
- *carbonated sediments* (30% < $CaCO_3$ ≤ 50%). Consequently, from the total number of 45 analyzed sediment samples, 1 sample had values included in the 30% < CAR ≤ 50% range interval.

CONCLUSIONS

The present study was performed in a transitional depositional environment in several lacustrine ecosystems, belonging to the Danube Delta, Romania. No significant seasonal variation (September vs. October 2024) was observed in the distribution of lithological components. Generally, the investigated lakes showed favorable conditions for accumulating the organic matter-rich sediments due to the inputs of autochthonous organic matter derived mainly from the underwater herbaceous plants and local specific arboreal vegetation. The accumulation of autochthonous organic matter in these shallow plant-dominated lakes may facilitate detrimental long-term challenges both in the size distribution of lakes and in the vertical sediment profiles, promoting shifts in shallow lake water levels, and ultimately causing the installation of the clogging phenomenon. The results obtained within this study are conducive to a better understanding of the total organic matter content and its horizontal distribution in deltaic aquatic environments, especially shallow-plant-dominated lakes, that are prevalent in the Danube Delta region. While these changes are part of the natural evolution of aquatic environments, long-term monitoring is essential to manage the impact of aquatic vegetation clogging in delta lakes. The ecological consequences of these physical changes considerably differ in function of the lake location, the lake depth and size, mixing regime and trophic status.

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