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Nature of Substratum Sediment Grains and Carbon Accumulation Studies of Ashtamudi Ramsar Wetland, Southwest of India in Context of Ecological Health

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Abstract

Understanding the granulometric composition and organic matter distribution of surficial sediments from the Ashtamudi lake, a Ramsar Site and the second largest estuarine system of Kerala, India, are very indispensable as it concerns the ecological health of the system. Surficial lake sediments are collected during monsoon and non-monsoon seasons, covering the entire stretches of the lake basin for understanding the distribution pattern of sediments and plausible sources of organic carbon. A total of 13 surface sediment samples are collected and subjected to textural as well as TOC analysis. The Ashtamudi lake sediments exhibit coarser and sand dominated texture, and the sand content in the sediments vary from 3.27 to 92.4% during the monsoon season (average 46.01 %). During non-monsoon, sand content varies from 0.78 to 93.65%, with an average of 44.62%. The silt content of the sediment samples varies from 5.3% to 44.34% (average 24.20%) during the monsoon season and 5 to 44.97 (20.46%) during the non-monsoon season. The clay fraction varies from 2.4% to 68.25% (average 31.26%), during monsoon season and 0.51% to 85.37% (average 33.54%) during non-monsoon. Textural attributes show that even though the percentages of granulometric composition varied, but there is no remarkable variation in their distribution among two different seasons, indicating an almost consistent behaviour in the sediment dynamics at different locations. Though the dredging activities are taking place in the lake, the dredged materials are being dumped on the lake banks, and it eventually reaches into the same system and gets distributed through the underwater fluxing. Similarly, the TOC content also shows consistent distribution during monsoon (5.39% to 8.76 %) and non-monsoon (4.04% to 8.68%) seasons. The high TOC content is due to the impacts of urbanization mainly by eutrophication, sewage disposal, growth of aquatic algae and associated floating macrophytes. This Ramsar wetland needs special care and attention owing to its vital importance for social dependence and environmental sustainability.

Keywords: Sediment texture, Organic Matter, Ramsar site, Anthropocene, Aquatic organisms

1. Introduction

Estuaries are dynamic as well as transitional aquatic environments forming a linkage with the hydrological systems at local and transboundary scales (Bianchi.,2007). Sediments in estuaries are formed mainly by the physical and chemical erosion of rocks present in the catchment area, which are further transported by various means and are deposited in the floor beds. Sediments in estuaries eventually trap nutrients that are carried from the land by rivers and from the ocean by tides (Czarnecki *et al*., 2014). So, in an estuarine environment, sediments and organic matter act as an integral part of ecological balancing and further biogeochemical cycling. The major contributors of Total Organic Carbon (TOC) in estuarine sediments are the detritus of decaying flora and fauna (Vijayaraj and Hema,2016). Sediment Organic matter has an important implication on the biogeochemical characteristics, particularly in estuaries and adjacent shelves (Zhao *et al*.,2019), and their dynamics is particularly important as they influence global carbon budgeting. The estuaries are the most important productive areas but are greatly impacted by various anthropogenic pressures derived from untreated domestic sewage, industrial, municipal, aquaculture, fertilizer and agricultural waste (Zhang *et al*.,2009; Mclusky and Elliott M., 2004). As a consequence, the toxic substances derived from these sources can be superimposed on the natural flux of sediment OM, and perhaps if excessive, can result in ecosystem degradation (Covelli *et al*., 2012; Lei *et al*., 2016). Therefore, the study of the origin, source and characteristics of grain size as well as associated TOC in the depositional sedimentary environments may be used as parameters for characterizing the ecological health of the system. Studies on elemental concentration, climatic records, bioaccumulation studies, and evolution have been carried out at Ashtamudi lake by various researchers (Hussain *et al*.,2020; Ankit *et al*., 2017; Chinnadurai *et al*., 2016; Nair *et al*.,2010). But there are relatively insufficient studies regarding the distribution pattern of sediments and also the origin and source of TOC in the estuarine environment of Ashtamudi. High population pressure, industrial development as well as urbanization in and around the area resulted in changes in the sedimentary distribution pattern of the Ashtamudi lake (Mohan *et al*.,2014; Akhil and Sujatha,2014. So, we present data on TOC and texture of lake floor sediments collected from the lake, Ashtamudi, Kerala, India, to identify the distribution pattern of sediments and plausible sources of organic carbon.

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2. Materials and Methods

2.1. Study area

Ashtamudi lake (Lat. 8^0 56'46.18" N and Long. 76^0 33' 16.33" E) is a large, palm-shaped, and major Ramsar estuarine wetland ecosystem of the southwest coast of India (Krishnakumar *et al.*, 2015) and has a catchment area of 61.4 km^2 (Chinnadurai *et al.*, 2016). (Fig. 1). The Ashtamudi lake is a part of the Ashtamudi Wetland system, and the lake debouches into the Ashtamudi wetland system near Peringalam, Kollam (Priju *et al.*, 2006). The lake has a permanent connection with the Arabian Sea, so the daily tidal fluctuations are greatly influenced by the lake system. The Kallada River is the only freshwater contributor to the Ashtamudi estuary, and it originates from the Kulathupuzha hills of the Western Ghats (Hussain *et al.*,2020). The lake system is a potential fishing ground for a wide variety of fish species (Hussain *et al.*,2020). The estuary is subjected to a very wide range of alterations in the ecological conditions due to anthropogenic pressures (Krishnakumar *et al.*,2015). The estuary receives urban as well as industrial waste products through many small and large drainage outlets. A large number of fish processing units are located on the western side of the estuary, which discharges organic wastes in enormous quantities into the system. Taking this point into consideration, Ashtamudi lake has been selected for the study and focused primarily on the changes that occurred due to urbanization on sediment texture as well as the source and distribution of organic carbon content in the lake basin.

Surficial lake sediments are collected during monsoon (July 2017) and non-monsoon (March 2018) seasons along the S-N transects covering the entire stretches of the lake basin. A total of 13 surface sediment samples are collected and subjected to textural as well as TOC analysis.

2.2. Analysis of Grain size composition

The samples are collected using stainless steel Vanveen Grab sampler and transferred into neatly labelled clean zip-lock polythene covers and kept under 5°C. Textural studies on the sediments are performed to find out sand, silt and clay distributions following the standard procedures(Folk *et al.*,1974). The sediment samples are first oxidized by 10% H_2O_2 to remove organic matter and then dispersed in a 0.05% $(NaPO_3)_6$ solution to disaggregate particles. Grain sizes are classified into clay (<4 ìm), silt (4–63 ìm) and sand (>63 ìm) according to standard nomenclature (Folk *et al.*,1974).

2.3. Analysis of Total Organic Carbon (TOC)

During the analysis of Total Organic Carbon (TOC), sediment samples are freezer-dried and are homogenized by grinding, and then the weighed aliquots are acidified by adding 2 mL of 1 M HCl to every 100 mg of sample. The acidified samples are dried at >60 °C under a stream of filtered air, then mixed with 1 mL Milli-Q water and freeze-dried again. Samples are weighed again to account for the change of weight during the acid treatment. Aliquots of approximately 20 mg are weighed into 5 × 8 mm tin capsules and then analyzed in a Thermo Scientific Flash 2000 CHNS-O analyzer at the central Chemical Lab, NCESS. The spatial variability of TOC in the lake system is studied using the ordinary kriging interpolation technique in Arc GIS 10.3 software environment (Krivorucho,2011).

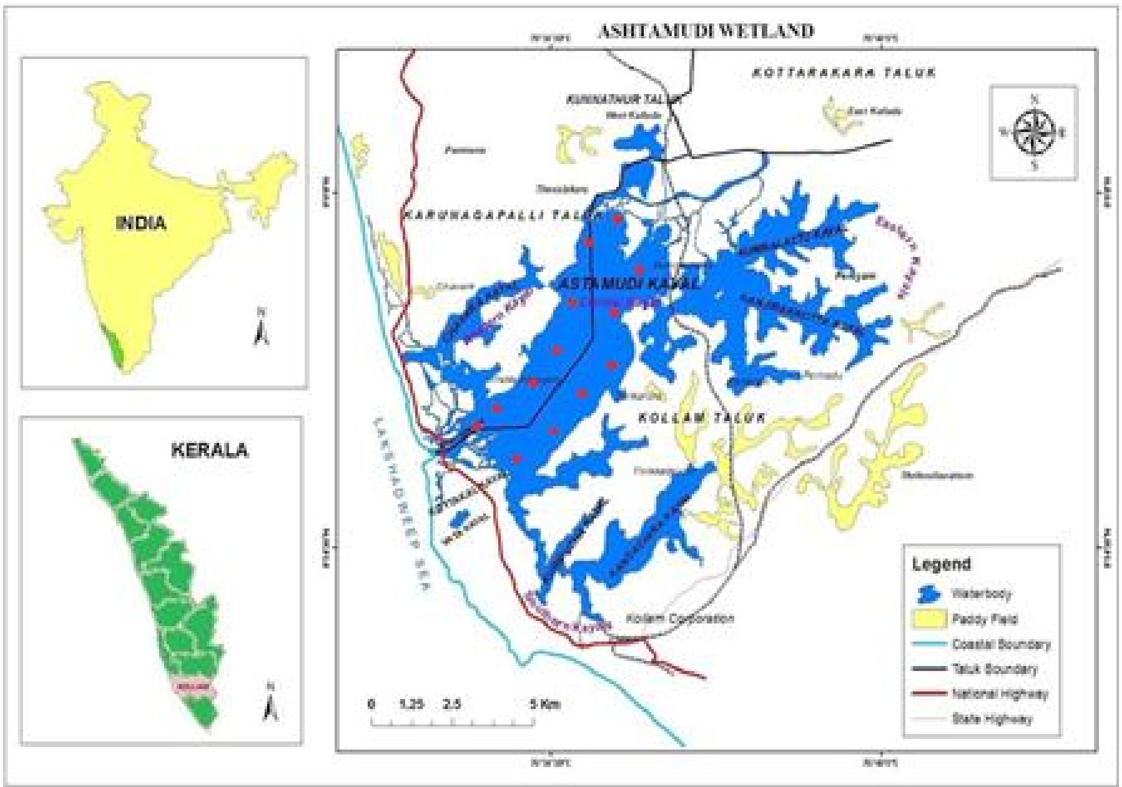

Fig. 1. Location map of Ashtamudi lake, Kerala, India

3. Results and Discussion

3.1. Granulometric analysis of Ashtamudi lake sediments

In Ashtamudi lake, the sediments are dominantly sandy near the lake margins and silty clay in the deeper parts of the lake basin (Fig. 2). The average concentration of sand, silt and clay percentages in the surficial sediments of Ashtamudi lake during monsoon and non-monsoon seasons is shown in figure 3. Both monsoon and non-monsoon seasons show similar textural patterns, but the observed percentage of composition (sand, silt and clay) vary. During the monsoon season, the sand content varies from 3.27% to 92.4 %. (average 46.01 %). During non-monsoon, the sand content varies from 0.78 to 93.65%, with an average of 44.62%. The silt content of the sediment samples varies from 5.3 to 44.34% (average 24.20%) during monsoon season and 5 to 44.97 (20.46%) during non-monsoon season.

Similarly, the clay fraction varies from 2.4 to 68.25% (average 31.26%), during monsoon season and 0.51 to 85.37% (average 33.54%),during non-monsoon.Textural classification of the Ashtamudi lake floor sediments deciphers the predominance of sand (Table 1). From the texture analysis and their spatial distribution, it is observed that finer materials have been transported in the run-off, thus leaving the coarser sediments deposit in the lake margins. Dredging activities are very dominant around the lake, and the dredged materials are dumped directly on the lake banks, and it eventually reaches into the same system and gets distributed through underwater fluxing. In the northern regions of the lake, Shoaling is observed with a high proportion of sand coming from the sea (offshore), which finally deposits in the lake banks. The western and eastern regions of the lakes also exhibit sand dominance, with an admixture of silt content both in monsoon and non-monsoon seasons. But in the southern regions of the lakes, the percentage composition of sand is more in the monsoon season than in the non-monsoon season. The inflow of sediments is more during the peak water flow of the monsoon. It is also observed that anthropogenic pressures are more dominant in the southern sides of the Ashtamudi lake. Excessive deposition of suspended sediments is observed in this region and can be attributed to the ongoing activities in the region. Coir retting is one of the major activities observed in the southern region of the lake. And also, a considerable amount of municipal and industrial wastes enters the lake through the canal opening on the southern side of the estuary. There are over 200 medium and large-scale industries releasing 267x 103 m^3 of wastewater per day either directly to sea or to the estuaries in Kerala (Ouseph, 1987 and Reji *et al*.,2010). In addition, excessive water extraction and reduction in water flow from the Kallada river, sand mining activities in the lake and reduced sediment inflow to the system because of the Kallada dam

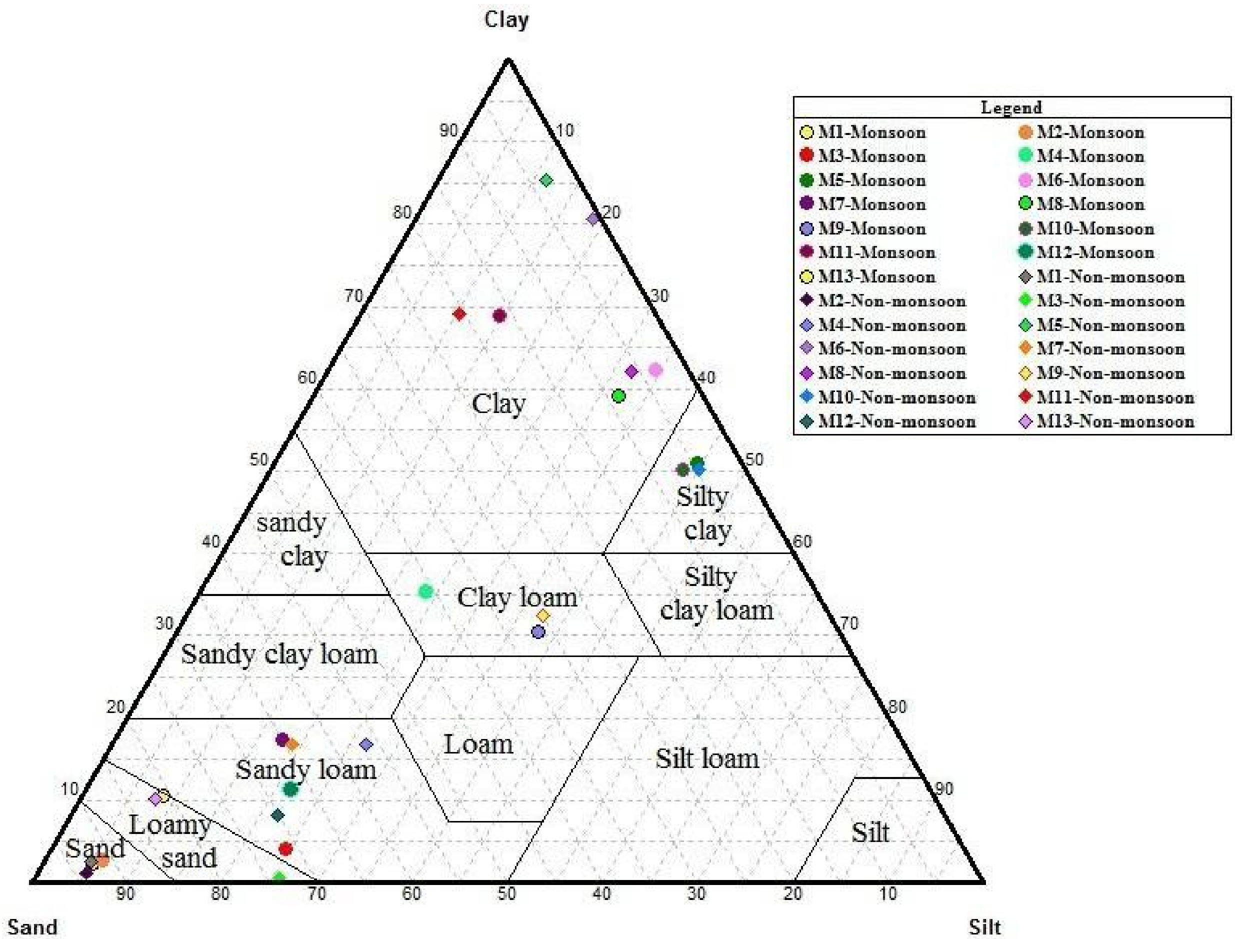

Fig. 2. Ternary diagrams (after Pickard,1971) showing the sediment texture of Ashtamudi lake, Kerala, India during monsoon and non-monsoon seasons

Table 1. Size spectral composition of the sediments of Ashtamudi lake (after Pickard,1971)

	Monsoon			Non-monsoon		
Stations	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Silt(%)**	**Clay(%)**
M1	92.4	5.3	2.4	92.55	5	2.45
M2	91.22	6.1	2.68	93.65	5.2	1.15
M3	71.21	24.6	4.19	73.78	25.71	0.51
M4	40.94	23.68	35.38	56.57	26.73	16.7
M5	4.62	44.34	51.04	3.26	11.38	85.37
M6	3.27	34.51	62.22	0.78	18.63	80.59
M7	65	17.6	17.4	64.17	18.94	16.89
M8	8.83	32.07	59.4	5.91	32.1	62.08
M9	31.77	38.17	30.56	30.09	37.41	32.5
M10	6.52	43.31	50.17	4.8	44.97	50.23
M11	16.33	14.72	68.95	20.59	10.31	69.13
M12	67.07	21.6	11.33	70.1	21.69	8.21
M13	80.83	8.55	10.62	81.84	7.97	10.19

construction result in the alterations of the sediment behaviour (Nair *et al*.,2020). Table 4 summarizes the comparison of the average chemical composition of TOC in the Ashtamudi lake basin with other major lake systems. Textural attributes show that even though the percentages of granulometric composition varied, but there is no remarkable variation in their distribution among two different seasons, indicating an almost consistent behaviour in the sediment dynamics at different locations. When compared with the selected lakes of Kerala (Table 2), the % TOC concentration of surface sediments in Ashtamudi lake (4.04-8.76%) is higher, excluding the Pookot lake (5.7-12.67%). Anthropogenic interventions and changes in land use patterns may be the reason behind the high TOC content in Ashtamudi lake. Being a forested wetland, the sediments in Pookot lake is bound with high organic carbon by litter decomposition from surrounding forests (Revathy and Krishnakumar,2018). While the % TOC concentration in Ashtamudi lake is showing low values when compared to lakes from other parts of India and the world (Table 2).

3.2. Total Organic Carbon in the surficial sediments of Ashtamudi lake

Carbon is the principal component of organic matter and entering into the lakes systems mostly by microbial degradation, exogenic inputs, suspended particles and productivity of overlying water (Baron *et al*.,2003). In Ashtamudi lake, Monsoon TOC content shows a range of values from 0.04% to 8 %, with an average of 4.97%. During non-monsoon, the TOC value ranges from 0.02 % to 8 %, with an average of 4.62%. The variation in the distributional pattern of sediments with respect to the organic carbon content in the Ashtamudi lake basin is shown in Fig. 4. The grain size partitioning studies of sediments will help to explain the enrichment of organic matter, thereby understand the trophic status of the system (Lakhan *et al.*, 2003). The spatial distribution pattern of TOC in the surficial sediments of Ashtamudi lake is shown in Fig. 5. During the monsoon and non-monsoon seasons, the spatial distribution pattern of TOC exhibits a trend of high enrichment (6.1-8%) in the southern as well as in the eastern regions of the lake. On the other hand, lower TOC concentration (0-2 %) is observed in the western part of the lake. The high TOC is observed both in southern and eastern regions and may be due to high anthropogenic influences by eutrophication, sewage disposal, growth of aquatic alga and associated floating macrophytes. The high enrichment of organic content in southern as well as the eastern regions of the lake may be due to the coconut husk retting activities in the area (Soumya *et al*.,2011). The

Table 2. Comparative evaluation of % TOC distribution in similar India/World lake systems

Lakes	**TOC (%)**		**References**
	Min	**Max**	
Current study	4.04	8.76	———
Vembanad lake	2.25	4.49	Sarkar *et al.*, 2016
Vellayani lake	0.5	4.56	Krishnakumar,1999
Pookot lake	5.7	12.67	Revathy and Krishnakumar, 2018
Manasbal Lake	3.2	29.6	Lone *et a*l., 2018
Wular Lake	1.42	18.78	Lone *et al.*, 2018
Anchar Lake	3.88	16.76	Lone *et al.*, 2018
Karlad lake	1.56	6.7	Babeesh *et al.*, 2016
Lake Victoria	1.9	33.9	Mwamburi, 2018
Wuliangsuhai Lake	4.5	22.83	Mao *et a*l., 2011
Daihai lake	6.84	23.4	Mao *et al.*, 2011
Williams Lake	7.88	25.6	Dean and Bradbury, 2007
Lake Shingobee	3.67	9	Dean and Bradbury, 2007

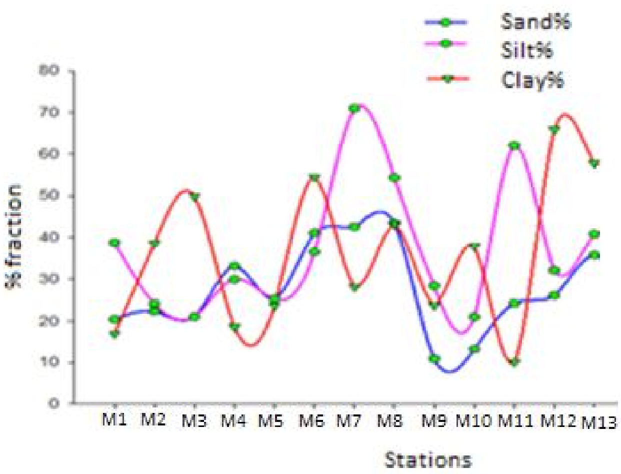

Fig. 3. Average concentration of sand, silt and clay percentages in the surficial sediments of Ashtamudi lake during monsoon and non-monsoon seasons

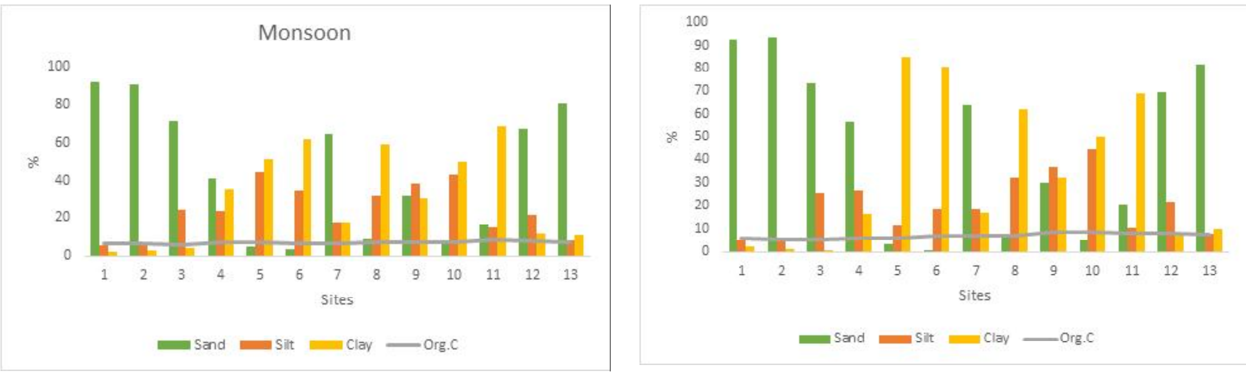

Fig. 4. Variation in the distributional pattern of sediments with respect to the organic carbon content in Ashtamudi lake basin

C-org. distribution in the sediments is also influenced mainly by the textural attributes present in the lake environment (Padmalal and Seralathan, 1995). Several sedimentological studies in the aquatic environment implied that enhanced association of C-org in finer sediments could be attributed to higher particle surface area, which in turn supports the absorptive ability of organic colloids. Studies of Sajan and Damodaran (1989), Badarudeen *et al.* (1997), Krishnakumar (1999), and Baiju (2007) reiterated the above facts.

4. Conclusion

The Ashtamudi lake is one of the major Ramsar estuarine systems of the SW coast of India. The present study identifies the distribution pattern and plausible source of organic carbon in the sediments collected from the Ashtamudi lake of Kollam. The sediment is predominantly sandy near the shorelines and silty clay in the deeper parts of the lake basin. Though the dredging activities are taking place in the lake, the dredged materials are being dumped on the lake banks, and it eventually reaches into the same system and gets distributed through underwater fluxing. The high percentage of organic carbon content shows that urbanization activities are affecting the lake systems. Being a Ramsar wetland, the lake system needs special attention as they are providing ecosystem services to people who are residing at the Kollam town as well as the adjacent areas.

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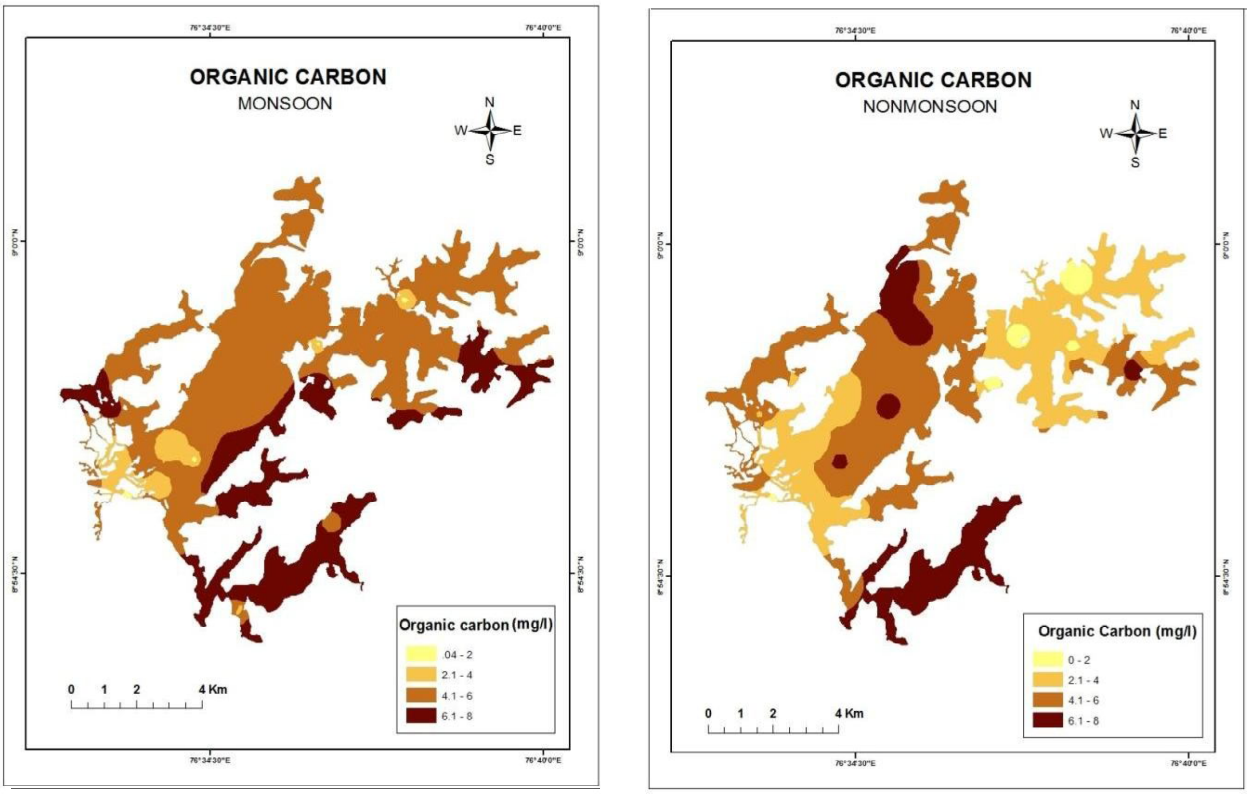

Fig. 5. Spatial distribution of Total Organic Matter (TOC) in surface sediments of the Ashtamudi lake, Kerala, India during monsoon and Non-monsoon seasons

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