Spatial and Temporal Variability of Soil Properties of Lateritic Wetlands *vis a vis* Coastal Wetlands of Northern Kerala

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Received : November 2024
Accepted : December 2024

Abstract

Global climate change has tremendous influence on various ecosystems and land use systems. In this context, a research study was undertaken to assess the spatial and temporal variability of the organic carbon stocks and related nutrient dynamics in the two major wetland soils of northern Kerala (lateritic and coastal wetlands) using geographic information system (GIS). Paddy growing wetland of RARS, Pilicode was the wetland selected in northern laterite and northern coastal wetland selected was paddy growing wetland known as Muppathilkandam, Thaikadappuram. Grid based soil samples were collected from selected locations in AEU 2 (coastal wetlands) and AEU 11 (lateritic wetlands) at quarterly intervals for one year (from February 2023 to November 2023) for assessing the temporal and spatial variability. In the clay loam soils of lateritic wetlands (AEU 11), organic carbon (C) content ranged from 0.60 per cent to 2.85 per cent. Available nitrogen (N) ranged from 81.54 to 476.67 kg ha^{-1}, microbial biomass carbon (MBC) varied between 216.97 and 1390.59 µg g^{-1} and dehydrogenase activity (DHA) varied between 1.28 and 13.59 µg TPF released g^{-1} soil 24 h^{-1}. In the coastal wetland soils (AEU 2), organic C was in the range from 0.45 to 1.20 per cent and available N ranged from 43.90 to 244.61 kg ha^{-1}. MBC ranged between 54.59 and 338.66 µg g^{-1} and DHA ranged between 0.65 and 9.66 µg TPF released g^{-1} soil 24 h^{-1}. On assessing temporal variability of soil properties in lateritic wetland soils, it was found that the mean organic C, exchange-able calcium and magnesium content were highest in August which was on par with May. The mean available sulphur, MBC and DHA were highest in August and the highest mean available N was observed in November. In coastal wetland soils, the highest mean value of organic C, available N, K, MBC and DHA were recorded in November.

Keywords : Spatial variability, Temporal variability, Wetland soils, GIS, Organic carbon

Soils are subjected to continuous temporal and spatial variations (Geypens *et al.* 1999). The nutrient status of the soil plays a crucial role in influencing the distribution (Pan *et al.,* 1999), productivity (Mou *et al.*, 1995) and diversity (Anderson *et al.*, 2004) of plant communities on a larger scale. On a smaller scale, it also impacts plant establishment (Maestre *et al.*, 2003) and interactions among plants (Robinson *et al.*, 1999). Therefore, gaining an in-depth understanding of nutrient concentration on a spatio temporal scale is essential in maintaining ecological functioning.

As per the reports of the Inter Governmental Panel on Climate Change (IPCC, 2000), future climatic variations in annual temperature and rainfall are expected to impact soil organic matter (SOM) dynamics, making sustainable agricultural strategies essential. Decomposition of SOM increases with increase in temperature, which is considered as a critical issue for agriculture sustenance in future (Conant *et al*., 2011). Soil affected by climate change will significantly reduce nutrient availability to plants, leading to decreased soil productivity. Embracing climate-smart agriculture can reshape and adapt agricultural practices to align with the evolving challenges posed by climate change (Parama, 2017).

Kerala's wetlands are crucial for the production of rice, the staple food for over half the world's population. Recent studies on the natural and manmade wetlands of Kerala have shown that the spatial and temporal variability in the physico chemical characteristics of soils are highly significant in their management. GIS maps aid in preventing both under application and over application of chemical fertilizers, contributing to the preservation of soil health (Biradar *et al.*, 2020). Hence an attempt has been made to assess the spatial and temporal variability of the wet land soils in the two agro-ecological units (northern laterites and northern coastal plains) of north Kerala using GIS for managing the soil fertility at precise level.

Material and Methods

Paddy growing wetland of Regional Agriculture Research station (RARS), Pilicode and Muppathil kandam, Thaikadappuram were the wetlands selected in northern laterite and northern coastal wetlands, respectively. The main crop grown in the selected wetland of RARS, Pilicode during the study period was paddy. It was planted in both Virippu (May - September, 2023) and Mundakan (October - January, 2023) seasons. Vegetables like chilli, ashgourd, OP melon, pumpkin etc. were planted during summer months (January to April, 2023). KAU Package of Practices (POP) for paddy with organic farming was followed for the crop management.

The main crop grown in Muppathilkandam, Thaikadappuram, during the study period was paddy in the virippu season (May - September, 2023). During summer months (January to April, 2023), the field was cultivated with vegetables like cucurbits, watermelon, sunflower etc. and was left fallow in some areas. Organic type of farming was adoped in this field with the basal application of lime, farm yard manure and bone meal.

A transect walk was conducted in the study areas and the location information (latitude/longitude) of the boundaries of both the wetlands were collected. The area of the wetland selected in RARS, Pilicode (AEU 11) was 36815 square metre (3.6 hectares) and that of Muppathilkandam, Thaikadappuram (AEU 2) was 13389 square metre (1.3 hectares). Grid maps of the study areas were prepared using the location information in the QGIS 3.4.0 platform. Ten surface samples at 0-30 cm depth were collected at the rate of one sample from each grid along with location details. Soil samples were collected from these locations at quarterly intervals for one year (from February 2023 to November 2023) for assessing temporal variability of soil properties. Analytical results pertaining to the geo referenced sampling locations at definite time intervals were used for assessing the spatial and temporal variability using QGIS and the maticmaps were preparedon soil variables.

Results and Discussion

Organic Carbon (%)

In lateritic wetland soils, organic C content varied between 0.60 and 2.85 per cent and in coastal wetland soils, it varied between 0.45 and 1.20 per cent. Higher organic C in finer textured lateritic wetland soils corroborates with the findings of Hartati and Sudarmadji (2016), that soils with finer textures enhance SOM content.

In both the wetland soils, the mean organic C content increased from February to May. This rise in mean organic C content can be attributed to the presence of litter from summer crop cultivation and the higher temperature. This is in line with the findings of Schulz *et al*. (2011) who reported that crop growth influences SOM content by increasing soil organic carbon (SOC) pools, particularly the decomposable fraction and enhancing the stability of SOM through interaction with mineral soil component. This also supports the findings of Sierra *et al*. (2017) who

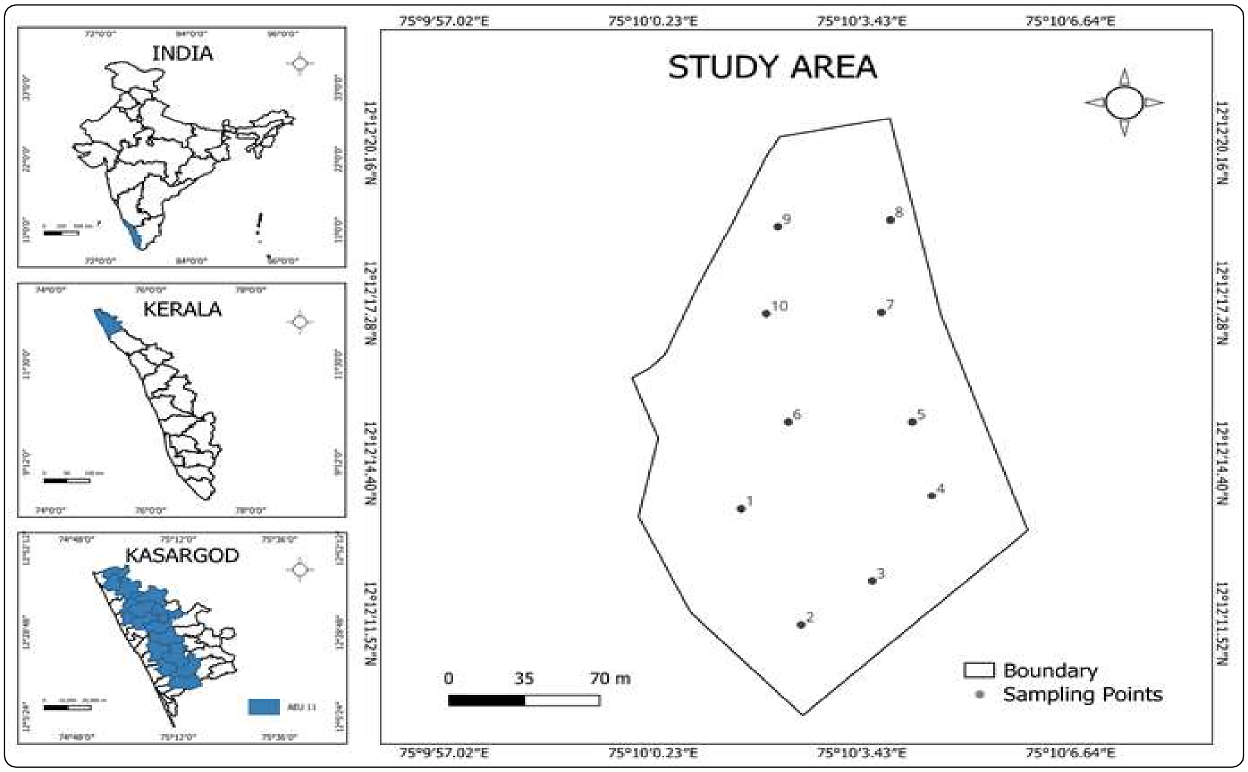

Fig. 1 : Location map of study area in AEU 11 of Kasaragod district

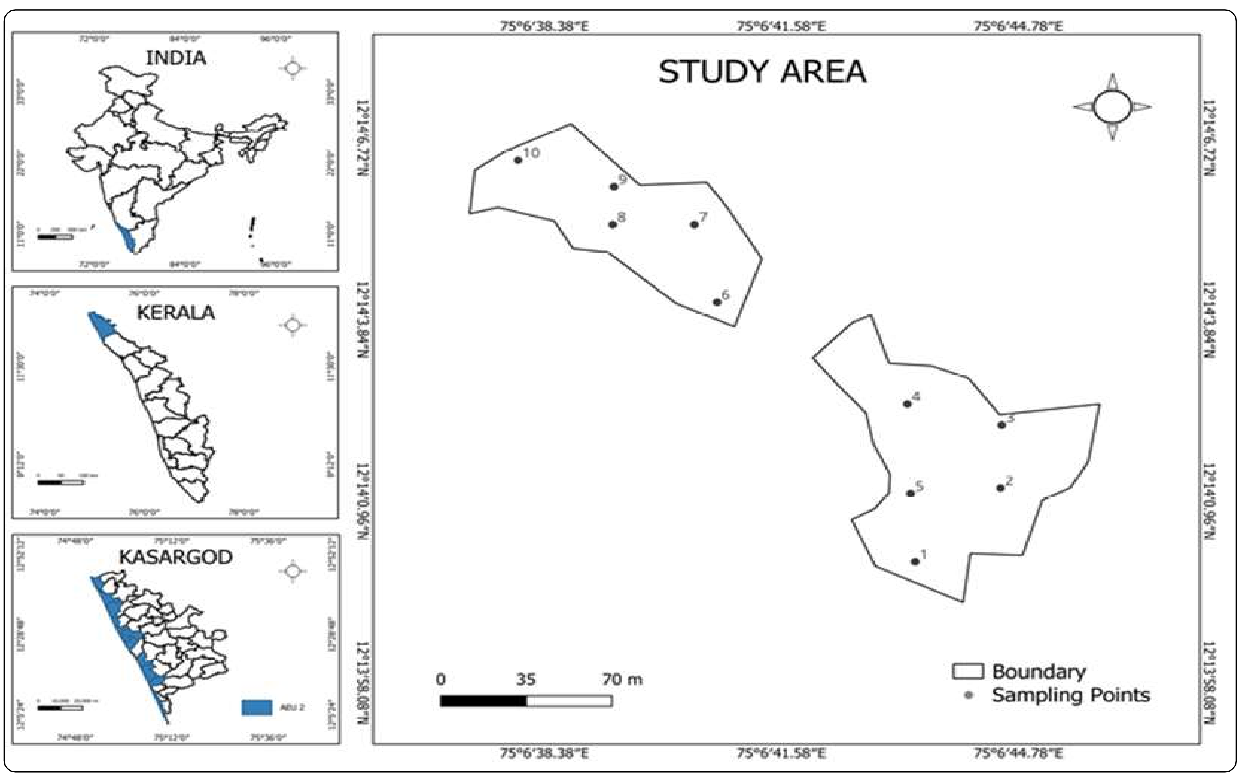

Fig. 2 : Location map of study area in AEU 2 of Kasaragod district

Fig. 3A : Grid map of the study area in AEU 11

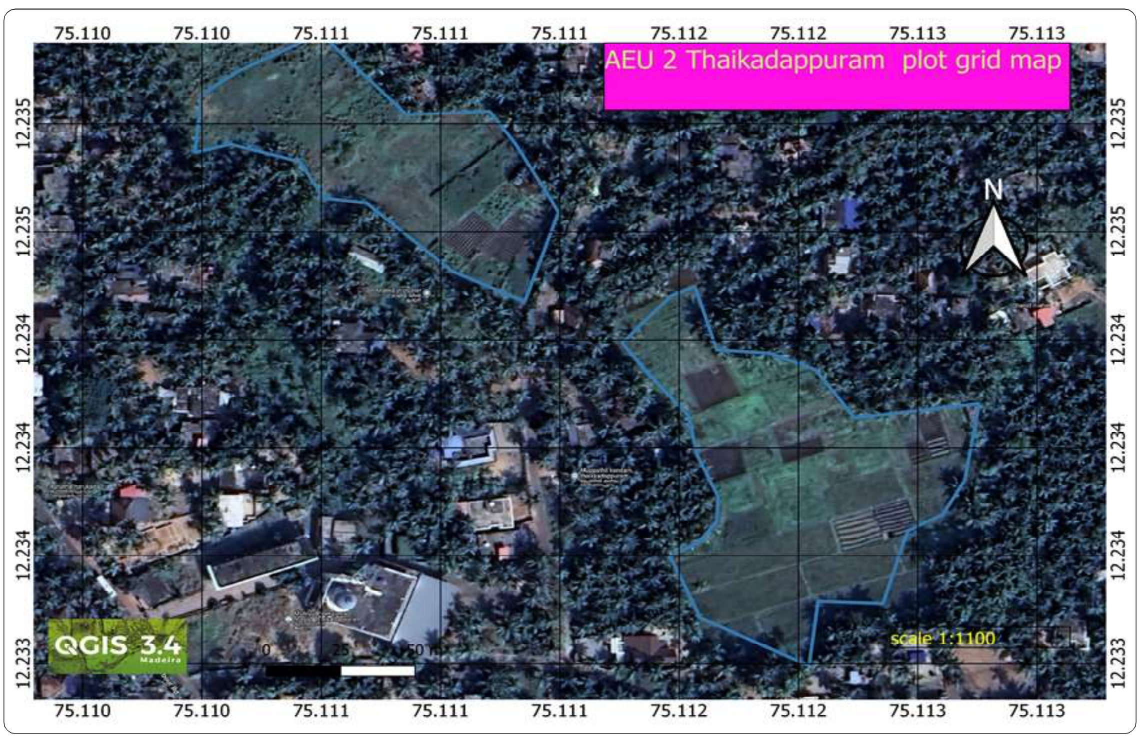

Fig. 3B : Grid map of the study area in AEU 2

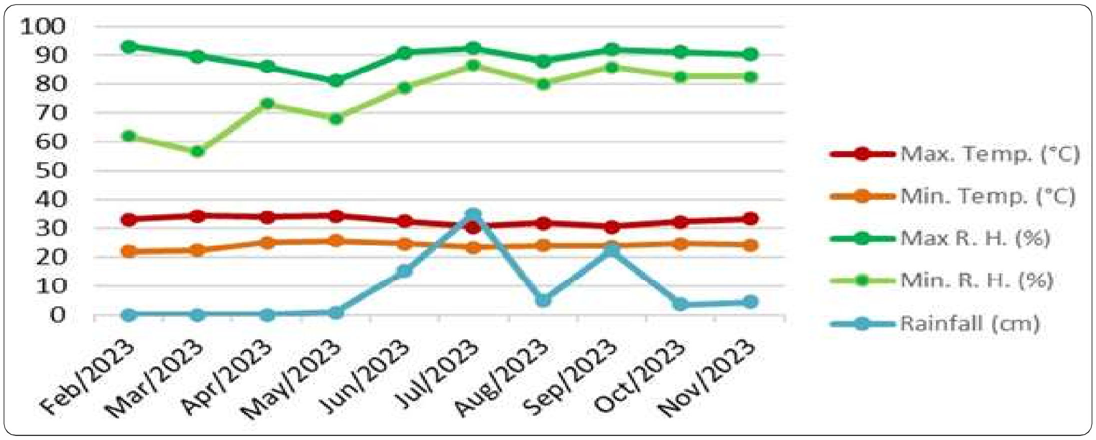

Fig. 4 : Monthly average of weather parameters in AEU 2 and AEU 11 from February 2023- November 2023

reported that increased oxygen content, higher temperatures and lower water levels appear to favour the oxidation of SOM thereby supporting higher levels of SOC.

In lateritic wetland soils, the highest mean organic C content was observed in August during the peak rainfall of SW monsoon (Table 1). This might be due to the slow mineralization of initially applied FYM for virippu rice cultivation in the study area due to water logging (Sun *et al*., 2009). This result aligns with the findings of Gondek and Filipek-Mazur (2006) who reported an increase in SOC content with FYM application.

In coastal wetland soils, the SOC content was lowest in August (Table 2). This could be attributed to the utilization of residual SOC for the initial growth of rice. Sandy soils, characterized by larger pores, expose active SOC pool to more rapid microbial decomposition, leading to a slower accumulation in passive SOC pools. Consequently any organic material inputs added to the topsoil of sandy soils are converted to the active SOC pool, which is then rapidly degraded into CO_2 and released back into the atmosphere (Stewart *et al*., 2008).

The mean SOC content in coastal wetland soils was highest in November. This rise could be attributed to several factors, including the availability of litter from the virippu rice crop, the fallow condition of the field during after virippu cultivation in the study area and favourable weather conditions for the decomposition of SOM.

TABLE 1

Spatial and temporal variation of organic C (%), MBC (µg g^{-1}) and DHA (µg TPF released g^{-1} soil 24 h^{-1}) in lateritic wetland soils

Months	Organic C		MBC		DHA	
	Mean	Range	Mean	Range	Mean	Range
February	0.63 [c]	0.54 - 0.84	163.51 [c]	111.63 - 241.62	1.40 [c]	0.39 - 1.96
May	0.78 [b]	0.60 - 1.20	222.75 [b]	129.86 - 283.17	3.28 [b]	2.34 - 4.05
August	0.56 [c]	0.45 - 0.72	96.51 [d]	54.59 - 188.63	1.13 [c]	0.65 - 2.43
November	0.99 [a]	0.63 - 1.14	451.93 [a]	338.66 - 556.52	5.68 [a]	2.26 - 9.66
SE(m)	0.048		16.448		0.455	
CD (0.05)	0.139		47.175		1.305	

TABLE 2

Spatial and temporal variation of organic C (%), MBC (µg g^{-1}) and DHA (µg TPF released g^{-1} soil 24 h^{-1}) in coastal wetland soils

Months	Organic C		MBC		DHA	
	Mean	Range	Mean	Range	Mean	Range
February	1.22 ^{b}	0.60 - 1.62	409.28 ^{c}	216.97 - 650.17	2.71 ^{c}	1.28 - 6.09
May	1.48 ^{ab}	0.72 - 2.19	567.09 ^{b}	304.05 - 790.28	4.36 ^{bc}	2.26 - 7.42
August	1.86 ^{a}	1.26 - 2.85	994.45 ^{a}	659.16 - 1390.59	8.59 ^{a}	5.15 - 13.59
November	1.23 ^{b}	0.63 - 1.65	412.32 ^{c}	278.90 - 653.12	5.69 ^{b}	4.02 - 7.84
SE(m)	0.154		53.331		0.589	
CD (0.05)	0.441		152.960		1.688	

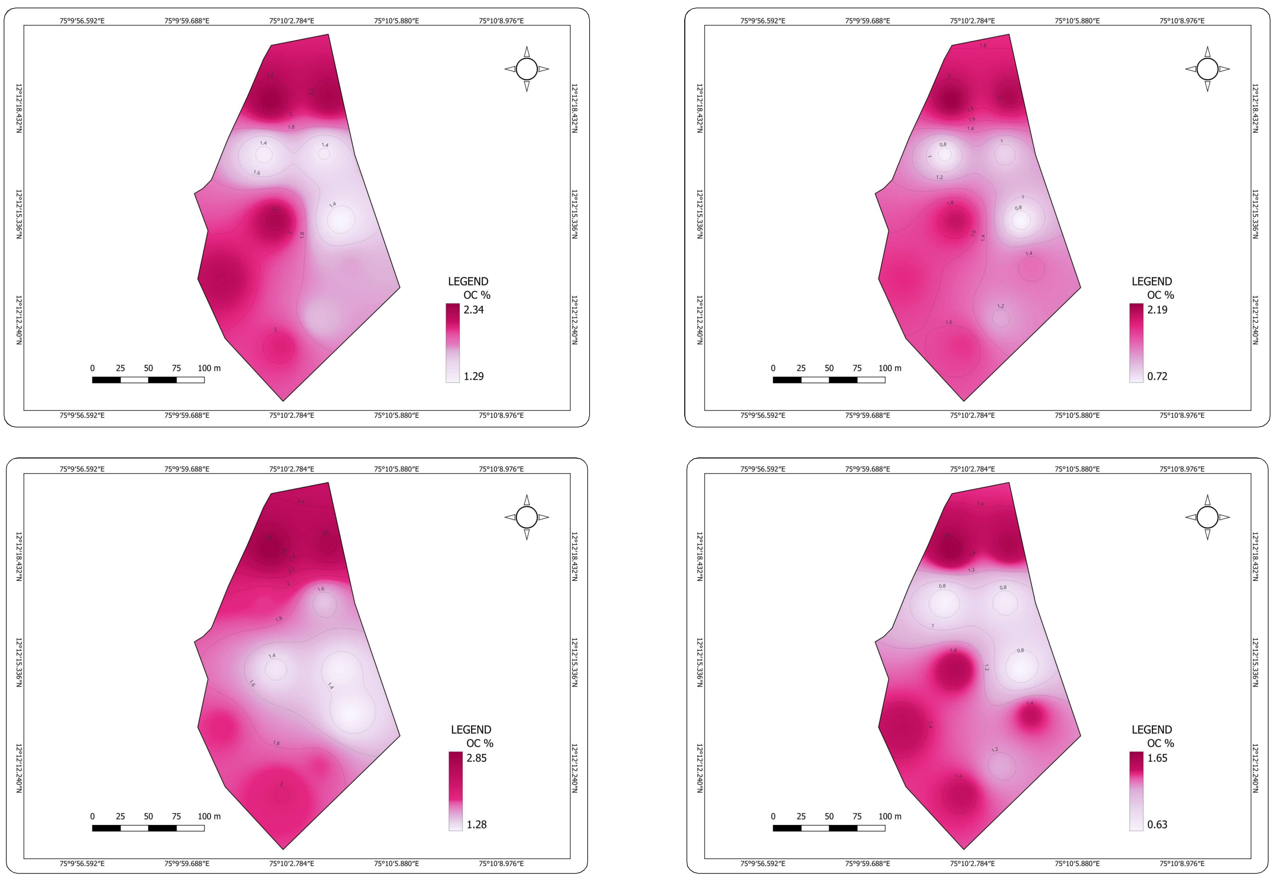

Fig. 5 : Spatial and temporal variation of organic C (%) in lateritic wetland soils in the four sampling months: a) February b) May c) August d) November

Microbial Biomass Carbon

In lateritic wetland soils, MBC varied between 216.97 and 1390.59 µg g^{-1}, while in coastal wetland soils, it ranged from 54.59 to 338.66 µg g^{-1} respectively. MBC is influenced by soil texture, with clay-rich soil promoting more efficient microbial utilization of litter material, potentially leading to higher levels MBC levels (Angst *et al.*, 2021).

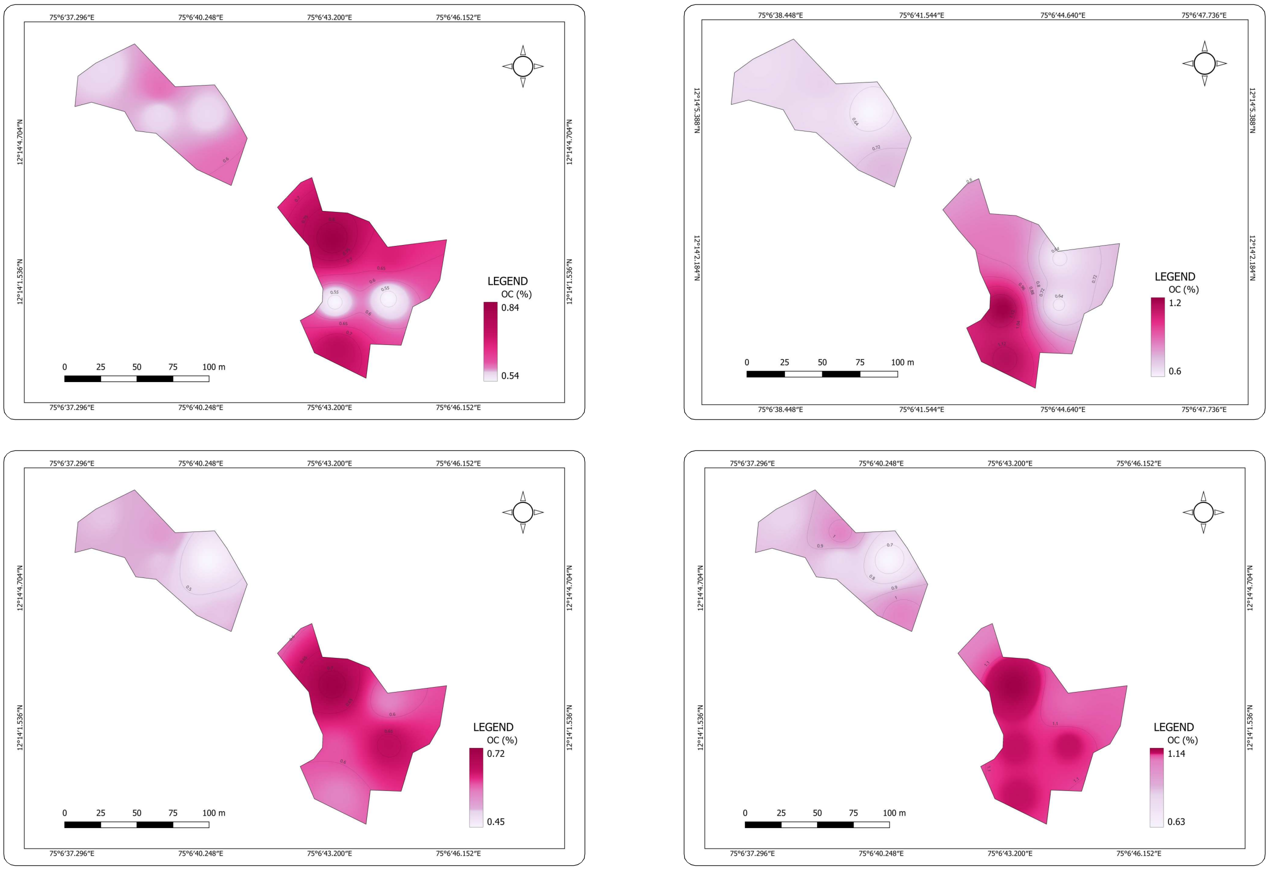

Fig. 6 : Spatial and temporal variation of organic C (%) in coastal wetland soils in the four sampling months: a) February b) May c) August d) November

The MBC in lateritic wetland soils was highest in August and lowest in February which was on par with that observed in November. This might be due to the high SOC content coupled with adequate soil moisture present in August. SOM provides energy to microbes and soils with a higher content of SOM generally exhibit higher microbial biomass and functional diversity (Luo *et al*, 2016). MBC recorded a positive relationship with soil moisture, influencing SOC mineralization differently across different soils under varying moisture levels (Singh *et al*., 2021).

In coastal wetland soils, the mean MBC was highest in November and lowest in August. This result can also be correlated with SOC content during the respective sampling periods in the study area as mentioned above.

Dehydrogenase Activity

Temporally, in both wetland soils DHA showed a similar trend with MBC. Similar results were observed by Saxena and Singh (2013), who reported a positive correlation between MBC and DHA, with higher activity in winter compared to summer. DHA was influenced by factors such as litter availability and soil oxygen levels. This supports the finding of Aon and Colaneri (2001) who reported that SOC, total N and water-filled pore space were found to have strong relationships with enzymatic activities such as dehydrogenase, irrespective of the season and the presence of crops.

Available Nitrogen

In both wetland soils, the available N content is in low N category (less than 280 kg ha^{-1}) with the mean available N highest in November (Table 3). This

TABLE 3

Spatial and temporal variation of available nitrogen (kg ha^{-1}) in lateritic wetland soils and coastal wetland soils

Months	Lateritic wetland soils		Coastal wetland soils	
	Mean	Range	Mean	Range
February	177.50 [b]	131.71 - 225.79	104.74 [bc]	56.45 - 156.80
May	179.38 [b]	137.98 - 288.51	131.71 [b]	112.90 - 169.34
August	111.64 [c]	81.54 - 144.26	94.71 [c]	43.90 - 150.80
November	288.50 [a]	156.80 - 476.67	163.70 [a]	87.81 - 244.61
SE(m)	21.464		10.048	
CD (0.05)	61.562		28.818	

might be due to the availability of SOM both from the settled SOM due to waterlogged condition and the left over litter from virippu rice cultivation together with atmospheric conditions favouring SOM decomposition and mineralization at this period of sampling. This is in line with the findings of Wang (2018) who reported that under field conditions, soil N net mineralization follow soil moisture and temperature levels. Higher levels of moisture and temperature were found to contribute to greater soil N net mineralization, potentially leading to higher plant-available N content in the soil.

In both the wetland soils, mean available N showed lowest values in August (during peak of rainfall). This might be due to leaching of nitrate nitrogen and nitrogen loss through nitrate reduction and denitrification under anaerobic condition (Unger *et al*., 2009).

Available Potassium

In coastal wetland soils, there was significant temporal variation of available K and the highest mean value of available K was recorded in November (Table 4). This might be due to the higher levels of SOC observed during this particular sampling period. Soil organic carbon is known to positively correlate with available K fractions in soil, thereby enhancing K levels. The presence of higher SOM content can improve K availability in the soil (Pathariya *et al.,* 2022). This might be also due to the lower Fe concentrations during November in this study area. In acidic soils, a negative correlation exists between available K and available Fe (Loncaric *et al*., 2020).

TABLE 4

Spatial and temporal variation of available potassium (kg ha^{-1}) in lateritic wetland soils and coastal wetland soils

Months	Lateritic wetland soils		Coastal wetland soils	
	Mean	Range	Mean	Range
February	127.28	80.98 - 181.66	62.70 [c]	24.53 - 112.22
May	156.88	105.06 - 263.65	92.04 [b]	66.75 - 126.11
August	116.21	56.22 - 220.19	32.20 [d]	15.68 - 60.70
November	133.89	63.53 - 251.02	118.59 [a]	82.77 - 210.13
SE(m)	16.093		8.209	
CD(0.05)	NS		23.545	

TABLE 5

Spatial and temporal variation of available B (mg kg^{-1}) in lateritic wetland soils and coastal wetland soils

Months	Lateritic wetland soils		Coastal wetland soils	
	Mean	Range	Mean	Range
February	0.14 [b]	0.10 - 0.19	0.13 [b]	0.08 - 0.24
May	0.28 [a]	0.20 - 0.38	0.27 [a]	0.17 - 0.49
August	0.12 [b]	0.10 - 0.15	0.09 [b]	0.07 - 0.10
November	0.25 [a]	0.18 - 0.36	0.14 [b]	0.12 - 0.14
SE(m)	0.015		0.018	
CD(0.05)	0.042		0.051	

In coastal wetland soils, the lowest values of mean available K were observed in August. This finding contradicts the observations of Fageria *et al*. (2011), who reported that submergence leads to the displacement of available K into the soil solution, increasing the concentration of bioavailable K. This contradiction might be due to low SOM content, particularly leading to a slowdown in the soil reduction process, resulting in fewer benefits in terms of soil fertility under flooded conditions, as reported by Sahrawat (1998). Additionally, K might have leached out during rainfall, especially from coastal sandy soils. Similar results were obtained by Akpoveta *et al*. (2014).

Available B content was deficient in all soil samples collected from both wetlands (<0.5 mg kg^{-1}). The acidic leaching conditions of Kerala soils hinder the retention of B, leading to a significant deficiency of available boron in these soils (Rajashekaran *et al.,* 2014).

In both wetland soils, mean available B levels were higher in May (Table 5). This increase is likely due to higher soil temperatures enhancing boron extractability, similar to the higher extraction rates observed with hot water in acidic soils (Sarkar *et al*., 2008).

In August (at the peak of rainfall), mean available B levels in both wetland soils decreased. Under acidic soil conditions, B is more water-soluble and can be leached below the root zones of plants by rainfall, a process that is particularly pronounced in light-textured soils (Santhosh, 2013).

Spatial variability maps proved to be an important tool in site specific farming.

Temporal variation exist for most of the soil properties. Hence, season wise nutrient management strategies may be evolved for improved productivity, reduced cost of cultivation by avoiding excess application of fertilizers and low negative impact on the environment

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