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Soil Quality Assessment Based on Physico-Chemical and Biological Properties in the Mangrove Ecosystem of Asramam, Kollam, Kerala, South India

Abstract

A study was conducted to investigate the physical, chemical, and biological characteristics of soil in the Asramam wetlands of Kollam District, Kerala, South India, and to understand how these factors influence the distribution of mangrove vegetation in the region. Soil samples were collected randomly from three representative locations within the wetland area. At each site, a soil pit of about 30 cm depth was prepared, and samples were collected from two distinct layers: 0–15 cm representing the surface layer and 15–30 cm representing the subsurface layer. The collected soil samples were transported to the laboratory for detailed analysis. Soil physio-chemical properties including soil pH, moisture content, electrical conductivity, soil organic carbon, available nutrients such as phosphorus, potassium, calcium, sulphur, ⁶ iron, zinc, manganese, copper, boron, and magnesium. In addition to these parameters, the biological aspect of the soil was assessed by estimating the percentage of root colonization by vesicular arbuscular mycorrhizal (VAM) fungi. The results revealed only minor variation in soil pH among the three study sites. In general, the surface soil was slightly less acidic compared to the lower layer, whereas electrical conductivity showed comparatively higher values in the topsoil. Organic carbon content was greater in the lower layer than in the surface soil. Among the nutrients analyzed, phosphorus, potassium, and calcium were more abundant in the topsoil, while sulphur, iron, and zinc were recorded in higher concentrations in the lower layer. Manganese, copper, and boron also showed relatively higher values in the surface soil, whereas magnesium was found to be higher in the deeper layer. The results of VAM root colonization was more pronounced in the lower soil layer. Vesicles were observed more frequently than arbuscules in the colonized roots. Overall, the findings of the study provide useful insights into the soil conditions that support and sustain the mangrove ecosystem of

the Asramam wetlands.

Key words: Mangrove ecosystem, Soil physico-chemical properties, nutrient dynamics, VAM, Root colonization;

Introduction

Mangrove ecosystems are widely regarded as among ¹ the most productive and ecologically important natural environments on Earth. These forests occur mainly ⁷ in the intertidal zones of tropical and subtropical coastlines, where they form a transitional boundary between terrestrial and marine ecosystems. Mangroves provide numerous ecological and economic benefits, including the preservation of biodiversity, stabilization of coastlines against erosion, and support for the livelihoods of communities living in coastal regions (Krishnamurthy, 1993). Mangrove forests are characterized by exceptionally high primary productivity, which has been estimated at approximately $2,500 \text{ mg cm}^{-2} \text{ day}^{-1}$ (Bunt, 1992). Due to this high productivity, along with rapid decomposition of organic matter and constant interaction between terrestrial and marine systems, mangroves ⁴ play a crucial role in the cycling and transformation of carbon and other nutrients in tropical coastal environments (Jennerjahn and Ittekkot, 2002). Mangrove forests perform many essential ecological functions that contribute significantly to the stability of coastal ecosystems (Snedaker, 1987; Dagar, 1982, 1987). Their complex root systems are capable of trapping sediments carried by river flow and tidal currents, which promotes the gradual deposition of silt and clay in coastal areas (Chatterjee, 1957; Naskar and Mandal, 1999). In addition, mangrove habitats support a diverse range of plant and animal species, including several endemic and threatened organisms. Many of these species are protected under national conservation legislation such as the Wildlife Protection Act of India (Naskar and Mandal, 1999).

Among the various environmental factors influencing mangrove ecosystems, soil properties play a critical role in shaping the structure and composition of mangrove vegetation.

Mangrove soils are typically alluvial, fine-textured, and rich in organic matter. They generally possess high moisture and salt content and often experience low oxygen availability because of prolonged waterlogged conditions (Macnae, 1968). These edaphic characteristics significantly affect the establishment, growth, and distribution of mangrove plant species. An important biological feature of mangrove soils is the occurrence of mycorrhizal fungi, particularly Vesicular Arbuscular Mycorrhizae (VAM). These fungi are widely distributed soil microorganisms that form symbiotic associations with the roots of numerous plant species (Gerdemann, 1968; Menge, 1982). Through this symbiotic relationship, VAM fungi enhance the absorption of nutrients by plants and promote overall plant health. In addition, they contribute to maintaining soil fertility by influencing microbial activity and facilitating nutrient cycling within the soil ecosystem.

Kerala previously supported extensive mangrove vegetation along its coastal and estuarine regions (Basha, 1991). Over time, however, the extent of mangrove cover in the state has declined considerably (Kurien, 1994). Several climatic factors such as temperature, rainfall, tidal fluctuations, and freshwater inflow play important roles in influencing the growth and survival of mangrove ecosystems (Chapman, 1977; Walter, 1977). Despite their ecological significance, mangrove habitats are increasingly under pressure from both natural changes and human-induced disturbances (Muraleedharan et al., 2009). In Kollam district of Kerala, mangrove vegetation occurs in several locations, including Adventure Park, Asramam, Munroe Thuruthu Islands, and Kumbalam. Among these areas, the mangroves at Asramam represent an important ecosystem supporting species such as *Sonneratia caseolaris*, *Rhizophora apiculata*, and *Rhizophora mucronata*. Investigating the physical, chemical, and biological properties of mangrove soils is essential for assessing the health, productivity, and sustainability of these ecosystems. Therefore, the present study focuses on the physico-chemical and biological characteristics of mangrove soils in this region in order to provide insights useful for the conservation and management of mangrove habitats and to understand their relationship with associated vegetation and microbial

communities

STUDY AREA AND METHODS

For the present study, the study area was selected in different localities of mangrove forest at Asramam area of Kollam District, Kerala South India. Asramam is located in the core of Kollam city in the state. At Asramam, the true mangrove species are confined to salty-marshy environment along back waters, whereas the mangrove associate species were also found in other areas apart from the mangrove environment. For the present study 3 sites were selected in Asramam wetland area. Site one is located at the Asramam banks of Ashtamudi lake, two sites around Asramam Adventure Park.

For the present study soil ¹ samples were collected from three selected areas in the Asramam. From each site six samples were collected, three from rhizosphere and other three from non-rhizosphere areas. The ³ soil samples were collected in such a way that a pit of 30 cm was made using a spade. Soil samples from the pits were collected from 0-15 cm from the top layer and 15-30 cm from the bottom layer. Care should be taken to avoid the mixing of soils. Soils from each layer were taken to a clean polythene bag. About 500 g of soil from the layer was collected and labeled and then brought to the laboratory for further studies. Stones, roots and other debris were separated from the soil. The sample thus obtained was further made into working samples of 10 g each and utilized for soil physical and chemical analysis. Standardized laboratory procedures were followed to ensure accuracy and reliability in each analysis. The parameters studied included soil pH and electrical conductivity described by Jackson, 1973. Soil moisture content, organic carbon percentage were analysed by using standard method (Motsara and Roy, 2008). Phosphorus availability ³ was determined using the method of Bray and Kurtz (1945) and modified by FAO (2021). Potassium, calcium and Magnesium were estimated using the method by Madaras and Koubova (2015). Sulphur availability in the soil was determined using the method of Motsara and Roy (2008). Soil micronutrient like iron (Fe),

manganese (Mn), zinc (Zn), copper (Cu) and boron (B) levels were determined by using the above method. The collected data were statistically analyzed. Correlation analysis was used to examine relationships between different soil parameters

For root colonization studies plants root ¹ samples were collected from rhizosphere areas with in the study areas and the collected root samples are thoroughly washed in tap water to remove soil particles. Selected and cleaned roots were cut into 1 cm in length by sterilized blade. The root pieces were placed in a small beaker with 10% KOH solution for about 60 minutes. After that the root bits were taken out washed with distilled water and stained. The staining solution contains 5% diluted in 5% acetic acid. Staining with Pelikan Blue (blue ink) was adopted for the present study (Vierheilig,et al.,1998). Keep the root in the stain for few days. Stained root become clearer after destaining with 50% glycerol. For quantification of AMF colonization, 100 bits of selection were selected randomly and left them on slides under microscope and thus percentage of root colonization was calculated with the formula:

$$\text{Percentage of root colonization} = \frac{\text{Number of root bits with infection}}{\text{Total number of root bits examined}} \times 100$$

Results and Discussion

The soil samples collected from three different sites of the Asramam wetlands was subjected to the determination of soil physio-chemical analysis and the results are as follows. The average pH of rhizospheric top soil was 5.8 and that of non-rhizospheric top soil was 5.9. Whereas the percentage of moisture content in the upper layer varies from 8 to 9.5%, while the lower layer ranges from 9.3 to 9.8%. The study resulted soil electrical conductivity in non rhizospheric top soil was 0.64 mmhos, and that of rhizospheric top soil was 0.09mmhos (Fig. 1).

The percentage of organic carbon highest in the non-rhizospheric down soil (2.94%) and the lowest in the rhizospheric down soil of the site (0.81%). In some mangrove forests, organic carbon content above 10% has been reported (Sukardjo, 1994; Rambok et al., 2010; Moreno and Calderon, 2011), reflecting the peaty nature of the soils. However, organic carbon levels of less than one percent reported by Sah et al. (1989) and Hossain et al. (2012) indicate poor nutritional conditions in the soils of certain mangrove forests. The present study reveals that the organic carbon content is relatively low, remaining below 3%(Fig. 2) . Whereas in the case of average available phosphorus in the rhizospheric topsoil was 53.55Kg/ ha in the top layers and 114.9Kg/ ha in the bottom layer(Fig. 3). The corresponding values in the non rhisospheric soils was 62.19Kg/ ha and 263.359Kg/ ha respectively from top and bottom layers.

The available soil potassium resulted highest in rhizosphere down soil (169.2 Kg/ha) and least by non rhizosphere down soil(Fig. 4).The study resulted highest average calcium content in non rhizosphere top soil of site 1 and least by non-rhizosphere soil of site 2(Fig. 5) . While the soil available sulphur shows highest in rhizosphere down soil(Fig. 6).Highest iron content resulted in non-rhizosphere top soil(Fig. 7). The present study shows highest zinc content in rhizosphere down soil lowest in non rhizosphere down soil(Fig. 8). The present study shows top soils of rhizosphere and non rhizosphere area have higher amount of available manganese 33.86ppm and 35.003ppm respectively(Fig. 9). The results of soil available copper, the down soil of 15-30 cm depth of non rhizosphere results an average value of 13.6ppm was obtained(Fig. 10). The corresponding value of rhizosphere soil was 12.65ppm. While the top soil layers of rhizosphere soil resulted 6.3ppm only. While the available boron resulted maximum at non rhizosphere down soil (0.424ppm) and least at rhisospere top soil (Fig. 11). Soil available magnesium resulted maximum at non rhizosphere down soil (35.85ppm) and least at rhizosphere top soil (Fig. 12). Researchers like Karim (1994) reported the calcium content is varied from 2350 to 3950 μ g/g and Magnesium content 1000 to 1500 μ g/g in the mangrove soil of Sundarban mangrove forest, Bangladesh. At this place Muhibullah, et al. (2005) reported highest soil potassium

content. The dual role of elements such as Cu, Fe, Mn, B, Zn, and Mg acting either as essential nutrients or as potentially toxic elements in mangrove ecosystems, has been highlighted in several studies (MacFarlane et al., 2003; Andrade et al., 2005; Kannappan et al., 2012)

Fig 1. Soil electrical conductivity

Fig 2. Soil organic carbon

Fig 3. Available Phosphorous

Fig. 4. Soil potassium content

Fig. 5. Available calcium content

Fig 6. Available Sulphur

Fig 7. Available Iron content

Fig 8. Available Zinc

Fig 9. Available Manganese Fig. 10. Available Copper

Fig. 11. Available Boron Fig. 12. Available Magnesium

(Site 1. Near Adventure park, Site 2. Near KTDC, Site 3. Asramam bank of Ashtamudi;

RhzT:-Rhizosphere Top soil, NRhz T :- Non – Rhizosphere Top soil, Rhz D- Rhizosphere

Down soil, NRhz D :-Non

The root samples were processed for VAM fungal identification. The following are the results. The presence or absence of Vesicles and Arbuscules in the root bits in each site is represented in the Table 1.

Table 1: Presence of VAM fungi from study sites

VAM

5	Site 1
	Site 2
	Site 3

Top soil

Down soil

Top soil

Down soil

Top soil

Down soil

Vesicles

+

—

—

—

+

+

Arbuscules

—

—

—

—

+

—

.

The present study shows maximum percentage of root colonization was observed in site 3, Asramam bank of Ashtamudi, where both arbuscules and vesicles are seen in the top layer of soil. In down soil contains only vesicles. In site 2, no root colonization was observed. In site 1, vesicles are seen in the top soil, where as Arbuscules are absent. The above study revealed that the top layer of rhizosphere soil shows highest percentage of root colonisation.

Conclusions

2 The results indicate that soil physico-chemical properties play a significant role in influencing the ecophysiology, vegetation patterns, species composition, and overall forest structure of mangrove ecosystems. Furthermore, the physico-chemical and biological characteristics of the soil contribute positively to soil quality and plant growth, thereby supporting ecosystem stability and restoration efforts. Overall, soil characteristics are key factors that regulate the structure, productivity, and sustainability of mangrove ecosystems.

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