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, 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 the most productive and ecologically important natural environments on Earth. These forests occur mainly 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 mg cm^{-2} 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 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 forestat Asramam area of KollamDistrict,Kerala South India. Asramamlocated 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 the Asramam banks of Ashtamudi lake, two sites around AsramamAdventure Park.

For the present study soil samples were collected from three selected area in the Asramam. From each sitesix samples were collected, three from rhizosphere and other three from non-rhizosphere areas.The soil samples were collected in such a way that a pit of 30cm was made using a spade.Soil samples from the pits were collected from 0-15 from the top layer and 15-30cm from the bottom layer.Care should be taken to avoid in the mixing of soils. Soils from each layer were taken to a clean polythene bag.About 500g of soil from the layer was collected and labeled and then bring to the laboratory for further studies.Stones, roots and other debris were separated from the soil.The sample thus obtained was further made in to 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 pHand electrical conductivity described by Jackson, 1973. Soil moisture content, organic carbon percentage were analysed by using standard method (Motsara and Roy, 2008).Phosphorus availability 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 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:

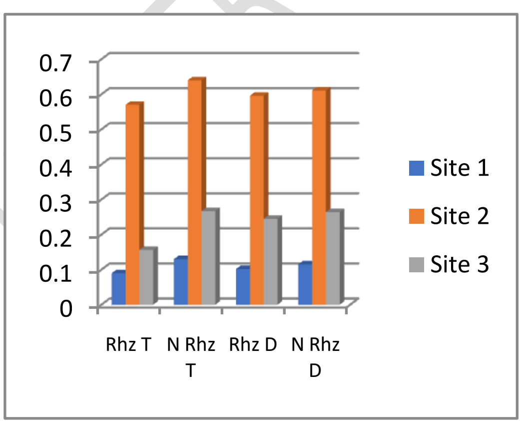
$$\text{Percentage of root colonization} = \frac{\text{Number of root bits with infection}}{\text{Total number of root bits examined}} \times 100$$

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 manganese33.86ppm 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 3950µg/g and Magnesium content 1000 to 1500µg/g in the mangrove soil of Sundarban mangrove forest, Bangladesh. At this placeMuhibbullah, *et al*. (2005) reported highest soil potassium content. The dual role of elements such as Cu, Fe, Mn, B, Zn, and Mgacting 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)



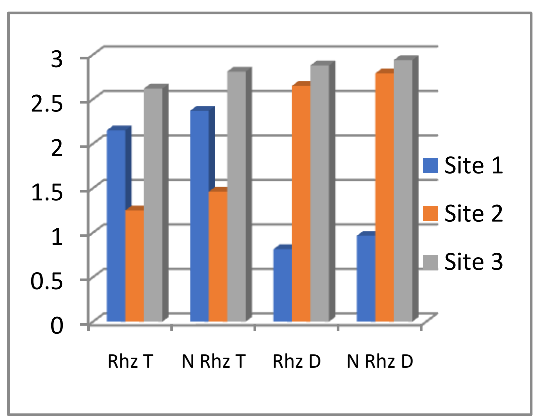
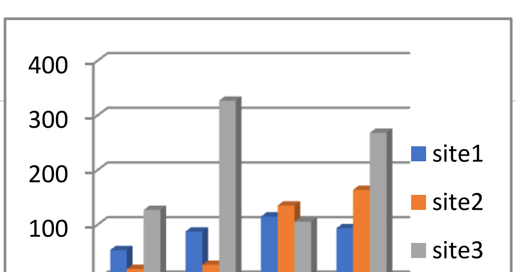


Fig 1. Soil electrical conductivity

Fig 2. Soil organic carbon



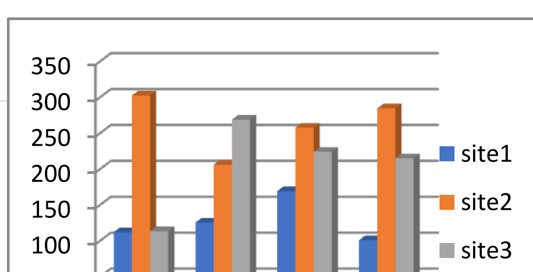


Fig 3. Available Phosphorous

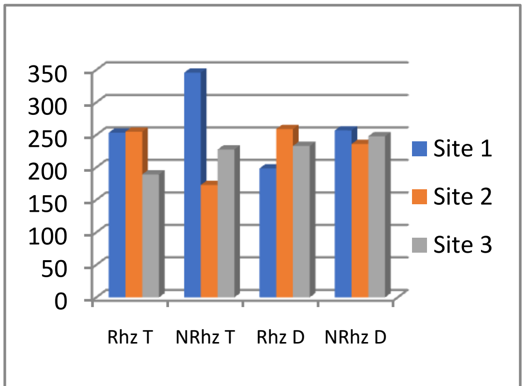


Fig. 4. Soil potassium content

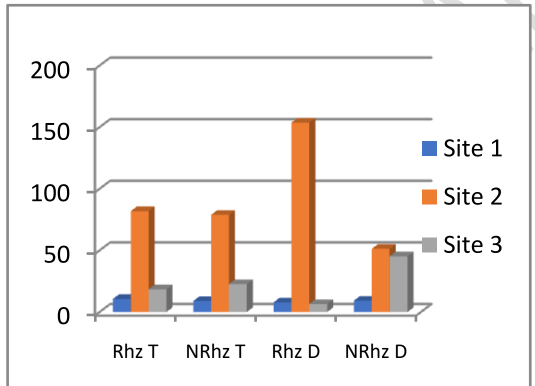


Fig. 5. Available calcium content

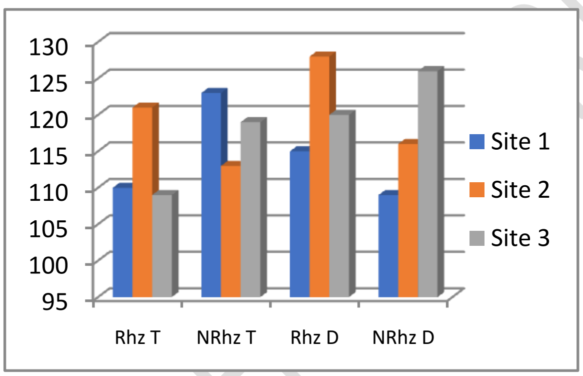


Fig 6. Available Sulphur

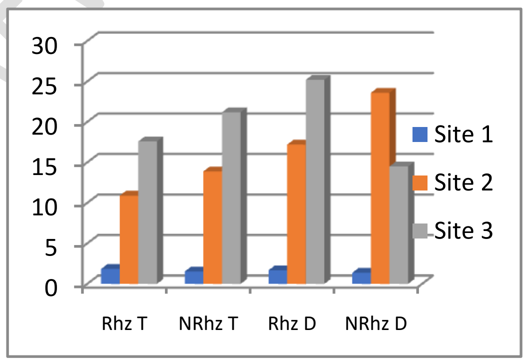


Fig 7. Available Iron content

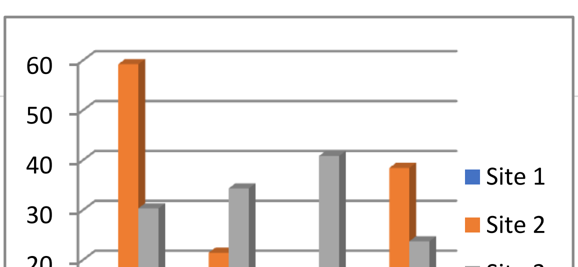


Fig 8. Available Zinc

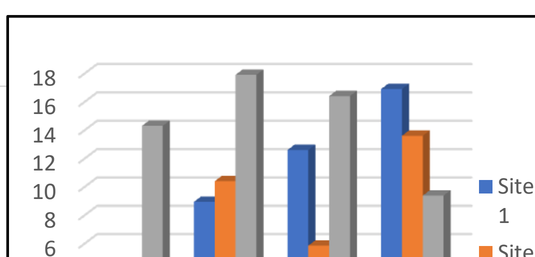
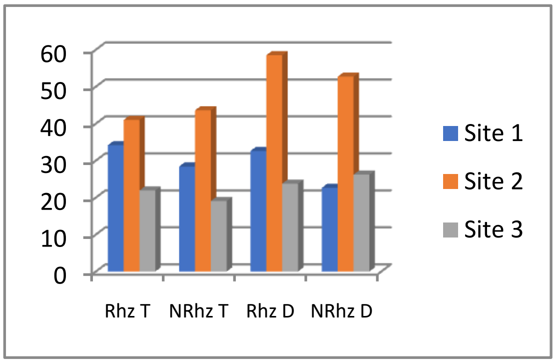


Fig 9. Available Manganese Fig. 10. Available Copper



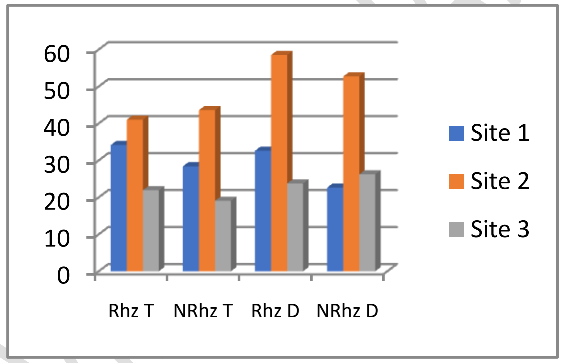


Fig. 11. Available BoronFig. 12. Available Magnesiu

(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	Site 1		Site 2		Site 3	
	Top soil	Down soil	Top soil	Down soil	Top soil	Down soil
Vesicles	+	_	_	_	+	+
Arbuscules	_	_	_	_	+	_

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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

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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References

Andrade E, Miyazawa M, Pavan MA, Oliveira EL. 2005. Re-evaluation of Manganese Solubility as Affected by Soil Sample Preparation in the Laboratory. Braz Arch Biol Technol. 48:643-646.

Basha, S.C. 1991. Distribution of mangroves in Kerala.Indian Forester, 117(6):439-448.

Bray, R.H. and Kurtz, L.T. 1945. Determination of Total Organic and Available Forms of Phosphorus in Soils. Soil Science, 59, 39-45. http://dx.doi.org/10.1097/00010694-194501000-00006

Bunt, J. S., 1992. Introduction. In “Tropical MangroveEcosystem “ A.I. Robertson Eds. 226 pp

Chapman , V. J. (ed.) 1977. *Wet coastal ecosystems.* Elsevier Scientific Publishing Company, Amsterdamand New York. 428 pp.

Chatterjee, D.1957. The nature and distribution of the mangrove plants. Proc. Mangrove Symposium. Ministry of Food and Agri., Calcutta, pp. 132-134.

Dagar, J.C., 1982. Some ecological aspects of mangrove vegetation of the Andaman and Nicobar Islands in India. Sylvatrop Philipp. For. Res. J., 7: 177-216.

Dagar, J.C., 1987. Mangrove vegetation, its structure ecology, management and importance with special reference to Andaman and Nicobar Islands. In: Proc. Symp. Management of Coastal Ecosystems and Oceanic Resources of the Andamans 17-18 July, 1987, Andaman Science Association (CART), Port Blair. pp. 8-23.

FAO., 2021. Standard operating procedure for soil available phosphorus, Bray I and Bray II method. Rome

Gerdemann, J.W. 1968. Vesicular arbuscular mycorrhiza and plant growth. Ann. Rev. Phytopathol. 6: 397-418.

Hossain, M.Z., C.B. Aziz and M.L. Saha, 2012. Relationships between soil physico-chemical properties and total viable bacterial counts in Sunderban mangrove forests, Bangladesh. Dhaka Univ. J. Biol. Sci., 21: 169-175

Jennerjahn , T.C and Ittekkot, V. 2002. Relevance ofmangroves for the production ans deposition oforganic matter along tropical continental margins,*Naturwissenschafen*, 89, 23-30.

Kannappan T, Shanmugavelu M, Karthikeyan MM. 2012. Concentration on heavy metals in sediments and mangroves from Manakudy Estuary (South West Coast of India). Eur J Biol Sci. 4:109-113.

Karim, A. 1994. The physical environment Z. Hussainand G. Achanya, (Eds). Mangrove of the Sundarbans, Bangladesh IUCN, Bankok., 2: 11- 42.

Krisnamurthy, K. 1993. The Mangroves. ENVIS Newsletter, Vol. 1, 1993, pp. 1-3.

Kurian C.V ,1994.Fauna of the mangrove swamps in Cochin estuary. Proceedings of the Asian Symposium on the Mangrove Environment.Res.Manag. University of Malaya, Kuala Lumpar , Malaysia ,pp . 226-230

Mac Farlane GR, Pulkownik A, Burchett MD. 2003. Accumulation and distribution of heavy metals in the grey mangrove, Avicennia marina (Forsk.) Vierh.: biological indication potential. Environ Poll. 2003; 123:139-151.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo-pacific region. Adv. Mar. Biol. 6:73-270.

Madaras, M., Koubova, M., 2015. Potassium availability and soil extraction tests in agricultural soils with low exchangeable potassium content. Plant and Soil Environ. Vol. 61, , No. 5: 234–239

Menge, J. A. 1982. Effects of soil fumigants and fungicides on vesicular-arbuscular mycorrhizal fungi. Phytolpathol. 72: 1125-1132.

Moreno, A.N.M. and J.H.M. Calderon, 2011. Quantification of organic matter and physical-chemical characterization of mangrove soil at Hooker Bay, San Andres Island-Colombia. Proceedings of the Global Conference on Global Warming, July 11-14, 2011, Lisbon, Portugal, pp: 1-7

Motsara, M., Roy, R.N. 2008. Guide to Laboratory Establishment for Plant Nutrient Analysis. Food and Agriculture Organization of the United Nations, Rome, 2008.

Muhibbullah, M D., Nurul Amin, S.M and Chowdhury, A.T. 2005. Some physico-chemical parameters of soil and water of Sundarban mangrove forest, Banglades. J. Biol. Sci., 5 (3): 354 – 357.

Muraleedharan, P.K., K. Swarupanadan, and V. Anitha. 2009. The conservation of mangrove in Kerala: Economic and ecological Linkages, Kerala ForestResearch Institute, Peechi. pp.8-18.

Naskar, K.R. & R.N. Mandal, (1999). Ecology and Biodiversity of Indian Mangroves. Publisher-Milton book Company, Dehradun, (India), 1: 3-348.

Rambok, E., S. Gandaseca, O.H. Ahmed and N.M.A. Majid, 2010. Comparison of selected soil chemical properties of two different mangrove forests in Sarawak. Am. J. Environ. Sci., 6: 438-441.

Sah, K.D., Sahoo, A.K., Gupta, S.K. and Banerjee, S.K.1989. Mangrove vegetations of Sunderbans and their effect on the physico- chemical and nutrient status of the soils. Indian Natn. Sci. Acad. B.55:125-132.

Snedaker, S.C., (1987). Mangrove forests of South America: Some traditional uses. Bakawan, 1: 10-12.

Vierheilig, H., Coughlan, A.P. , Wyss, U., and Piche Y., 1998. Ink and vinegar staining technique Sukardjo, 1994;

Walter, H. 1977. Climate. In: Eco-systems of the world: Wet coastal Ecosystems, Vol.1. (ed.) V.J.Chapman, Elsevier, New York. pp.54-66.