Sediment quality evaluation towards developing scientific restoration protocol for mangroves

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The role of mangroves as bio-shields and as critical habitats are being increasingly recognised and proved in the recent years. However, urbanisation and other anthropogenic activities have reduced the mangrove cover of most coastal areas. To overcome this, restoration programs are planned in several areas. Planting of mangrove seedlings without considering the ecological criteria suitable for the biological success of the mangroves, have given poor success rates. Hence the Central Marine Fisheries Research Institute initiated a program on development of scientific protocol for mangrove restoration. The mangrove saplings reared in the nursery developed at Moothakunnam, Ernakulam District during June 2010 (Kripa *et al*., 2011) were ready for transplanting in September 2010. These were transplanted in 13 stations of different sediment quality, as a participatory community programme in Moothakunnam, Sathar Island and Puthuvypu of Ernakulam District. The mangrove species planted were *Rhizophora mucronata* and *Bruguiera gymnorrhiza*.

Among the abiotic characteristics, sediment quality is an important factor in mangrove ecology. Zonation in mangroves, their growth and other biological characters depend to a large extent on the sediment and hydrological condition of the site. In the initial phase, if the site selected for planting the nursery saplings or the propagule, does not meet the required sediment and water characteristics, the growth and survival will be affected. Hence an experiment was conducted to identify the optimal sediment soil parameters for *R. mucronata* and *B. gymnorhiza* which are two important native species of this area.

Soil reaction (pH) influences the chemical transformation of most nutrients and their availability to mangroves. Since mangrove soils are typically waterlogged, and hence anaerobic, microbial decomposition takes place through a series of oxidation-reduction (redox) processes. The redox potential (Eh) is a quantitative measure of reducing power which provides a diagnostic index of the degree of anaerobiosis or anoxia. Anoxic sediments have redox potentials below -0.2 V, while typical oxygenated soils have potential of above +0.3V.

The species composition and growth of mangroves is directly affected by the physical composition of mangrove soils. The proportions of clay, silt and sand, together with the grain size, dictate the permeability (or hydraulic conductivity) of the soil to water, which influences soil salinity and water content. Nutrient status is also affected by the physical composition of the soil, with clayey soils being generally higher in nutrients than sandy soils. Organic matter deposited over time in mangrove soils plays a significant role in supporting growth of plants and animals by providing nutrients.. Soil organic carbon is a well known index of accumulated soil organic matter.

For studying the sediment qualities of different sites where planting was done, sediment samples were collected using PVC corers of 15 cm length and 3 cm diameter, closed with screwing lid for both open ends. These corers were marked for identification of 0-5 cm and 5-10 cm depth. They were inserted into the sediment to a depth of 10 cm after removing the lower cap, where the mangrove saplings were transplanted during low tide, to take duplicate samples of sediment from each location of planting. The samples were transported intact to the laboratory in the corer itself and kept in the refrigerator. The sediment samples were transferred to labeled petridishes the following day. They were measured for pH and Eh in the original moisture holding capacity of the sediment to estimate the soil reaction and the oxidation reduction potential in the field. The air dried soil samples after processing were subjected to analysis on texture (% sand, silt and clay), % organic carbon and salinity. The methodology followed for these analyses are given in Table 1.

Table 1. Methodology used in sediment analysis

Parameter	Method	Reference
pH	pH meter	Boyd and Tucker (1992)
Oxidation-reduction potential	Eh meter	Hesse, (1971)
Salinity	Argentometry	Jackson (1958)
Organic carbon	Walkely and Black method	Jackson (1958)
Sediment texture	International pipette method	FAO (1976)

Soil reaction and oxidation reduction potential

The wet pH values showed a range of moderately acidic to near neutral condition (6.2-6.9) at the top sediment (0-5 cm) in all locations. The dry pH measured with the soil – water (1: 2.5) suspension ranged from 6.2 – 6.6, confirming no chance for extreme acidity of these sediments on drying and exposure. The wet and dry Eh showed the oxidised state of sediment in the top layer in all stations (Fig. 1). Similar trend in sediment pH and Eh was seen in the deeper (5-10 cm) layer also (Fig. 2).

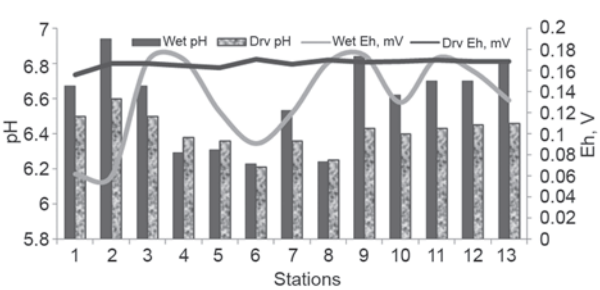

Fig. 1. Soil reaction and oxidation reduction potential in 0-5 cm depth of sediment

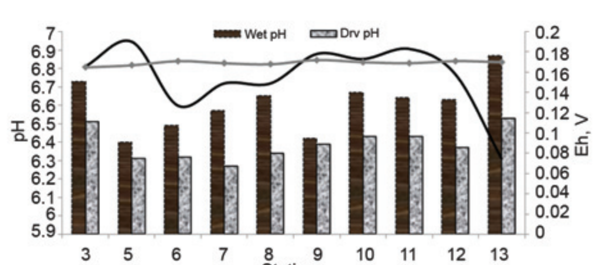

Fig. 2. Soil reaction and oxidation reduction potential in 5-10 cm depth of sediment

Soil texture

The results of estimation and analysis of soil texture are indicated in Fig. 3 and 4. The stations with sediment of at least 11% clay and 5% silt in the top layer (Stations 1, 2 and 13) showed good growth of mangroves. In the lower layer, an increased clay (15%) and silt (7%) levels with muddy texture was observed in station 13. The mangrove survival percentage was also higher in these stations (>90%). Most mangrove soils are generally formed when sediment derived from coasts, river banks, or from upland areas accumulates after being transported down rivers and creeks. Mangrove top soil generally contains clay (fine-grained) whereas the soil beneath the surface is a mixture of silt and clay (known as mud).

Sediment grain size as well as other environmental factors (*e.g.*, salinity, inundation,

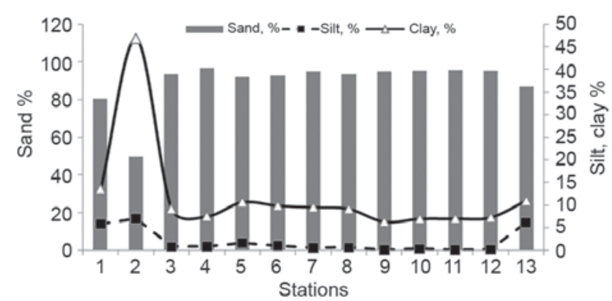

Fig. 3. Soil texture at top 0-5 cm

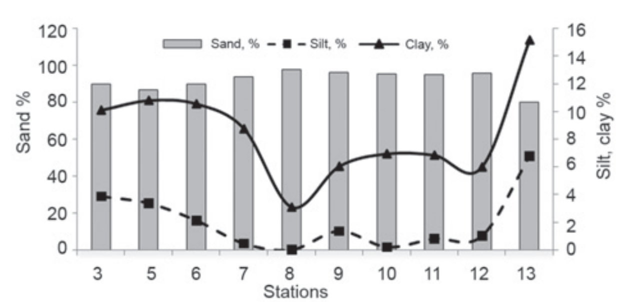

Fig. 4. Soil texture at 5-10 cm

nutrient availability or pollution level) can influence the presence and distribution of floral/faunal species. Macrobenthos for example, is commonly found in fine and medium sandy grains within mangrove habitats. Transportation of coarser or finer grains during tidal movements into these habitats may result in migration of various species of macrobenthos to more suitable areas (Gueirrero *et al*., 1996).

Soil salinity and organic carbon

Soil salinity did not vary considerably among the stations (Fig. 5 and 6). The organic carbon content at 0-5 cm and 5-10 cm is also depicted in Fig. 5 and 6. In top layer (0-5 cm), the organic carbon percentage was substantially more (>1.5) in stations with good growth of mangroves (stations 1, 2 and 13) than in the stations with scarce growth (<0.5). The sediment

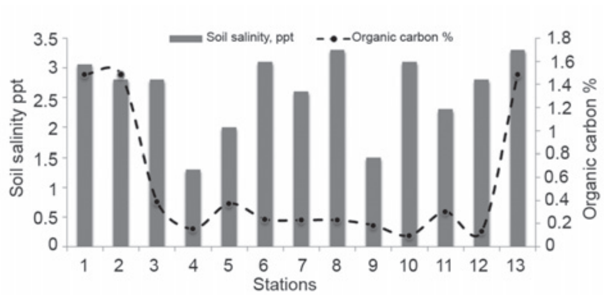

Fig. 5. Salinity and % organic carbon in sediment from different mangrove stations (0-5 cm)

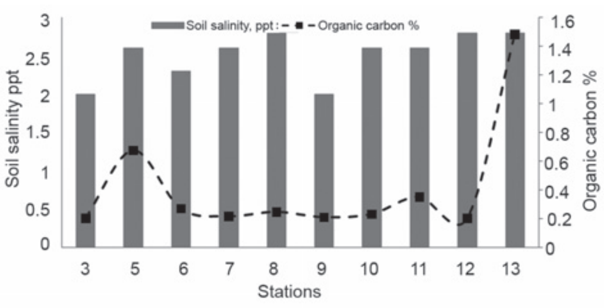

Fig. 6. Salinity and % organic carbon in sediment from different mangrove stations (5-10 cm)

acts as a sink, storing large amounts of organic matter that decomposes at a very slow rate. The source of organic matter found in mangrove sediments might have derived from plants (*e.g.*, litterfall, wood litter) and animal detritus, bacteria or plankton as well as from sewage and agricultural run-off. These nutrients (*i.e.*, organic matter) are then cycled throughout mangrove environments to be used by plants and animals.

The experiment clearly gave an indication that, sediment plays a major role in growth and survival of mangroves transplanted for restoration. It can be inferred that atleast 11% clay and 1.5% organic carbon in sediment are essential for the initial growth and survival of transplanted mangroves. Mangrove soils, are in general, neutral to slightly acidic due to the sulphur-reducing bacteria and the presence of acidic clays. A pH lower than 6 retards growth of mangrove seedlings. For healthy stand of mangrove trees, both in terms of root growth and shoot growth, sites should offer a relatively neutral pH to induce good root as well as shoot growth. In general, mangrove vegetation is more luxuriant at lower salinities. Kathiresan (2002) recorded low levels of available nutrients, high salinity and low microbial load in degraded mangrove soil, as compared to those in the soil of luxuriant mangroves. Therefore, the areas suitable for mangrove restoration should be identified through soil analysis prior to transplanting. Lack of such scientific approach in taking up restoration plans has lead to failure of mangrove restoration attempts. It is essential to follow scientific protocols while implementing mangrove restoration programs.