Vegetation Structure Analysis Of Man-Made Mangroves Along Vellar Estuary

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Abstract: Mangroves tolerate high salinity, high instabilities in wind, tidal extremes, temperature and muddy anaerobic soil with the development of some adaptive morphological characteristics; no studies have been made on the manmade mangrove vegetation characteristics in the Vellar estuary. Leaf area index recorded at all the sites varied significantly and the variations in specific leaf area and leaf area index reflects the non-homogenous canopy structure of all the mangroves. The SLA of all the sites ranged between 57.29 and 81.72 cm^2/g. The lowest values recorded at site 2 and the highest values were recorded at site 1. Based on the observation and analysis of artificial mangroves grown in the vellar estuary, A. marina recorded a higher density of 4.35 and 3.98 hectare at site 3 and 1, followed by A. officinalis (3.52 hectare).

Keywords: Man-made; Mangroves; Vegetation; Vellar; Density; Diversity

1 INTRODUCTION

Mangroves are the salt tolerant woody halophytes associated with tropical environments that are well adapted to the inter-tidal conditions. It grows in different types of soil and therefore their vegetation, structure and species composition may vary considerably at the global, regional and local scales (Vilarrubia, 2000; Sherman et al., 2003). Mangrove forest structure and vegetation have also been varied depending on carbon stocks and organic matter of the mangrove soil (Field et al., 1998; Jennerjahn and Ittekkot, 2002; Chmura et al., 2003; Hossain and Nuruddin, 2106). Numerous factors influence the occurrence of mangroves and their growth viz. geographical latitude, wave action, rainfall, freshwater runoff, aridity, salinity, nutrient inputs and erosion/sedimentation rates (Cintron and Novelli, 1984). The soil in the mangrove forests acts as pool of carbon that is in interface with the atmosphere, loading about three times the biomass which sorts the vegetation and the structure of mangroves (Sa et al., 2001). Earlier studies attempted to relate the salinity with the standing biomass of mangroves and their productivity. It is also evident that under mangrove biomass production and retention are harmfully affected by the high salinity and so it influences the vegetation in the mangrove forest (Lin and Sternberg, 1993; Suwa et al., 2009). Biological group classification in Sunderbans mangroves showed that Avicinnea marina and A. officinalis bear wide range of soil salinity, while Ceriops decandra, Dalbergia spinosa, Derris trifoliate, Aegiceras corniculatum and Excoecaria agallocha found to habitat in the low salinity areas. In addition, the local pattern of tidal flood impacts the soil characteristics that control the species zonation of mangroves. The Vellar estuary is one of the fertile estuary flowing over the southeast cost of India, Parangipettai, Tamilnadu (lat. 11°29'N; long. 79°46'E) and nearly 1.5 km upstream from the mouth at the tidal zone and mangrove plantation covering an area of 10 ha which was established in the northern bank of estuary by Kathiresan (1991).

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In order to protect the coastal area, artificial mangroves have been established as it provides habitat, food and breeding grounds for numerous fauna. It is also been important in the shoreline stabilization, reduction of coastal erosion, storm protection, sediment and nutrient retention, flood and flow control and water quality. Since, mangroves tolerate high salinity, high instabilities in wind, tidal extremes, temperature and muddy anaerobic soil with the development of some adaptive morphological characteristics; no studies have been made on the manmade mangrove vegetation characteristics in the Vellar estuary. Though, a muddy substratum of erratic depth and reliability is the necessary phytogeographical condition for mangrove growth, the present study has been attempted to analyse the vegetation characteristics of man-made mangroves in the vellar estuary.

2. MATERIALS AND METHODS

2.1. Leaf Area Index (LAI) and biomass

Leaf area index of artificial mangroves in the vellar estuary were estimated using AccuPAR Linear PAR/LAI ceptometer (Model PAR-80, Decagon Devices, Inc.). It consists of an integrated microprocessor-driven data logger probe which contains 80 photodiodes. The photodiodes measure photosynthetically active radiation (PAR) in the wavelength range of 400-700 nm. PAR can be expressed in the units of micromoles of photons per meter squared per second ($\mu mol\ m^{-2}\ s^{-1}$). The instruments measures light interception in crop and the forest canopies and calculates LAI by using the following equation:

$$LAI = [(1-1/K)\ fb-1]\ \ln \tau / A(1-0.47\ fb)$$

where K is the extinction coefficient for the canopy, fb is the fraction of incident PAR, τ is the ratio of PAR measured below the canopy to PAR above the canopy and $A = 0.283 + 0.785a - 0.159a^2$ (a is the leaf absorptivity in the PAR band, AccuPAR assumes the value to be 0.9 during the sampling). Indirect leaf area estimation (LAI_e) was recorded at each sites during the study period. One above canopy reading of PAR and 10 below canopy PAR measurements were collected at each sites and the above canopy reading was obtained by assuming that all light received at the canopy was homogenous, whereas, the below canopy readings assumed that the light intercepted by the canopy is affected by the canopy gaps, so that the light distribution was not homogenous. All readings were taken during the day time from 7.00 AM to 2.00 PM only under sunny conditions. LAI_e were then calculated as per the equation mentioned above and the results are interpreted as monthly averaged replicates for each sites and the estimate were made for the year 2015. To validate the LAI_e, direct LAI (LAI_d) were measured at each sites. 10 leaves were selected randomly and the specific leaf area was calculated. It was expressed as the ratio of calculated leaf area to total dry weight of 10 leaves (Bouriaud, 2003). LAI_d was calculated according to Breda (2003);

LAI_d = SLA * Total dry weight of the leaves

2.2. Girth at Breast Height (GBH)

It can be used to calculate the above ground biomass using allometric relationships between the biomass of the individual plant parts and the GBH or DBH. It can be calculated by using the allometric equation proposed by Komiyama et al. (2005) are as follows:

Leaf weight = 0.126p (D^2B) 0.848

Above ground weight = 0.247 (D^2)1.23

Root weight = 0.196p0.899 (D^2)1.11

Tree trunk weight = 0.687 (D^2H) 0.931

Where, D - trunk diameter at breast height 1t 30 cm above grounds in Rhizophoraceae; DB - trunk diameter at the lowest living branch; H- tree height; P - wood density of trunk.

2.3. Plant density and Relative Density

Density of the mangroves is the number of individuals of a species per unit area, of a mangrove stand signifies the numerical strength of a species in the community. The total number of tree species and the number of individual species were counted in each study site (1, 2 & 3). Transects of 10 x 10 were selected in each study site and the plants above one meter height or > 15 cm GBH (Girt at breast height) were considered as trees. From the above, the relative density, frequency, relative frequency, abundance, dominance and relative dominance were calculated as per Cintron and Novelli (1984) and Kathiresan (2007). The density and the relative density can be calculated from the following equations.

$$\text{Density } (Di) = \frac{\text{Total number of individual of the species in all the quadrets}}{\text{Total No. of quadrates studied}}$$

$$\text{Relative Density } (RDi)\ (\%) = \frac{\text{Number of individual of a species x 100}}{\text{otal number of individuals}}$$

3. RESULT

Leaf area index recorded at all the sites varied significantly and the variations in specific leaf area and leaf area index reflects the non-homogenous canopy structure of all the mangroves. The SLA of all the sites ranged between 57.29 and 81.72 cm^2/g. The lowest values recorded at site 2 and the highest values were recorded at site 1. The relationship between the direct (LAI_d) and indirect estimated LAI (LA_e) were determined by the correlation analysis. The coefficient of determination for these variables (R^2 = 0.59-0.98) was found to be higher at all the study sites except site 2 (Table. 1) indicating that the use of LAI_e techniques is adequate for the artificial mangroves. Moreover, all LAI_e measurements during the study period suggest a slight overestimation over LAI_d except for site 2, where a significant underestimation of LAI_d was obtained for other sites. LAI_e measurements for all the study sites ranged from 2.71 to 9.23. As compared to LAI_d, site dependant percent of error was obtained that ranged between 0.28% and 57.61%.Owing to the non-normal distribution of LAI_e detected by a Shapiro-Wilks test (mean: 4.19; $p < 0.001$), a non-parametric tests of Kruskal-Wallis was applied to determine the significant differences of LAI_e between the study sites and study period. It was found that the study sites exhibiting high LAI values (Site 1 and 3) were significantly different from other sites.

***Table.1**. Leaf area index (LAIe and LAId) and Specific leaf area (SLA) values and relationships between LAI indices*

Sites	LAI_e	LAI_d	SLA (cm^2/g)	R^2
Site 1	9.25 9.68 9.19 8.62 9.07	6.19 4.14 6.08 4.92 6.27	81.72	0.98
Site 2	2.15 2.87 3.28 2.55 2.72	3.19 2.77 4.59 6.32 5.18	57.29	0.59
Site 3	7.15 5.29 6.19 5.82 4.91	4.18 2.72 5.79 7.16 5.37	72.3	0.83

Site 2 exhibited the lowest LAI value of 1.8 and was significantly different from other sites. In the present study, the results indicated that LAIe had clear spatial variations in the site 1 and 3 with the highest reported values. The significant difference were not found in these sites, whereas the lowest LAIe values were found in site 2 showed the significant difference (Table 2)

***Table.2**. Mean values of LAIe within each study site (Kruskall-Wallis, H = 73.99)*

Study Sites	Mean	Ranks
Site 1	9.16	168.25b
Site 2	2.71	13.08a
Site 3	5.87	132.5b

(*Different letters indicates significant differences between the study sites)

A Kruskal-Wallis pairwise comparison determined that the changes were recorded within the sampling months was not significant for a determination of LAIe temporal patterns and the significant temporal patterns for LAIe were inferred with ANOVA test (F: 4.83, $p < 0.01$).

3.1. Density and Relative Density

Based on the observation and analysis of artificial mangroves grown in the vellar estuary, A. marina recorded a higher density of 4.35 and 3.98 hectare at site 3 and 1, followed by A. officinalis (3.52 hectare). Rhizophora sp. showed higher density at site 2, with a limited density of A. marina sp. (Table. 3). The relative density of artificial mangroves showed the higher percentage for A. marina for both site 1 and site 3, followed by R. mucronata at site 2

***Table.3**. Vegetation structure of man made mangroves*

Sites	Species	Total No. of Plants	Total No. of quadrates in which sp. occurs	Density (hectare)	Relative Density (%)
Site 1	A. marina	92	3	3.98	1.49
Site 2	R. mucronata	79	4	3.51	0.87
	R. apiculata	45	6	2.45	0.58
	A. marina	62	4	0.83	0.22
Site 3	R. mucronata	15	1	2.30	0.34
	R. apiculata	10	4	3.28	0.53
	A. marina	77	6	4.35	1.76
	A. officinalis	62	4	3.52	1.51

4. DISCUSSION

The amount of intercepted light through the forest canopy can be inferred by measuring the leaf area index, which can be achieved either directly or indirectly for any given forests. The accuracy for the measurement of LAI depends on the errors that can accumulate upon any chosen method. Furthermore, underestimation of LAI can be achieved while using indirect method and hence caution should be needed. It has been reported previously for different mangrove vegetation canopies and has been poorly documented (Breda, 2003). In this study, site 1 and 3 showed the tendency to underestimate LAIe values and the two main causes for underestimations are leaves clumping and contribution of stem and branches. If it was not taken into the consideration, these artificial mangroves can lead to overestimation of the Plant Area Index (PAI). To overcome this conflict, the PLI was taken into consideration and the LAI was calculated with the input of woody to total leaf ratio and foliage clumping effect or validate the indirect LAI estimations with direct LAI estimations. In this study, all indirect data (LAIe) obtained were validated with the direct data (LAId) which was calculated from the SLA measurements. Therefore, Site 1 and 3 found to have highest LAId to LAIe error, indicating that PAI may play a major contribution to the LAIe in these study sites. However, the majority of LAIe reported here tend to slightly overestimate true LAI. This overestimation can be recognized to the input of an incorrect value for the leaf distribution parameter within the ceptometer LAI calculation. Leaf distribution refers to the orientation and distribution of leaves within the canopy and its importance for calculating LAI which is vital, since it evaluates the amount of photosynthetically active radiance that is being intercepted by the forest canopy. The importance of leaf orientation with mangrove canopies was determinant when forming the optimum productivity for mangrove forests (Miller, 1971). He recorded that with steeper inclined leaves, gorss photosynthesis continued to increase upto LAI of 8; but the lower LAI values had occurred with the gross productivity of artificial mangrove leaves which is inclined to be horizontal. The results of the present study showed that LAId and LAIe found to have significant correlations for almost all the sites studied and the percent error ranged between 0.28% and 57.6%, which is within the range as previously reported by Boriaud (2003). Mean LAI ranged between 2.71 and 9.16 being the lowest reported values in site 2 and site 1 the highest one. In general, LAI of mangroves inclined to be relatively low in comparison with other tropical forests and thus the manximum LAI of upto 5 had been reported for the Caribbean mangroves (Pool, 1972). The low LAI estimates for the mangroves could be attributed due to: the interception of effective light in canopy, incapacity of lower mangrove leaves to flourish at low light intensities and the absence of low light adapted plant layers on the site floor (Odum, 1982). Therefore site 1 indicated that the reponse of A. marina to light availability was enhanced by the nutrient availability. In common, the tendency of LAIe found to increase after the maximum or very high peaks of % nitrogen for the senescent leaves, whereas it was highly sensitive to exogenous nutrient input demonstrating that the study sites received constant to very few exogenous nutrients either from pond discharge or freshwater influence. The present study agrees with earlier report of Onuff (1977), who demonstrated that A. marina are capable of assimilating the nitrogen excess results in the production of higher rate of biomass. It was also reported that 33% of nitrogen accumulation in mangrove leaves enhances the nutritive value of leaf litter increasing its consumption. The structural features of the mangrove forest can be assessed by considering the tree height and basal area, so that the artificial mangroves grown can be identified as young or old (Bernini and Rezende, 2011). In this study, the dominant species was found to be A. marina in site 1 and site 3. However, the trees (A. marina) at site 1 measured with low basal area and height, and high stem density. These structural patterns suggests that the artificial mangroves (A. marina) at site 1 are older than the others sites. The stage structure showed the significance difference with the other species in the vellar estuary. Site 1 have the larger tress of A. marina upto 12 m height with high average basal area, whereas in site 2 and 3, A. marina, A. officinalis, R. mucronata and R. apiculata were small (3-9 m) with small basal area indicating that A. marina at site 1 are structurally older than the species in other sites. Rhizophora sp. was found to be restricted to site 2 and site 3, which endowed with low stem density and basal area which grows as an undergrowth of A. marina and A. officinalis. The distribution of artificial mangroves can be correlated with the age of mangroves and the availability of sunlight in the vellar estuary. The availability of sunlight found to be limited at site 1 than the site 2 and 3 due to the dense canopy and therefore showed a scattered distribution of light. Site 2 comprised of R. mucronata, R. apiculata and A. marina which were found to be younger with low basal area and high stem density and hence there may not be enough space and light beneath the trees empowering this species to survive abundantly along the edges of the waterlines along vellar estuary.

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