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Demarcation of sites ideal for mangrove afforestation from Ernakulam, Thrissur and Malappuram districts of Kerala, India

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ABSTRACT

Restoration/ Afforestation of mangroves is yet to make a successful leap in the state of Kerala. The present investigation has been carried out to delineate the sites for species specific mangrove afforestation along the central part of Kerala, include Ernakulam, Thrissur and Malappuram districts based on hydrogeochemical and sedimentological characteristics. The tolerance range of selected mangrove species towards different physico-chemical parameters and textural characterization have been taken in to account for demarcating the most ideal sites for species specific mangrove afforestation. Thus it can be concluded that out of 54 sites studied, 9 sites each for *Avicennia officinalis* and *Sonneratia alba*; 11 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha*; 13 sites for *Rhizophora mucronata* can be treated as the most ideal sites for the afforestation of such species along 3 districts of Kerala.

1. Introduction

Reinstatement programmes of mangroves are often recommended when the ecosystem has been modified to such an extent that it cannot regenerate naturally. Although restoration frequently emphasizes planting as the primary method, mangroves can regenerate naturally if the normal tidal hydrology is restored and the supply of seeds or propagules of mangroves from adjacent stands reinstated. As physico-chemical attributes of both water and sediment are a major entity towards the growth and proliferation of mangroves, their comprehension with respect to the targeted afforestation area is very much important. Assessment of the feasibility of the area prior to planting practices will reduce the risk of adaptability of species to such habitats and thereby cut short financial mobilizations to a greater extent. In this background, the present study has been undertaken for the demarcation of ideal sites for afforestation of selected mangrove species along the inland shoreline environments of central part of Kerala.

2. Materials and Methods

The present investigation was an attempt to delineate sites ideal for species specific mangrove afforestation along the heterogeneous coastal environments of central Kerala. The afforestation possibilities of the mangrove species *Avicennia officinalis, Bruguiera cylindrica*, *Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* were assessed based on their range of tolerance to various hydrogeochemical and sedimentological characteristics (Neethu and Harilal, 2018, 2018a, b, c) and the textural characterization (USDA). Similarly, for assessing the supportive nature of habitats, the physico-chemical characteristics of both water and sediments associated with such habitats were assessed using and compared with those of the tolerance range of selected mangrove species. Altogether 18 habitats each in Ernakulam, Thrissur, and Malappuram districts of Kerala (Figure 1 to 3) were worked out. Details of districts, together with the specification of sites selected are given below:

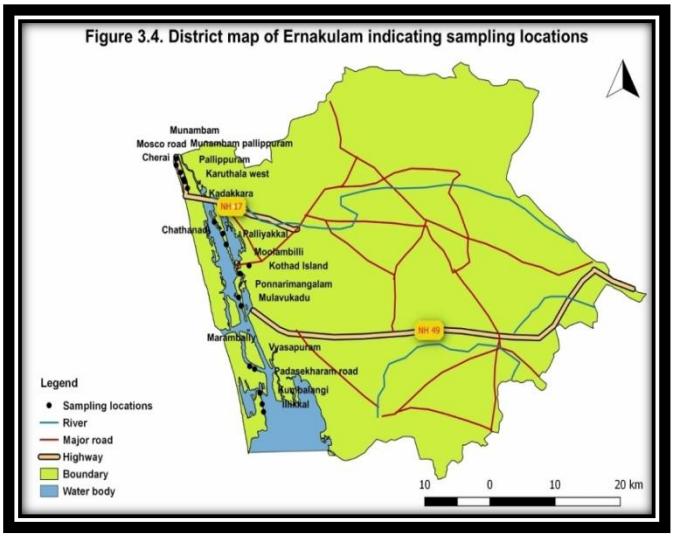

Fig.1. District map of Ernakulam indicating sampling locations

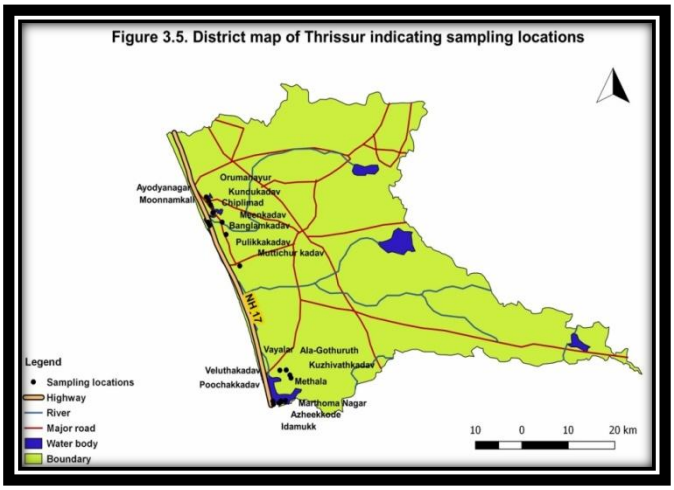

Fig.2. District map of Thrissur indicating sampling locations

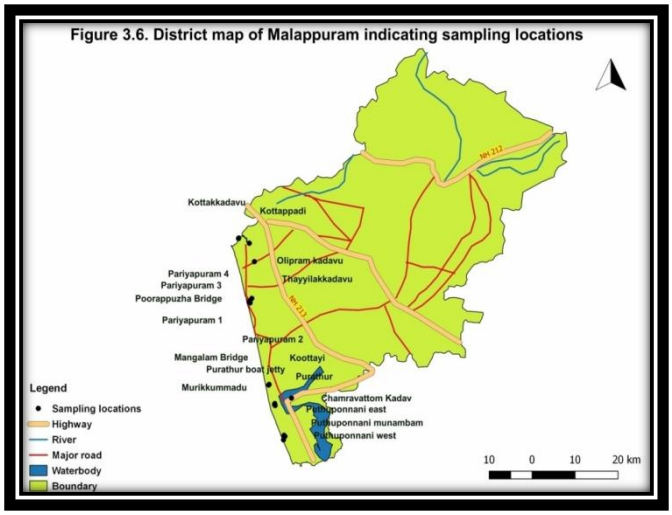

Fig.3. District map of Malappuram indicating sampling locations

Collection of both water and sediment samples were carried out from all the 54 locations falling in 3 districts. Entire collection was carried out during post monsoon season, which is characteristic in having higher concentration of all elements under target. Also this season is reported to be ideal for the introduction of most of the mangrove species. All the collected samples were subjected to physico-chemical analysis either on spot or in the laboratory, following standard methods (APHA, 2005 and Trivedy et al., 1987). The physico chemical parameters analyzed for water samples include pH, turbidity, total solids, total dissolved solids, total suspended solids, salinity, resistivity, conductivity, acidity, alkalinity, total hardness, magnesium, calcium, chloride, sulphate, sodium, total nitrogen, phosphorous and potassium. Similarly, sediment samples were subjected to the analysis of pH, moisture percentage, textural percentage of sand, silt and clay, organic carbon, total nitrogen, phosphorous, potassium and sodium following standard methods (Subramanyam and Sambamurthy, 2002; Trivedy et al., 1987 and Jackson, 1973).

The tolerance range of mangrove species towards different physico-chemical parameters have been taken into account for assessing the most significant growth determinants of each mangrove species. The numbers of sites possessing all these attributes or a share were treated as ideal sites for afforestation of respective mangrove species.

3. Results and Discussion

For assessing the possibilities of mangrove afforestation, physico-chemical analysis of water and sediment samples from 18 sites in Ernakulam district (EKM 1 to EKM 18) has been carried out. The results are depicted in Tables 1 & 2.

Table 1. Results on the physico-chemical characterization of water samples along different locations in Ernakulam district

Sl No:	Parameters	EKM 1	EKM 2	EKM 3	EKM 4	EKM 5	EKM 6	EKM 7	EKM 8	EKM 9	EKM 10	EKM 11	EKM 12	EKM 13	EKM 14	EKM 15	EKM 16	EKM 17	EKM 18
1	pH	7.03	6.69	7.35	7.27	7.27	7.28	7.47	6.98	6.44	6.92	7.25	7.53	7.33	7.95	8.04	7.93	7.71	7.02
2	Turbidity (NTU)	0.1	0.2	0.9	0.5	0.4	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	0.2	0.1
3	T.S (mg/l)	5000	5200	7800	6600	5400	9200	7600	2000	800	4600	5200	4800	6400	16000	17600	19400	24800	21600
4	T.D.S (ppt)	3.936	3.111	6.092	5.146	4.464	7.529	6.531	1.687	0.7788	4.002	4.259	4.645	6.226	12.68	12.67	14.8	16.55	17.56
5	T.S.S (mg/l)	1064	2089	1708	1454	936	1671	1069	313	21.2	598	941	155	174	3320	4930	4600	8250	4040
6	Salinity(ppt)	4.372	3.44	6.981	5.891	5.036	8.868	7.605	1.786	0.798	4.505	4.836	5.234	7.166	15.56	15.57	18.54	22.52	20.91
7	Conductivity (mS)	7.694	6.082	11.89	10.06	8.728	14.72	12.74	3.303	1.523	7.82	8.321	9.098	12.17	24.78	24.75	28.94	32.35	34.33
8	Resistivity(Ω)	127	160.7	82.24	97.07	112.3	66.43	76.55	296	642	124.9	117.4	107.5	80.27	39.45	39.5	33.77	30.19	28.5
9	Acidity (mg/l)	17.6	74.8	13.2	48.4	57.2	11	11	11	35.2	13.2	13.2	8.8	17.6	11	13.2	8.8	8.8	26.4
10	Alkalinity (mg/l)	70	110	90	190	230	80	90	70	70	100	120	100	140	130	160	130	120	160
11	Hardness(mg/l)	80	79	141	116	103	168	142	46	26	87	90	103	134	283	284	332	400	378
12	Calcium (mg/l)	8.01	5.607	12.015	9.612	9.612	11.214	12.015	4.806	4.806	8.01	8.01	8.01	10.413	16.821	20.826	23.229	24.03	25.632
13	Magnesium (mg/l)	14.698	15.852	27.025	22.399	19.234	34.085	27.268	8.278	3.409	16.312	17.043	20.208	26.294	58.675	56.484	66.709	82.778	76.448
14	Chloride(mg/l)	2840	4160.6	7440.8	3479	3053	5310.8	4515.6	1235.4	681.6	2840	4458.8	3223.4	4245.8	10337.6	10408.6	12240.4	12609.6	13376.4
1	Sulphat	117	98	135	120	114	137	135	67.5	30.5	115	119	123	133	151	151	156	157.	157.

5	e(mg/l)																	5	5
16	Sodium (ppt)	3.48	4.21	2.2	0.07	1.96	0.53	0.15	6.97	9.77	2.46	2.51	0.72	0.59	4.41	10.47	12.57	6.57	14.45
17	Potassium (mg/l)	662.00	662.00	656.99	641.983	651.993	651.993	651.993	672.012	681.982	656.997	656.997	656.997	656.997	630.996	597.995	587.986	620.986	575.982
18	Total Phosphorous (mg/l)	8.0	45.5	12.5	109.5	140.0	4.0	6.0	0.03	0.03	9.5	3.5	0.03	12.5	14.5	6.0	4.5	6.0	15.0
19	Total Nitrogen (mg/l)	42	28	35	28	35	21	28	28	28	21	21	21	35	21	28	21	28	21

Table 2. Results on the physico-chemical characterization of sediment samples along different locations in Ernakulam district

Sl No:	Parameters	EKM 1	EKM 2	EKM 3	EKM 4	EKM 5	EKM 6	EKM 7	EKM 8	EKM 9	EKM 10	EKM 11	EKM 12	EKM 13	EKM 14	EKM 15	EKM 16	EKM 17	EKM 18
1	pH	6.44	5.76	5.98	6.4	6.69	8.14	6.95	2.87	2.46	6.05	6.74	6.67	7.58	4.29	8.1	8.03	8.5	8.3
2	Moisture %	5.5	13.2	5.2	21.8	8.6	3.3	5.5	8.3	11.5	5.9	3.2	7.36	5.5	12.3	7.5	9.6	13.6	8.6
3	Sand %	64.3	67.2	68.5	45.9	37.3	86.9	57.6	70.3	70.0	97.5	93.2	78.3	86.2	87.7	94.7	82.1	80.8	92.4
4	Silt %	0.2	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.3	0.1	0.1
5	Clay %	35.5	32.4	31.2	54.0	62.6	13.0	42.3	29.6	29.9	2.3	6.6	21.5	13.7	12.2	5.1	17.6	19.1	7.5
6	Organic carbon (g/kg)	235.8	421.6	1.03	511.1	597.8	70.2	183.3	90.7	170	0.37	0.26	51.2	47.2	66.4	28.0	75.0	88.4	41.5
7	Nitrogen (mg/kg)	2590	2590	1470	2310	2590	840	1540	2310	3290	770	420	2450	1330	770	1470	840	560	420
8	Total Phosphorous (mg/kg)	117.5	136	35	130	151	92.0	58.8	80	64	34	31	98.5	83.5	51.0	36.0	46.5	79.0	31.0
9	Potassium(mg/kg)	60.61	20.02	62.52	27.49	15.01	60.02	47.51	79.99	77.5	69.99	72.49	39.99	45.00	37.5	60.02	32.49	7.51	57.52
10	Sodium (ppt)	0.0075	0.1185	0.17	0.5475	0.6375	0.1125	0.2275	0.055	0.025	0.005	0.015	0.07	0.145	0.6	0.1375	0.4	0.6625	0.3175

The result showed that the ideal sites in Ernakulam district for mangrove introduction were EKM 3 (Padasekharam road), EKM 10 (Chathanad) and EKM 11(Palliyakkal) for Rhizophora mucronata; Kumbalangi (EKM 1) for Avicennia officinalis and Karuthala west (EKM 13) for Bruguiera cylindrica.

Moderately ideal sites towards the afforestation of all the 5 species (Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata and Sonneratia alba) under study were Ponnarimangalam (EKM 6) and Mosco road (EKM 16). Illikkal (EKM 2), Marambally (EKM 5) and Munambam pallippuram (EKM 18) for 4 species (A. officinalis, B. cylindrica, E. agallocha and R. mucronata); Vyasapuram (EKM 4) and Cherai (EKM 15) moderately ideal for the three species (A. officinalis, B. cylindrica and R. mucronata) have also been reported. The other moderately ideal sites were Padasekharam road and Palliyakkal for A. officinalis, B. cylindrica and E. agallocha; Karuthala west and Pallippuram (EKM 14) for A. officinalis and E. agallocha; Mulavukadu (EKM 7) for R. mucronata; Kothad Island (EKM 9) and Munambam (EKM 17) for A. officinalis; Moolambilli (EKM 8) for R. mucronata; Kadakkara (EKM 12) for B. cylindrica; Chathanad (EKM 10) for B. cylindrica and Kumbalangi (EKM 1) for E. agallocha and S. alba.

The results on the physico-chemical characteristics of water / sediment samples from 18 locations of Thrissur district are depicted in Tables 3-4.

Table 3. Results on the physico-chemical characterization of water samples along different locations in Thrissur district

Sl No:	Parameters	TSR 1	TSR 2	TSR 3	TSR 4	TSR 5	TSR 6	TSR 7	TSR 8	TSR 9	TSR 10	TSR 11	TSR 12	TSR 13	TSR 14	TSR 15	TSR 16	TSR 17	TSR 18
1	pH	7.41	7.38	7.02	7.17	7.16	6.62	7.14	7.01	6.93	6.85	7.11	7.13	7.27	7.1	7.7	8.02	7.75	7.61
2	Turbidity (NTU)	1.2	0.1	1.2	0.2	1.2	0.5	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.6	1.2	0.2
3	T.S (mg/l)	15200	16400	16200	4400	15600	7200	8800	4400	1400	600	5000	13400	16600	18400	23400	39200	42600	18400

4	T.D.S (ppt)	9.675	10.48	10.37	2.642	9.105	4.842	5.807	2.844	1.047	0.1607	3.088	8.863	10.41	12.06	14.87	25.4	25.59	12.49
5	T.S.S (mg/l)	5525	5920	5830	1758	6495	2358	2993	1556	353	439.3	1912	4537	6190	6340	8530	13800	17010	5910
6	Salinity(ppt)	11.68	12.74	12.63	2.875	10.93	5.508	6.684	3.1	1.08	0.1576	3.389	10.64	12.63	14.83	18.72	33.85	34.13	15.37
7	Conductivity (mS)	18.92	20.52	20.27	5.164	17.8	9.471	11.36	5.554	2.046	0.3143	6.042	17.32	20.37	23.62	29.07	49.68	50.03	24.41
8	Resistivity (Ω)	51.74	47.72	48.26	189.1	55.01	103.4	86.1	176.1	478	3105	161.9	56.29	47.94	41.46	33.58	19.68	19.55	40.06
9	Acidity (mg/l)	8.8	22	17.6	28.6	17.6	41.8	17.6	17.6	13.2	17.6	8.8	17.6	13.2	13.2	13.2	15.4	22	8.8
10	Alkalinity (mg/l)	160	180	150	180	170	120	140	130	115	50	90	100	120	130	120	200	190	130
11	Hardness (mg/l)	215	233	230	70	216	102	130	72	28	14	70	196	227	268	336	580	620	282
12	Calcium (mg/l)	15.219	16.821	15.219	7.209	16.02	9.612	10.413	7.209	4.005	4.806	7.209	14.418	16.02	20.025	23.229	40.851	40.851	19.224
13	Magnesium (mg/l)	43.093	46.502	46.745	12.66	42.85	18.99	25.32	13.147	4.382	0.487	12.66	38.954	45.528	53.075	67.683	116.376	126.115	56.971
14	Chloride (mg/l)	6816	7369.8	5949.8	1917	6432.6	3464.8	4451.7	2030.6	781	355	2300.4	6390	9230	8662	10437	17508.6	17068.4	11005
15	Sulphate (mg/l)	155.5	151	161	93	164	130	138	103	44	18.5	109	149	158	163	149	156	145	155
16	Sodium (ppt)	34.1	26.05	29.3	46.35	32.35	41.85	34.6	45.35	50.35	52.6	45.6	30.05	26.4	28.55	14.2	5.65	6.95	6.45
17	Potassium (mg/l)	336.00	333.49	336.00	340.99	335.99	338.50	336.00	340.99	340.99	343.50	340.99	336.00	333.49	335.99	331.00	326.00	328.49	328.49
18	Phosphorous(mg/l)	15.5	27.5	24.0	34.0	82.5	31.5	21.5	4.5	3.5	3.5	0.5	13.5	12.5	7.5	3.5	25.7	20.5	5.0
19	Total Nitrogen (mg/l)	28	28	28	21	35	35	35	42	35	28	28	42	35	35	49	35	35	35

Table 4. Results on the physico-chemical characterization of sediment samples along different locations in Thrissur district

Sl No:	Parameters	TSR 1	TSR 2	TSR 3	TSR 4	TSR 5	TSR 6	TSR 7	TSR 8	TSR 9	TSR 10	TSR 11	TSR 12	TSR 13	TSR 14	TSR 15	TSR 16	TSR 17	TSR 18
1	pH	8.51	7.32	7.76	7.44	7.76	6.67	5.54	7.45	5.76	5.57	7.62	7.72	6.76	6.58	5.66	6.57	8.16	5.26
2	Moisture %	6.3	8.2	9.2	7.35	5.32	8.6	4.58	6.28	12.4	9.6	5.6	7.1	6.8	9.12	6.35	8.5	7.25	5.5
3	Sand %	97.2	89.1	81.4	89.0	76.7	69.8	92.3	94.3	81.1	85.1	87.8	78.7	57.5	80.0	75.1	95.8	81.8	59.2
4	Silt %	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
5	Clay %	2.7	10.8	18.5	10.9	23.2	30.0	7.4	5.6	18.5	14.8	12.1	21.2	42.4	19.9	24.7	4.0	18.1	40.7
6	Organic carbon (g/kg)	9.4	4.4	20.2	12.5	7.1	18.3	9.8	5.1	28.7	14.8	8.8	13.0	41.8	11.1	16.4	4.4	9.0	28.6
7	Nitrogen (mg/kg)	560	1120	1330	630	490	1260	770	420	1330	910	700	910	1120	770	840	560	630	1260
8	Phosphorous (mg/kg)	46.5	42.0	78.5	67.5	53.5	85.0	83.5	14.5	52.5	46.5	75.2	46.0	80.0	55.0	40.0	80.0	54.5	40.0
9	Potassium(mg/kg)	5.01	2.50	22.48	5.01	39.99	22.48	12.51	57.52	12.51	2.50	5.01	27.49	2.50	32.49	34.99	34.99	20.02	24.99
10	Sodium (ppt)	0.415	0.36	0.275	0.21	0.3975	0.255	0.365	0.25	0.355	0.3025	0.31	0.2	0.5275	0.575	0.44	0.94	0.69	0.745

Kuzhivathkadav (TSR 6), Vayalar (TSR 7) and Ala-Gothuruth (TSR 8) of Thrissur district were noted to be perfectly ideal sites for the afforestation of Rhizophora mucronata. Azheekkode and Methala were the ideal sites for Bruguiera cylindrica and Excoecaria agallocha. Marthoma Nagar was the ideal site for Avicennia officinalis, E. agallocha, R. mucronata and Sonneratia alba. Kuzhivathkadav and Vayalar were the ideal sites for E. agallocha. Ala-Gothuruth

and Banglamkadav were ideal for B. cylindrica. Veluthakadav was ideal for A. officinalis, B. cylindrica and R. mucronata. Muttichur kadav, Ayodyanagar and Moonnamkall were ideal for R. mucronata whereas, Kundukadav was ideal for both A. officinalis and R. mucronata.

The moderately ideal sites for afforestation were Kuzhivathkadav (TSR 6), Vayalar (TSR 7) and Chiplimad (TSR 16) for A. officinalis and B. cylindrica; Poochakkadav (TSR 1) for B. cylindrica, E. agallocha and R. mucronata; Azheekkode (TSR 2) and Methala (TSR 4) for A. officinalis and R. mucronata; Marthoma Nagar (TSR 3) for B. cylindrica; Idamukk (TSR 5) for B. cylindrica, E. agallocha, R. mucronata and S. alba; Ala-Gothuruth (TSR 8) for A. officinalis and E. agallocha; Veluthakadav (TSR 9) and Kundukadav (TSR 14) for E. agallocha and S. alba; Muttichur kadav (TSR 10) for A. officinalis, B. cylindrica, E. agallocha and S. alba; Meenkadav (TSR 11) for A. officinalis, B. cylindrica, E. agallocha and R. mucronata; Orumanayur (TSR 12) for A. officinalis, R. mucronata and S. alba; Ayodyanagar (TSR 13) for E. agallocha; Moonnamkall (TSR 15) for A. officinalis, E. agallocha and S. alba; Banglamkadav (TSR 17) for A. officinalis and S. alba and Pulikkakadav (TSR 18) for A. officinalis, E. agallocha and R. mucronata.

The physico-chemical characteristics of water and sediment samples worked out from Malappuram district are depicted in Tables 5 – 6.

Table 5. Results on the physico-chemical characterization of water samples along different locations in Malappuram district

Sl No:	Parameters	MPM 1	MPM 2	MPM 3	MPM 4	MPM 5	MPM 6	MPM 7	MPM 8	MPM 9	MPM 10	MPM 11	MPM 12	MPM 13	MPM 14	MPM 15	MPM 16	MPM 17	MPM 18
1	pH	7.94	7.91	7.83	7.84	7.58	7.4	7.61	8	7.96	7.42	7.73	7.51	7.91	8	7.14	7.42	7.81	7.78
2	Turbidity (NTU)	0.1	0	1	0	0.1	1.1	31.4	37	34.8	13.3	2.4	0.1	7	3.2	0.4	1	1.6	2
3	T.S (mg/l)	41800	42000	42000	41800	42400	36800	37600	42400	43400	41200	9800	43000	45600	44000	40400	42600	43000	45400
4	T.D.S (ppt)	24.62	24.16	24.86	23.91	24.18	20.86	21.54	24.22	24.15	23.67	5.724	24.54	25.05	24.98	22.83	24.64	25.48	25.29
5	T.S.S (mg/l)	17180	17840	17140	17890	18220	15940	16060	18180	19250	17530	4076	18460	20550	19020	17570	17960	17520	20110
6	Salinity(ppt)	32.72	31.78	32.82	31.34	32.28	27.29	28.07	31.8	32.03	31.12	6.544	32.78	33.48	32.97	30.04	32.76	33.96	34
7	Conductivity(mS)	48.13	47.28	48.61	46.78	47.27	40.73	42.11	47.35	47.2	46.2	11.19	48.05	48.98	48.83	44.64	48.03	49.81	49.43
8	Resistivity (Ω)	20.33	20.66	20.12	20.91	20.67	23.96	23.24	20.64	20.73	21.16	87.35	20.34	19.97	19.99	21.87	20.32	19.64	19.77
9	Acidity (mg/l)	35.2	39.6	39.6	35.2	35.2	30.8	57.2	57.2	39.6	57.2	17.6	35.2	30.8	26.4	35.2	30.8	26.4	26.4
10	Alkalinity (mg/l)	140	130	150	150	150	150	250	170	160	160	110	160	150	150	130	150	150	160
11	Hardness(mg/l)	600	700	602	592	592	518	550	620	390	720	130	392	410	620	356	600	638	630
12	Calcium(mg/l)	38.448	40.05	39.249	37.647	36.045	34.443	34.443	37.647	40.857	39.249	11.214	42.453	39.249	40.851	34.443	36.846	40.05	43.25
13	Magnesium(mg/l)	122.706	146.079	122.706	121.246	122.22	105.177	112.968	128.063	70.118	151.435	24.883	69.631	75.961	126.115	65.736	123.68	130.984	127.08
14	Chloride(mg/l)	14200	19738	14200	17750	19312	17040	18034	19738	20945	19028	5325	13348	21016	20590	11644	19525	20164	20590
15	Sulphate(mg/l)	180	167	180	180	160	160	160	158	154	156	130	158	158	156	156	156	154	152
16	Sodium (ppt)	17.4	8.75	8.55	9	14.8	2.3	10.3	11	18.5	7.75	36.35	14	28.05	23.9	8.9	22.65	3.8	22.55
17	Potassium(mg/l)	320.99	323.5017	323.5017	323.507	320.99	328.49	323.50	320.99	318.00	323.50	338.50	320.99	314.00	316.49	323.50	315.50	328.49	316.49
18	Total Phosphorous(mg/l)	0.6	2.0	1.5	1.5	0.03	6.0	49.5	25.0	7.5	58.0	2.0	6.0	0.9	3.5	0.03	0.5	0.45	0.5
19	Total Nitrogen (mg/l)	28	28	28	28	28	28	35	35	28	35	21	35	35	35	28	28	21	35

Table 6. Results on the physico-chemical characterization of sediment samples along different locations in Malappuram district

Sl No:	Parameters	MPM 1	MPM 2	MPM 3	MPM 4	MPM 5	MPM 6	MPM 7	MPM 8	MPM 9	MPM 10	MPM 11	MPM 12	MPM 13	MPM 14	MPM 15	MPM 16	MPM 17	MPM 18
1	pH	6.16	5.3	5.1	4.9	6.13	6.46	6.78	6.45	6.34	6.83	6.76	5.26	6.4	6.33	6.69	6.92	7.73	7.21
2	Moisture %	5.26	6.12	9.5	12.5	8.5	6.5	6.84	9.8	8.7	12.58	7.4	11.1	7.8	6.85	12.5	8.5	7.6	9.6
3	Sand %	78.3	89.2	64.3	46.3	81.7	81.7	80.4	58.4	87.4	70.4	89.2	87.8	88.8	89.8	73.9	72.8	61.0	79.3
4	Silt %	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2
5	Clay %	21.6	10.7	35.6	53.6	18.1	18.1	19.4	41.5	12.5	29.4	10.6	12.1	11.1	10.1	26.0	27.0	38.9	20.5
6	Organic carbon (g/kg)	14.77	19.03	11.15	39.8	9.2	18.89	16.59	17.49	11.58	37.11	2.32	36.17	21.0	5.66	17.28	42.86	16.39	26.06
7	Nitrogen (mg/kg)	560	1120	1540	1260	700	1050	700	700	490	840	350	560	560	420	630	1750	1680	1190
8	Total Phosphorous (mg/kg)	13.5	28.0	62.0	23.5	29.0	59.5	62.5	93.0	50.5	62.5	76.5	0.495	66.0	86.0	61.0	45.5	45.5	60.0
9	Potassium (mg/kg)	2.5	5.00	2.5	39.99	0	20.02	24.99	22.48	5.01	37.5	0	12.51	10.01	0	17.52	39.99	52.51	50.01
10	Sodium (ppt)	0.115	0.0325	0.0175	0.235	0.068	0.0725	0.04	0.0075	0.078	0.0825	0.065	0.105	0.008	0.075	0.06	0.38	0.4375	0.3675

In Malappuram district, Kottappadi (MPM 18) is the most ideal site for afforestation of all the five mangrove species. Mangalam Bridge side (MPM 6), Purathur boat jetty (MPM 10) and Kottakkadavu (MPM 17) were ideal for Rhizophora mucronata whereas, Koottayi (MPM 7) and Murikkummadu (MPM 9) were ideal for Bruguiera cylindrica. Puthuponnani east (MPM 12) was ideal for B. cylindrica and Excoecaria agallocha whereas, Pariyapuram 2 (MPM 2) was ideal for E. agallocha (Plate 3.6).

Poorappuzha Bridge side was (MPM 5) noted to be moderately ideal for all the five species. Other moderately ideal afforestation sites were Olipram kadavu (MPM 16) for A. officinalis, B. cylindrica ,S. alba, E. agallocha and R. mucronata; Purathur boat jetty (MPM 10), Chamravattom Kadav (MPM 11) and Kottakkadavu (MPM 17) for A. officinalis, B. cylindrica and E. agallocha; Pariyapuram 3 (MPM 3) , Pariyapuram 4 (MPM 4) and Puthuponnani west (MPM 13) for E. agallocha and R. mucronata; Purathur (MPM 8) for B. cylindrica; Thayyilakkadavu (MPM 15) for A. officinalis; Pariyapuram 1 (MPM 1) and Puthuponnani east (MPM 12) for S. alba and A. officinalis; Murikkummadu (MPM 9) and Puthuponnani Munambam (MPM 14) for E. agallocha; Pariyapuram 2 (MPM 2) for B. cylindrica and R. mucronata; Mangalam bridge (MPM 6) for A. officinalis, E. agallocha and S. alba and Koottayi (MPM 7) for A. officinalis and S. alba.

From all the results, it can be concluded that, three sites in Thrissur district and one site each in Ernakulam and Malappuram districts were ideal for the afforestation of A. officinalis. B. cylindrica was noticed to be ideal for afforestation of five sites in Thrissur, four sites in Malappuram, and one site in Ernakulam district. The species Excoecaria agallocha was found to be ideal for afforestation in five sites in Thrissur and three sites in Malappuram districts. With respect to Rhizophora mucronata, six sites in Thrissur, five sites in Ernakulam and four sites in Malappuram, was found ideal for afforestation. Three sites in Thrissur district were found to be perfectly ideal for the introduction of R. mucronata. The species Sonneratia alba was found to be ideal for afforestation along one site in Thrissur district.

Upon comparing the present result with standard textural class preferred by each mangrove species, the sites ideal for their afforestation have been demarcated (Table 7).

Table 7. Ideal Sites for species specific mangrove afforestation from the district of Ernakulam, Thrissur and Malappuram.

Sl. No:	Ideal Places for Afforestation	District	Mangrove Species
1.	Mosco road	Ernakulam	*Avicennia officinalis* and *Sonneratia alba*
2.	Munambam		
3.	Marthoma Nagar	Thrissur	
4.	Veluthakadav		
5.	Kundukadav		
6.	Banglamkadav		
7.	Poorappuzha Bridge side,	Malappuram	
8.	Mangalam Bridge side		
9.	Koottayi		
10.	Ponnarimangalam	Ernakulam	*Bruguiera cylindrica* and

11.	Karuthala west		*Excoecaria agallocha*
12.	Pallippuram		
13.	Methala	Thrissur	
14.	Muttichur kadav		
15.	Meenkadav		
16.	Pariyapuram 2	Malappuram	
17.	Chamravattom Kadav		
18.	Puthuponnani east		
19.	Puthuponnani west		
20.	Puthuponnani Munambam		
21.	Illikkal	Ernakulam	*Rhizophora mucronata*
22.	Padasekharam road		
23.	Moolambilli		
24.	Kothad Island		
25.	Kadakkara		
26.	Idamukk	Thrissur	
27.	Kuzhivathkadav		
28.	Orumanayur		
29.	Moonnamkall		
30.	Pariyapuram 1	Malappuram	
31.	Thayyilakkadavu		
32.	Olipram kadavu		
33.	Kottappadi		

The results were comparable with that elucidated on the basis of hydrological and sedimentological aspects. All these sites possessed significant share of growth determining attributes of different mangrove species.

Thus it can be concluded that out of 54 sites studied, 2 site for Avicennia officinalis and Sonneratia alba; 3 site each for Bruguiera cylindrica and Excoecaria agallocha; 5 sites for Rhizophora mucronata can be treated as the most ideal sites for the afforestation of such species along Ernakulam district of Kerala. 4 site for Avicennia officinalis and Sonneratia alba; 3 sites each for Bruguiera cylindrica and Excoecaria agallocha; 4 sites for Rhizophora mucronata can be treated as the most ideal sites for the afforestation of such species along Thrissur district of Kerala. In Malappuram district, 3 site for Avicennia officinalis and Sonneratia alba; 5 sites each for Bruguiera cylindrica and Excoecaria agallocha; 4 sites for Rhizophora mucronata can be treated as the most ideal sites for the afforestation of such species.

4. Conclusion

Assessment of the feasibility of an area prior to planting practices will reduce the risk of adaptability of species to such habitats and thereby cut short financial mobilizations to a greater extent. In this background, the present study has been undertaken for the demarcation of ideal sites for afforestation of selected mangrove species along the inland shoreline environments of Kerala.

The afforestation possibilities of mangrove species were assessed based on their range of tolerance to various hydrogeochemical and sedimentological characteristics. Collection of both water and sediment samples were carried out from 54 locations falling in 3 districts of Kerala such as Ernakulam, Thrissur and Malappuram. Entire collection was carried out during post monsoon season, which is characteristic in having higher concentration of all elements under target.

The tolerance range of mangrove species towards different physico-chemical parameters have been taken into account for assessing the most significant growth determinants of each mangrove species. Based on the textural classes of soil/sediment preferred by various mangrove species, attempt has also been carried out to demarcate ideal sites for mangrove afforestation. The results were comparable with that elucidated on the basis of hydrogeochemical and sedimentological aspects.

Thus it can be concluded that out of 54 sites studied, 9 sites each for Avicennia officinalis and Sonneratia alba; 11 sites each for Bruguiera cylindrica and Excoecaria agallocha; 13 sites for Rhizophora mucronata can be treated as the most ideal sites for the afforestation of such species along 3 districts of Kerala.

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