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Considerations on Some Ecological Factors Influencing The Biology of Indian Mangroves.

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The following comments constitute a summary of discussions and exchanges of views, during the National Symposium on Biology, utilization and conservation of mangroves.

Some Ecological Factors Determining Forest Ecosystems

In the absence of human direct or indirect impacts, determining ecological parameters are mainly constituted by bioclimatic criteria and edaphic factors. This general assumption is valid for terrestrial as well as for estuarine ecosystems. This means that whenever we try to establish ecological relationships, we try for instance to quantify the values of environmental parameters which are responsible for the presence or the absence of a given biological system.

At a global scale the distribution of terrestrial ecosystems follows a general ecological framework which seems to remain applicable to all major tropical vegetation types. For instance :

- mean annual rainfall > 1500 mm
- mean temperature of the coldest month > 20°C
- average length of the dry season < 3 continuous dry months;

these criteria favour the development of lowland moist dense evergreen forests in areas devoid of anthropic disturbances. If we consider another example i. e. :

- mean annual rainfall > 800 mm
- mean temperature of the coldest month > 20°C
- average length of the dry season 5-9 continuous dry months;

the corresponding major forest type, is generally a dry deciduous forest, in lowland areas. A comprehensive account on the phytogeography of the Indian subcontinent has been published by Meher-Homji (1973.)

A similar framework can be (and has been) established for all existing dense tropical woody types of vegetation, at a worldwide scale (Blasco and Legris, 1985). However such a framework does not exist for edaphic types such as swamp forests, heath forests or mangroves. Mangroves seem to remain almost constant all over the world in terms of phenology (evergreen) and morphological or anatomical and physiological adaptative characters, even under very distinct ecological localities.

If we refer to the following forest map of India (Fig. 1), it is quite obvious that major terrestrial ecosystems are classified and characterized, taking into account : i) their broad ecological criteria (moist, dry etc...) and ii) their main physiognomic properties (dense, open etc...).

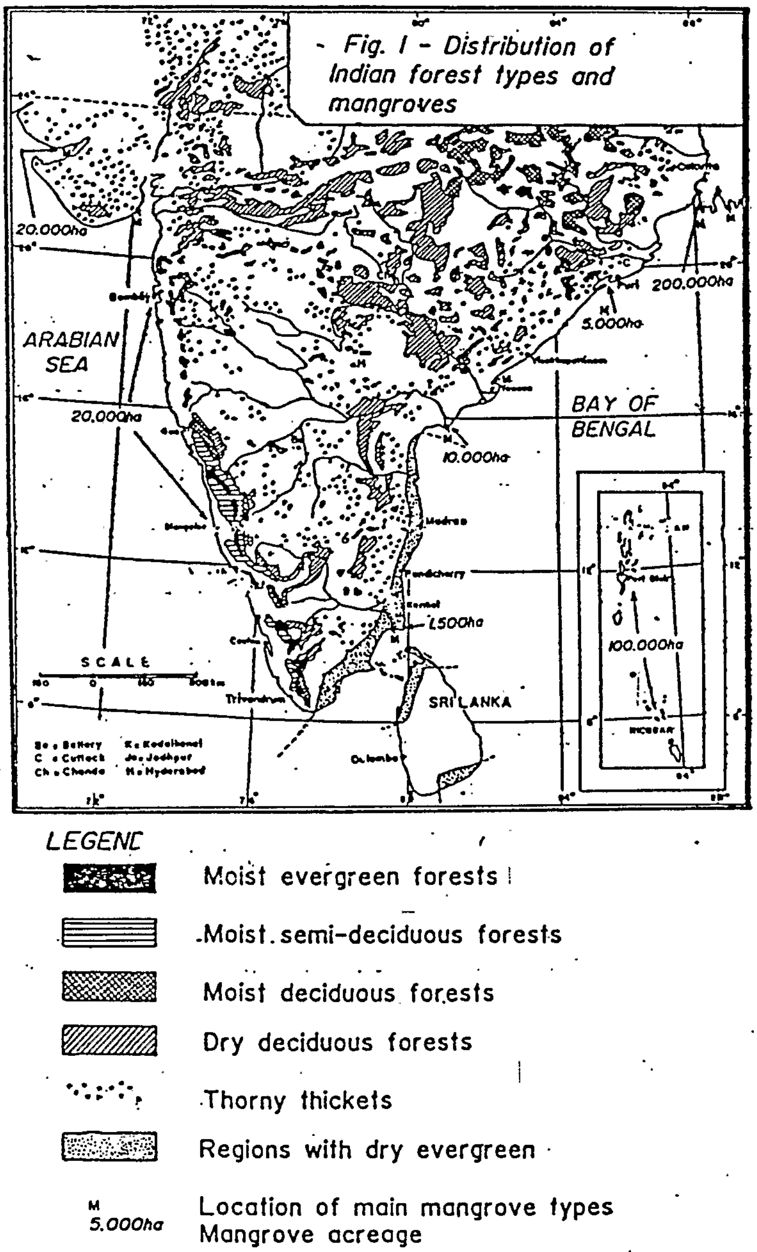

Fig. I - Distribution of Indian forest types and mangroves

Regarding mangrove ecosystems distributed along the Indian coasts, none of these criteria are taken into account, although they are tremendous ecological and biological differences between the mangroves of west Bengal (Curtis, 1933) those of the Cauvery (Kerrest, 1980) and those of the Gulf of Kutch (Blasco, 1977).

Among main scientific gaps in our knowledge we should recognize that we do not have a clear perception neither of the impact of climatic factors on mangrove species in India or the role of soil properties on the distribution and productivity of these species.

Apparently the fundamental impacts of climatic factors on mangrove stands could be summarized as follows :

rainfalls in catchment areas are more determining than local rainfalls;

- rainfall interference are mainly noticed through the control of local salinities which take into account the rate of evaporation which also includes thermal conditions;
- when the salinity increases the number of mangrove woody species decreases;
- when mean annual thermic amplitude increases, the number of mangrove species decreases;
- mangrove standing phytomass decreases with increasing salinity;

The following table gives a synoptic view of the role of climatic factors on the mangroves of this part of the world.

Some Soil Properties in Pichavaram Mangroves (South India)

Until now it remains extremely difficult to establish simple and comprehensive relationships between mangrove plants distribution or productivity and local soil properties. The following soil studies have been carried out in South Eastern India (Cauvery delta) where the mangroves of Pichavaram are amongst the best known in India thanks to the works carried out at Annamalai University (Parangipettai, Tamil Nadu) and at the French Institute, in Pondicherry.

The aim of the following results and comments is mainly to try to characterize each major mangrove zone, through its soils properties (see map 2). They also give an idea of the complexity of mangrove ecology even if we consider only its edaphic component.

Soils morphology

Five Profiles belonging to a sequence that runs from *Rhizophora* mangroves to the inland bare flats were observed and sampled.

Table 1. Bioclimatic conditions and mangrove types

Coastal Zone	Nb of Spec.	Mean ann. rainfall (R)	Nb dry months	Thermic ampl. t	rd	mangroves (climax)	References
Ganges	15–20	1600 mm	5–6	11°C	84	D. T.	Blasco (1975)
Bombay	12–15	1800 mm	7–8	7°C	75	D. T.	Blasco (1975)
Kathiawar	10	470 mm	9	12°C	20	D. L.	Blasco (1977)
Pakistan	8	195 mm	10–11	11°C	8–12	D. v. l.	Saifullah (1982)
Persian Gulf	1	<100 mm	12	13°C	<5	d. sc.	Zahran (1982)

t = Mean annual thermic amplitude
rd = Annual number of rainy day
Mangroves : D. = dense; T. = tall; L. = low; v. l. = very low;
d. = dwarf; sc. = scattered.

Table 2. Analytical data of phreatic waters (mmoles/l)

Water table	pH	Na^+	K^+	Mg^{++}	Ca^{++}	Σ Cations	Alkalinity	Cl^-	$SO_4^{=}$	Σ Anions	H_4SiO_4	C. E. mS/cm
1	8.1	535	10	68.75	4.01	690.5	20	644	16.5	697	0.242	69.7
2	7.9	667	14.4	91.25	12.3	891.5	10.4	830	32.1	904.6	0.118	90.46
3	7.4	1620	24.4	205	31	2116.8	7.44	1960	78.7	2124.9	0.073	212.5
4	7.3	1620	31.5	225	29.1	2154.8	2.35	1980	95	2172.4	0.122	217.2

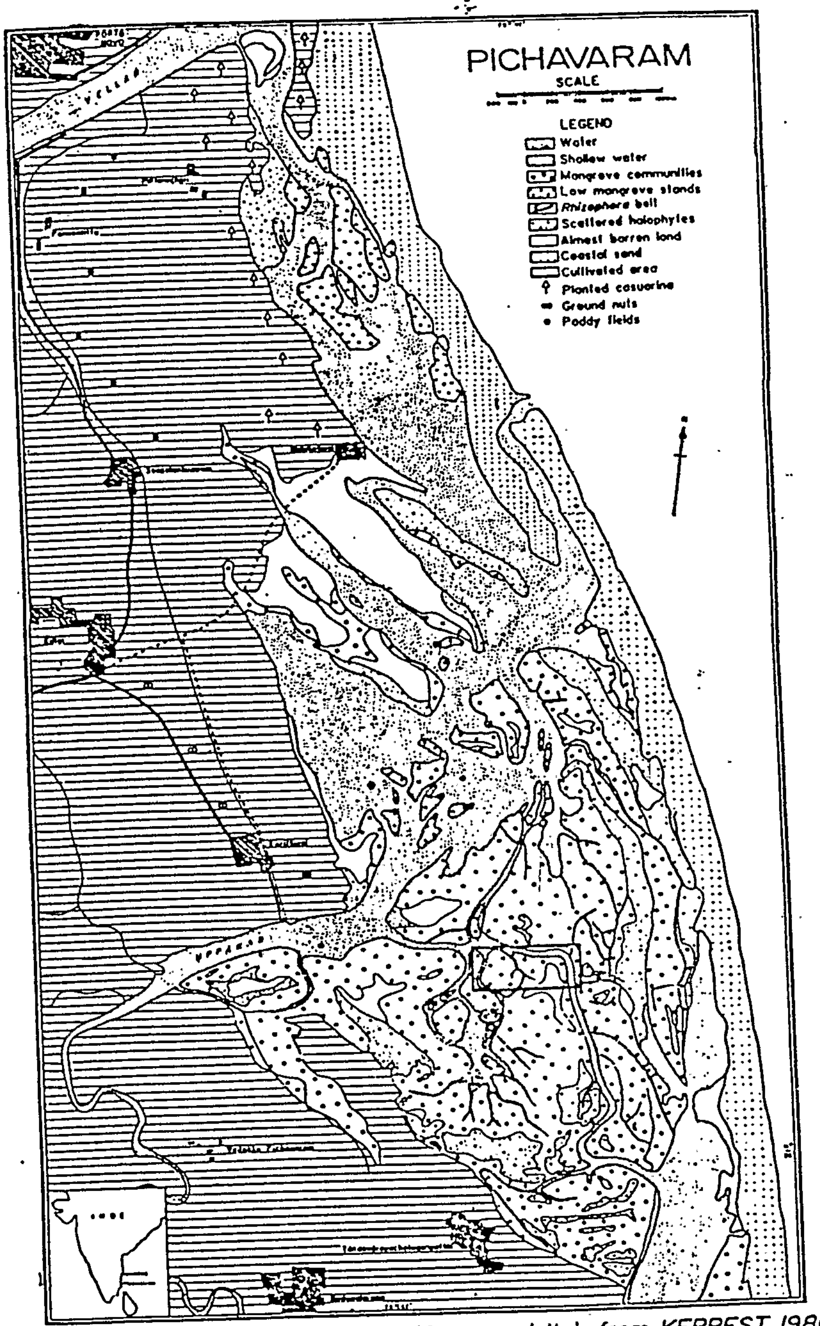

Fig. 2 - Mangroves of Pichavaram (Cauvery delta), from KERREST 1980
Location of study area ▭

CMP 1 : under an assemblage of *Rhizophora sp.* and some *Avicennia.*

0–30 cm : dark grey–blue, clayey, highly solid, very fibrous, many big roots.

30–60 cm : grey–blue, clayey, butter–like consistency, many roots.

60–90– cm : clayey–sand, highly solid, matted red fibres.

CMP 2 : under very mixed vegetation consisting of *Avicennia marina, A. officinalis, Bruguiera, Ceriops, Lumnitzera, Suaeda.*

0–45 cm : highly oxidized horizon, grey–blue with red and brown mottles, clayey, dry, compact.

55–90 cm : dark grey–blue, clayey, highly consistent, fibrous water table at depth of 70 cm.

CMP 3 : under a grass cover of *Suaeda* and *Sesuvium,* with a few *Avicennia marina* and *Lumnitzera.* Powdery crust on surface.

0–25 cm : grey–brown with brown and rust–coloured mottles and streaks, clayey, dry, very hard.

25–50 cm : grey with numerous rust–coloured mottles, very hard, dry, compact, water table absent at this level.

CMP 4 : bare flat. Surface "carpet" of salt, very dry with a few needles of *Gypsum.*

0–40 cm : grey, clayey, very hard.

40–90 cm : "chestnut mash" colour, clayey, semi–developed consistency, water table at 80 cm.

CMP 5 : bare flat with many dead trunks of *Avicennia.* Surface salt carpet thicker than in CMP 4, more humid profile, clayey, with red and brown mottles, fibrous, water table at 50 cm.

To summarize, all the profiles are markedly dry and highly firm, despite the fact that the area was watered by the rainfalls, the great depth to the water table must also be noted.

Chemical characteristics

The most conspicuous feature concerning these soils is their high salinity. The results (Tables 2 and 3) show that the four water table samples characterized by a very high conductivity.

All water tables have a salinity higher than that of sea water (Table 2).

Table 3. Analytical data of soils (pH, C, S, Salinity)

Salinity : extract 1/2

Samples	Depth cm	pH	S ‰	C ‰	C. E. mS/cm	pH	Ca--	Mg	K	Na	Cl	SO_4	HCO_3
							en meq/100 g dry soil						
CMP 11	0-30	7.2	8.75	37.2	32.7	7.3	5.02	15	1.8	55	60.8	13.52	0.95
CMP 12	30-60	7.9	21.2	36.5	28.1	7.6	2.5	11.6	1.48	51.2	55.2	6.4	0.72
CMP 13	60-90	8.4	8.2	16.4	19.8	7.7	1.04	5.88	1.04	36	37.2	3.28	0.57
CMP 21	0-20	7.5	2.73	25.3	39.8	6.7	5.66	16.2	1 64	71.5	81.6	9.04	0.42
CMP 22	20-40	6.1	8.94	88.8	37,7	5.7	5.84	16.2	1.6	67	73.8	14.76	0.07
CMP 23	40-60	6.5	21.9	42.6	35 24	7	5.24	14.2	1.96	54	57 8	14.13	0.23
CMP 24	60-80	7.4	17.3	27.6	25.16	7.5	4.52	10.56	1.64	44.4	45.7	11.5	0.68
CMP 30	Croute	6.9	4.2	42 6	64.5	6.7	19.4	43.6	1.4	7.45	115.2	18.3	0.72
CMP 31	0-20	8	1.78	9.6	25.2	7.8	3.26	10.24	0.8	45.6	49.5	5.94	0.92
CMP 32	30-50	8.4	1.4	7.8	21.9	7.7	2.84	8.28	0.76	37	40.8	5 38	0.53
CMP 33	50-70	8.2	1.51	6	26.1	7.4	2.84	8 48	0.88	45.8	50.3	5.94	
CMP 40	Croute	7.9	3.06	12.8	83.9	7.3	10 5	32	0.68	130.5	155.5	14.9	0.47
CMP 41	40-50		2.36	9.58	45	6.3	4.4	17.4	1.15	85.5	94.5	11.4	0.17
CMP 42	60-70		2.3	13.6	56.5	5.8	6.3	25	1.35	107.5	119.8	16.8	0.07
CMP 43	80-90		2.97		65	5.9	7.6	29	1.95	124.5	144.5	17.3	0.11
CMP 50	Croute	7.6	5.85	27.1	140.	7.2	19.5	74 6	3.1	199.5	259.5	32.8	0.54
CMP 51	20-40	7.7	3.2	14.9	65.2	7	4.55	25.2	1 75	99	111.5	13.7	0.27
CMP 52	40-60	7.6	3 5	18.6	63.2	6	7.35	31	2,15	127	146 5	16.2	0.07
CMP 53	60-80	7.1	6.5	35	72.6	5.7	9.5	38.4	3.2	140	168.5	20.9	0.1
CMP 60	Croute	6	26.9	57 3	185.5	5.3	20.5	97.2	7.3	280	339.5	55.2	0.07

There is a sudden change in the salinity of water tables of bare flats which is more than twice that of the water table of mangrove swamps.

Soil salinity determined on a 0.5 aqueous extract (which is very close to the extract at saturation) shows that all profiles are highly saline and that in general, the salinity of surface horizons is higher than that of deeper horizons. Moreover, the salinity of surface crust samples from bare flats attains values higher than 100 mS/cm.

Both water tables and soils are characterized essentially by a sodium chloride type of salinity, anions being represented by chlorides and sulphates and the cations by Na^+ and Mg^+. Moreover, both sulphur and carbon content are, on the whole, relatively low compared to other tropical mangrove soils.

From the geochemical point of view (Table 4) soils are clayey and relatively rich in alkaline and earth-alkaline elements and iron, compared to other mangrove soils, especially with reference to calcium and magnesium which are poorly represented in most of the other mangrove soils (Senegal, Gabon, Sierra Leone, Indonesia, Brazil).

Mineralogical peculiarities

X ray diffractograms of disoriented powdered samples show that all samples contain quartz, halite and feldspars with, in addition, gypsum and opal-cristobalites in certain cases. The salty surface crusts (CMP 40, 50, 60) consist essentially of halite and gypsum. The presence of opal-cristobalites is doubtlessly due to the supply of silica by diatoms as has been observed in the mangroves of Senegal following prolonged periods of severe drought (Marius, 1982).

The clay fraction consists mainly of smectite associated with a bit of kaolinite (Fig. 3). This is also a rather distinct feature found in Pichavaram soils, most of the mangrove being generally largely dominated by kaolinite. The smectite in these soils originates from the Cauvery drainage basin which is characterized by vertisols derived from basic rocks in the Tiruchirappali region. The abundance of smectite is the main factor responsible for the poor drainage regime of these soils and for the high salt concentration in the water table during the dry season.

Summary and conclusion

These few examples concerning bioclimatic and soils properties in Indian mangroves show the very great complexity of problems related to mangrove ecological processes.

Table 4 - Chemical composition of Pichavaram mangrove soils.

samples	Depth cm	loss at 1000	SiO	Al O	MgO	CaO	Fe O	Mn O	TiO	Na O	K O
CMP 11	0-30	12.32	51.2	16.1	2.79	1.8	8.7	.084	.67	3.52	1.60
CMP 12	30-60	11.18	52.4	16.7	2.58	1.9	8.5	.118	.69	3.30	1.63
CMP 13	60-90	5.77	61.8	15.7	2.00	2.7	6.6	.111	.72	3.37	1.80
CMP 21	0-20	11.02	49.6	18.4	2.86	.5	9.6	.079	.71	3.93	1.53
CMP 22	20-40	12.08	54.4	17.1	2.50	1.4	7.7	.047	.72	3.53	1.59
CMP 23	40-60	10.55	54.5	16.6	2.26	1.7	8.0	.069	.71	3.33	1.73
CMP 24	60-80	6.77	56.4	14.7	1.98	2.6	6.7	.072	.69	3.46	1.81
CMP 30	Croûte	13.03	51.3	15.9	3.07	1.7	8.5	.075	.69	3.65	1.75
CMP 31	0-20	6.47	59.3	15.9	2.27	2.2	7.4	.079	.71	3.39	1.81
CMP 32	30-50	5.92	61.8	14.8	2.08	2.8	6.8	.084	.72	3.58	1.79
CMP 33	50-70	5.81	60.1	16.3	1.99	2.4	7.8	.210	.74	3.50	1.78
CMP 40	Moquette	12.05	48.1	15.9	3.86	1.0	8.6	.113	.70	3.44	1.87
CMP 42	40-50	10.85	50.8	18.1	3.10	1.0	9.8	.179	.72	4.53	1.63
CMP 43	60-70	10.20	50.4	16.8	2.87	1.2	9.1	.054	.72	4.38	1.61
CMP 44	80-90	11.48	49.9	18.1	3.04	.7	9.5	.046	.70	4.67	1.58
CMP 50	Moquette	16.80	40.8	14.5	3.71	.7	8.1	.031	.58	8.52	1.68
CMP 51	30-40	12.34	49.4	18.5	2.91	.6	8.2	.046	.73	4.81	1.59
CMP 52	40-60	13.17	48.0	17.5	2.98	.8	8.3	.039	.67	6.15	1.52
CMP 53	60-80	14.82	46.4	17.6	2.97	.6	7.9	.035	.64	6.30	1.57

(CMP 1 : *Rhizophora* - CMP 2 : *Avicennia marina* - CMP 3 : *Suaeda* + *Sesuvium* - CMP 4 : barren land + *Suaeda* - CMP 5 : barren land).

Fig. 3 - Xray diagram of clay fraction, from two stamples

The mangroves of India constitute an interesting and probably unique case in South East Asia for many reasons which have been recently commented by Untawale (1985). The extent of indian mangroves is about 350,000 hectares, along the 5600 km of coastline. (Indonesia 2,176,000 hectares, Malaysia 650,000 ha, Sri Lanka 3600 ha). The great ecological diversity and economic impacts from the wet tropical mangroves in West Bengal to arid subtropical mangroves in the Gulf of Kutch are observed.

Among interesting edaphic features recorded in this paper, it appears that the mangrove soils on the Eastern coast of India clearly present a lack of potential acidity. The salinity of water tables is surprisingly high.

From the geochemical point of view, mangrove soils in Pichavaram are clayey and relatively rich in alkaline and earth-alkaline elements and iron, compared to other mangrove soils, especially with reference to calcium and magnesium which are poorly represented in most of the other mangrove soils (Senegal, Gabon, Sierra Leone, Indonesia, Brazil).

The extremely high population density is seen, particularly in delta areas where it often exceeds 800 km^2 and goes up to 1500 per $km.^2$

About 25 Indian agencies are at present officially involved in mangrove research and management. A huge amount of scientific literature is now available (600 to 1000 references) from these ecosystems.

We may expect from a better co-ordination of research activities in the country a much better understanding of the respective roles of climatic and edaphic paramaters on the biology of mangroves.

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