

Floristic Composition of the Deltaic Regions of India

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Abstract

The formation of deltas are of common occurrence along the east than the west coast of India. Various abiotic and biotic factors as well as the coastal geomorphology, influence formation of deltaic environment. The cover of salt tolerant flora is of significance in the stabilization of the delta. The root system of pioneer species, hold the sediments and enhances the accretion. The stabilized deltaic regions are further strengthened by climax species of mangroves. The composition and distribution pattern, are normally governed by the salinity gradient. The natural developments ultimately result in the formation of dominant and highly productive mangrove ecosystem in the deltaic regions.

Along the Indian coast, major deltas in Ganges, Mahanadi, Godavari, Krishna, and Cauvery, are situated along the east coast, and the mangrove forests account for about 80% of the total, while on the west coast only 20% mangrove forests are reported. The poor mangrove cover along the west coast is mostly due to the absence of major delta formations. The total mangrove cover in deltaic swamps has been estimated to be approximately 2,56,000 h. The flora of the deltaic regions is comprised of 47 species of mangroves and 37 species of associate angiosperms.

INTRODUCTION

Along the Indian coast, major deltas are confined to the east coast and the estuaries along the west coast are mostly without delta. Estuaries and deltas with coastal plain and shallow seabeds form suitable environments for the formation of mangroves and other salt marsh vegetation.

The coastal vegetation plays an important role in the deltaic environment by enhancing the sedimentation and stabilization of the seashore and seabottom. Besides, coastal vegetation contributes considerable amount of organic matter (Odum and Heald, 1972; Day *et al.*, 1973; Prakash *et al.*, 1973; Boto, 1982) thereby increasing the productivity of the coastal waters. Earlier studies on the deltaic vegetation of India provides rather scanty and patchy information (Venkatesan, 1966; Blasco, 1975; Banerjee and Rao, 1985, Govt. of India, 1987). The present paper is an attempt on documenting the formation and composition of flora in the deltaic regions of India.

DELTAIC ENVIRONMENTS OF INDIA

The west coast of India is characterised by steep slopes, rises, promontories and drowned estuaries while the east coast shows a sequence of delta formations (Ahmad, 1972). The larger deltas of India are Ganga, Mahanadi, Godavari, Krishna and Cauvery. The Gulf of Kuchchh represents the deltaic environment to a smaller

TABLE I
Physical dimensions of various deltaic environments of India (After K. L. Rao, 1979)

| Name of the delta | Area km ² | Annual average discharge m ³ |
|-------------------|--|--|
| Sabarmati | 21,674 | 3,200 |
| Mahi | 34,842 | 8,500 |
| Narmada | 98,796 | 40,705 |
| Tapi | 65,145 | 17,982 |
| Subarnarekha | 19,296 | 7,940 |
| Brahmani | 39,033 | 18,310 |
| Mahanadi | 141,589 | 66,640 |
| Godavari | 312,812 | 105,000 |
| Krishna | 258,948 | 67,675 |
| Penniar | 55,213 | 3,238 |
| Cauvery | 87,900 | 20,950 |
| | 945,949 (0.95 million km ²) | 402,945 (0.402 × 10 ³ m ³) |

extent along the west coast of India. All the deltas, except Cauvery are lobate shaped and are characterised by low wave energy, high tidal range and generally low littoral drift (Rao, 1979). The total area of deltaic environment has been estimated to be cc 0.95 million km². and the total annual discharge of cc 0.402 thousand million m³ (Table 1). The deltaic regions show heavy alluvial deposits of 3–4 m thick and composed of fine clay, silt loam and clay loam.

The physical dimensions for the delta regions of India are described by Rao (1979). The projection of the delta ranges from 8 km of the Cauvery to 60 km of the Mahanadi. However, the Ganges represents the largest, active and subsidence delta. It has protruberance of cc 40–50 km of the land in the Indian section. Other deltas are categorised as of emerging type. The Mahanadi delta complex is contributed by Mahanadi, Brahmani and Baitarni rivers. The Mahanadi delta has a coastal plain, and islands are formed in the relatively protected regions of the delta. The Godavari delta has projection of cc 35 km in the sea and the alluvial cover is relatively shallower. The Krishna delta has protruberance of cc 37 km and the bays in the region are small and subjected to feeble wave action. The Cauvery delta is dominated by tidal action, resulting in the formation of sand-bars and lagoons. The Narmada and Tapi rivers along the west coast contribute heavy amount of sediments in the region of Gulf of Cambay forming mudflats and marshes.

CLIMATOLOGY

The climatological and tidal data, for various localities, but relevant to deltaic regions are depicted in Fig. 1 and 2 a,b.

The tidal amplitude ranges from 0–11.5 m along the coast of Gujarat (Gulf of Kuchchh–West coast) while along the east coast, it ranges from –0.07–1.9 m at Madras and 0.47–5.82 at Sagar Island, Calcutta (Table 2). The atmospheric temperature varied from a minimum of 13.6°C at Calcutta during January to 37.6°C at Madras during May, whereas, at Bhavnagar, along the Gujarat coast,

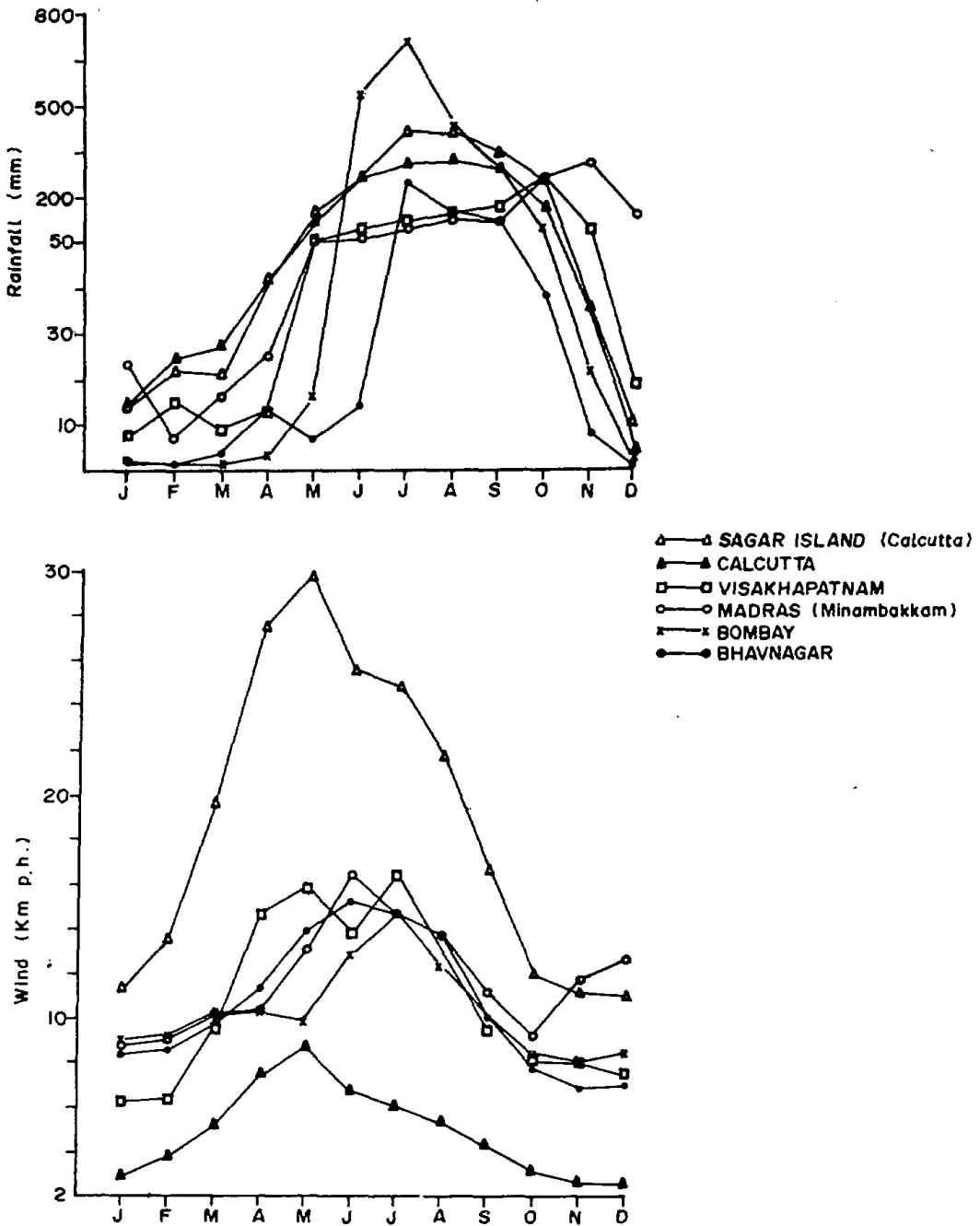
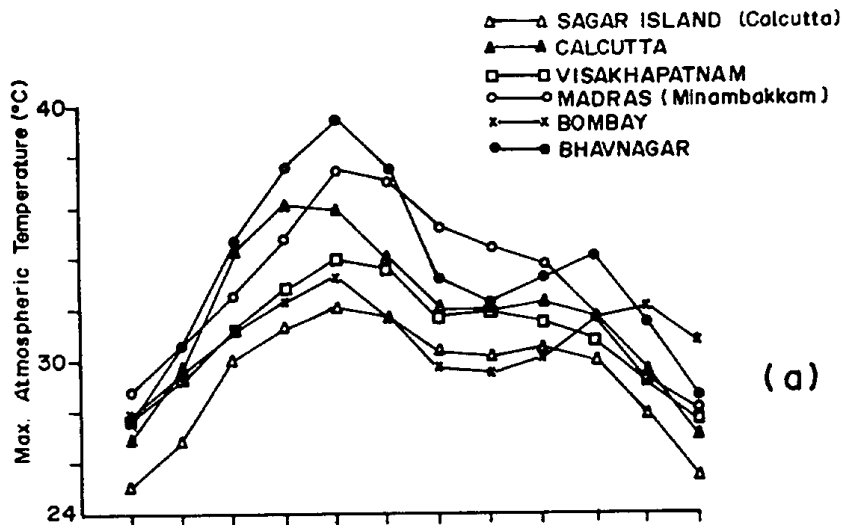
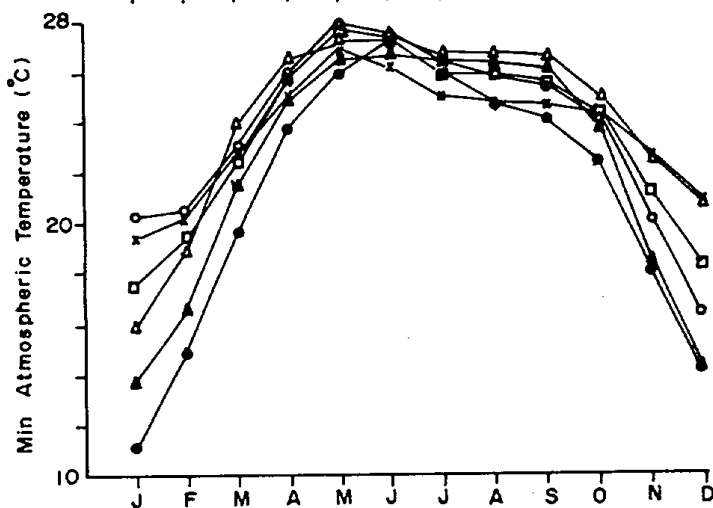


Figure 1. Rainfall and Wind velocity data of stations near about some of the deltas

thermal amplitude was very wide (11.1°C–39.6°C). The minimum annual total rainfall of 600 mm occurs along the Gujarat coast while along the east coast, it ranged from 973 mm at Vishakhapatnam to 1900 mm at Sagar Island. The maximum precipitation takes place during May to August. At Madras along Tamil Nadu coast, maximum rainfall occurs during October. The humidity varies from



(a)



(b)

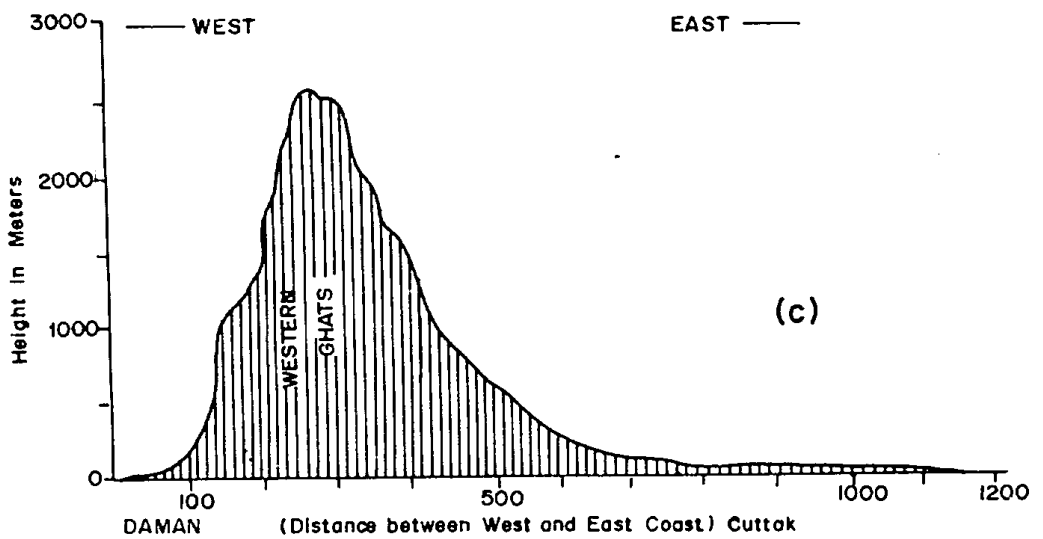


Fig. 2a-c

TABLE II
Tidal data for the various localities

| Station | MHW (height in m) | LHW (height in m) |
|---------------------|----------------------|----------------------|
| Bhaunagar | 11.5 | 0.72 |
| Bombay | 5.07 | 0.00 |
| Madras | 1.44 | -0.07 |
| Visakhapatnam | 1.9 | -0.24 |
| Sagar (Hugli River) | 5.82 | 0.47 |

minimum of 30.5% along northwest coast during March to 85.5% at Sagar Island, along northeast coast during July. In general, climate remains relatively dry along the Gujarat coast.

DELTAIC VEGETATION

Deltaic vegetation is composed of mangroves, associate species and terrestrial flora, which occur in the intertidal and elevated (subaerial) land (above the spring tide mark), respectively. The tidal flora comprises of 47 species of mangroves and seven species of associate mangroves while terrestrial flora consist of 37 species (Tables 3 and 4). The mangrove regions of estuaries have been reported (Jagtap, 1985) to support limited number of marine algae and couple of seagrass species, which also could be true of the deltaic regions.

Almost 70% of the total mangrove cover of India exists in the deltaic regions. The total area of mangroves from the deltas of India have been estimated (Table 5) to be 2,56,000 ha of which 78% occurs in Ganges (Sunderbans) delta alone (Fig. 3a and Plate 1a). The distribution of mangroves in Sunderbans becomes poorer as it progresses towards the sea. Other deltaic regions except Mahanadi, (Fig. 3b and Plate 1b) show relatively poor mangrove cover (Figs 4a to 4d) and the Gulf of Kuchchh as well as Gulf of (Khambhat) Khambayat (Fig. 5) and Kerala coast have most degraded mangroves.

The maximum number of mangrove species (27) have been reported from Mahanadi delta and minimum number (7) of species from Gulf of Kuchchh region. The ecological status of mangrove species in various deltaic regions of India, is given in Table 3. Mangroves species like *Avicennia* spp. and *Aegiceras majus* form the dominant vegetation of Godavari, Krishna and Cauvery deltas. However, *Ceriops decandra* and *Sonneratia apetala* form the dominant mangroves in the Mahanadi delta. Species like *Excoecaria agallocha*, *Heritiera fomes* and *Xylocarpus moluccensis* are the dominant mangroves in the Gangetic (Sunderbans) delta. The Gulf of Kuchchh region is dominated by shrubby mangrove, *Avicennia marina* and *Salicornia brachiata*. Species of *Rhizophora*, which are dominant along the estuaries have been reported to be rare in the deltaic regions. Other species like *Clerodendron inerme*, *Hibiscus tiliaceus*, *Thespesia populnea*, *Sesuvium portulacastrum* and *Porteresia coarctata* commonly occur in the deltaic regions in association with the mangroves. There is not much information available on the composition of benthic

Figure 2. a) Maximum atmospheric temperatures near about some of the deltaic regions b) Minimum atmospheric temperatures near about some of the deltaic regions c) Topographic profile across Peninsular India along approximately 20° 30' N. Lat. Distance in kms.

TABLE III
Mangroves and associate flora in the deltaic regions of India

| Mangrove species | East coast | | | | | West coast | |
|---|------------------------|----------|----------|---------|---------|------------------|---|
| | Ganges (Sunderbans) | Mahanadi | Godavari | Krishna | Cauvery | Gulf of Kutch | |
| <i>Acanthus ilicifolius</i> L. | C | C | C | C | C | - | - |
| <i>Acrostichum aureum</i> L. | R | R | - | - | C | - | - |
| <i>Aegialitis rotundifolia</i> Roxb. | C | R | R | R | - | - | - |
| <i>Aegiceras corniculatum</i> (L.) Bl. | - | - | D | R | R | - | - |
| <i>A. floridum</i> R. and S. | - | - | D | R | R | - | - |
| <i>A. majus</i> Gaertn. | C | R | D | D | C | - | D |
| <i>Avicennia alba</i> Bl. | C | C | D | D | D | - | - |
| <i>A. marina</i> Vierh. | C | C | D | D | D | - | - |
| <i>A. officinalis</i> L. | - | - | - | R | R | - | - |
| <i>Bruguiera caryophyllioides</i> Bl. | - | - | R | R | R | - | - |
| <i>B. cylindrica</i> (L.) Bl. | - | - | R | R | R | - | - |
| <i>B. conjugata</i> Merr. | - | - | ? | R | + | - | - |
| <i>B. eriopetala</i> W and A. | C | C | R | R | - | - | - |
| <i>B. aymorhiza</i> (L.) Lamk. | - | R | - | - | - | - | - |
| <i>B. parviflora</i> (Roxb.) W. et A. ex Griff. | - | R | - | - | - | - | - |
| <i>B. sexangula</i> (Lour.) Poir. | - | R | - | - | - | - | - |
| <i>Cerbera manghas</i> L. | C | R | R | R | R | - | - |
| <i>Certops decandra</i> (Griff.) Ding Hou | - | D | R | R | R | - | R |
| <i>C. tagal</i> (Perr.) C. B. Robins | - | R | R | R | R | - | - |
| <i>C. roxburghiana</i> Arn. | - | R | R | R | - | - | - |
| <i>Cynometra mimosoides</i> Wall. | - | R | R | R | - | - | - |
| <i>Derris heterophylla</i> (L.) Merr. | C | C | C | C | C | - | C |

| | | | | | | |
|---|---|---|----|----|----|---|
| <i>Excoecaria agallocha</i> L. | D | C | C | CD | CD | C |
| <i>Heritiera fomes</i> Buch. -Ham. | D | R | C | — | — | — |
| <i>H. littoralis</i> Dryand. ex Aiton | — | R | — | — | — | — |
| <i>H. globosa</i> Kosterm. | — | R | — | — | — | — |
| <i>H. minor</i> Roxb. | R | — | — | — | — | — |
| <i>Kandelia candel</i> (L.) Gaertn. | R | R | R | ? | — | — |
| <i>Lumnitzera racemosa</i> (L.) Gaertn. | — | R | CD | CD | R | — |
| <i>Nypa fruticans</i> Wurm. | C | — | — | — | — | — |
| <i>Rhizophora candelaria</i> DC. | C | — | R | R | — | — |
| <i>R. apiculata</i> Bl. | — | — | R | — | — | — |
| <i>R. conjugata</i> Hensl. | — | — | — | — | D | — |
| <i>R. lamarekii</i> Montr. | — | — | — | — | R | — |
| <i>R. mucronata</i> Lamk. | R | C | — | — | CD | — |
| <i>R. stylosa</i> Griff. | — | — | — | — | R | — |
| <i>Salicornia brachiata</i> Roxb. | — | — | C | — | R | D |
| <i>Salvadora persica</i> L. | — | — | C | C | C | C |
| <i>Sonneratia apetala</i> Buch. Ham. | C | C | C | C | R | — |
| <i>S. caseolaris</i> (L.) Eng. | — | R | — | — | — | — |
| <i>S. griffithii</i> Kurz | — | R | — | — | — | — |
| <i>Suaeda fruticosa</i> Forsk. | — | R | — | — | — | — |
| <i>S. maritima</i> (L.) Dum | C | — | C | C | D | C |
| <i>S. nudiflora</i> | — | — | C | C | — | — |
| <i>S. monoica</i> Forsk. | — | — | C | C | R | — |
| <i>Xylocarpus granatum</i> Koenig | R | C | — | — | — | — |
| <i>X. moluccensis</i> (Lamk.) Roem. | D | R | R | R | — | — |
| <i>Clerodendrum inerme</i> Gaertn. | C | C | C | C | C | C |

TABLE IV
Floristic composition in the subaerial deltaic
regions of India

* *Aeluropus lagopoides* (L.) Trin.
Amoora Cucullata Roxb.
Arthrocnemum fruticosum Moq.
Aria lanata Don
Atriplex stocksii Boiss
Azima tetracantha Lam.
Borassus flabellifer L.
Caesalpinia crista L. (*C. nuga* Ait.)
Calotropis gigantea R. Br.

* *Cressa cratica* L.
Cynodon dactylon Pers.
Cyperus arenarius Retz.
Dalbergia spinosa Roxb.
Dendrophthoe falcata (L. f.) Etting.

* *Fimbristylis cymosa* R. Br.
Geniosporum tenuiflorum (L.) Merr.
Gynandropsis pentaphylla DC

* *Heliotropium curassavicum* L.
Kyllinga monocephala Rottb.
Opuntia monacantha Haw.
Pongamia pinnata (L.) Pierre
Prosopis spicigera L.
Sarcolobus carinatus Wall.
Scirpus littoralis Schrad.
Solanum trilobatum L.
Stictocardia tiliacifolia Hall. f.
Urochondra setulosa (Trin.) Hubbard
Vitex negundo L.
Zoysia matrella Merr.

* back mangroves

TABLE V
Mangrove areas in various deltaic environments of India.

| Deltaic region | State | Mangrove Area (ha) | Reference |
|----------------|-------------|--------------------|-----------------------------|
| West coast | | | |
| Gulf of Kutch | Gujarat | 11,000 | Untawale, 1980 |
| East coast | | | |
| Gangetic | West Bengal | 200,000 | Govt. of India, 1987 |
| Mahanadi | Orissa | 21,458 | Patnaik and Choudhary, 1989 |
| Godavari | Andhra | 10,000 ù | |
| Krishna | Andhra | 10,000 ù | |
| Cauvery | Tamil Nadu | 15,000 ù | |
| | | 258,458 | |

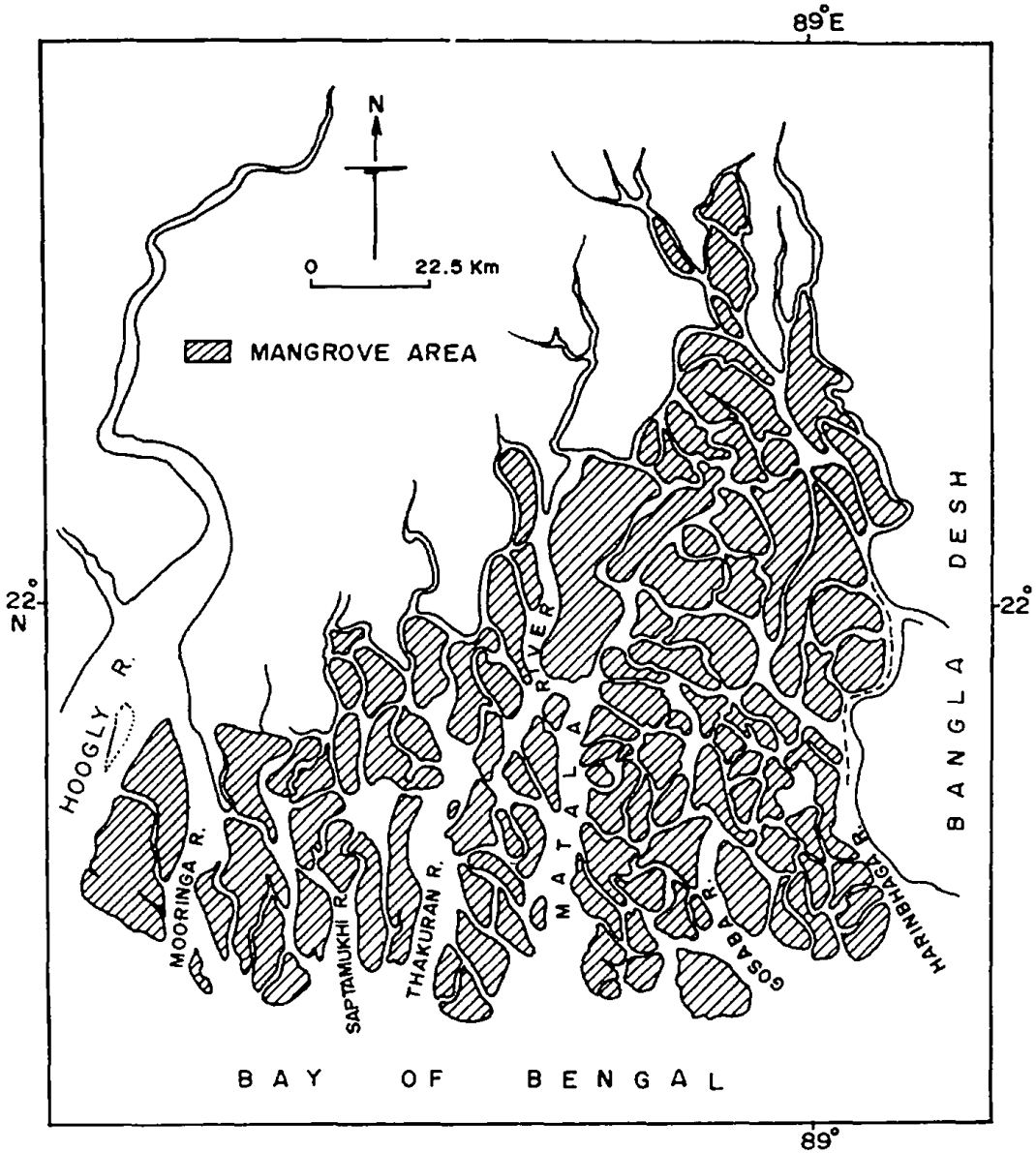


Figure 3a. Mangrove area in Ganges (Sunderban) delta

algae and seagrasses from the deltaic regions except Sunderbans and Godavari to a little extent.

Halophila beccarii is commonly associated with mangrove environment while *H. ovalis* grows on the open mudflats in the high saline zones. Seaweeds like *Catnella impudica*, *Caloglossa leprieurii*, *Bostrychia tenella* form the characteristic flora of the mangrove environment, and occur throughout the year. Other species like *Gracilaria verrucosa*, *Polysiphonia* spp., *Chaetomorpha linum* and *Enteromorpha clathrata* occur seasonally during premonsoon and post-monsoon periods. The cyanophycean members like *Oscillatoria* sp., *Anabaena* sp. and few chlorophycean members like *Rhizoclonium* spp., dominate the mangrove regions, during monsoon period.

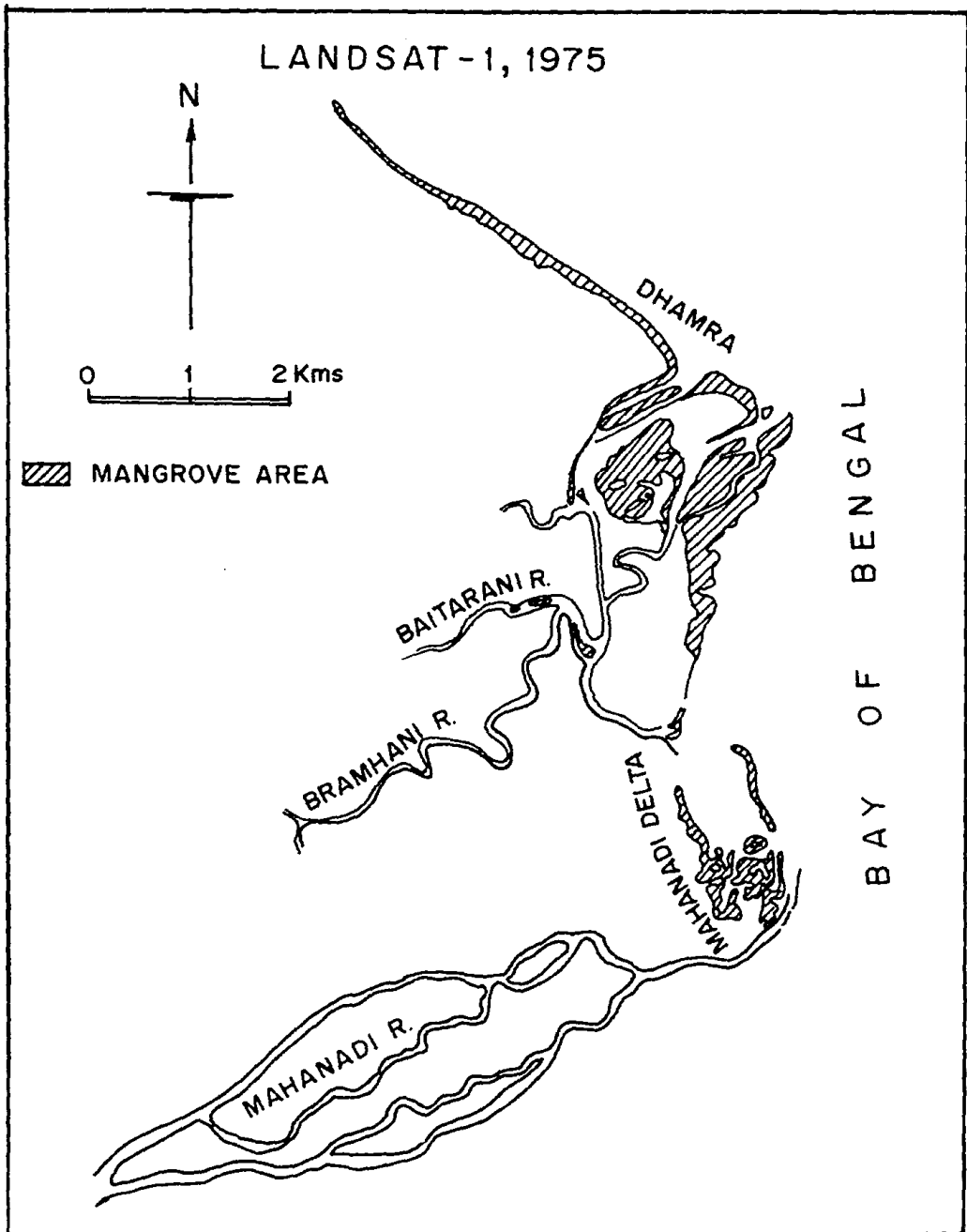


Figure 3b. Mangrove area in Mahanadi-Brahmani-Baitarani delta

DISCUSSION

The deltaic environments are characterised by the low tidal range and are known as allochthonous coasts. The freshwater discharge along with terrestrial sediments, due to flocculation effect, leads to the rapid deposition of terrigenous



Plate 1a. Satellite imagery of Ganges delta showing the distributaries and vegetation

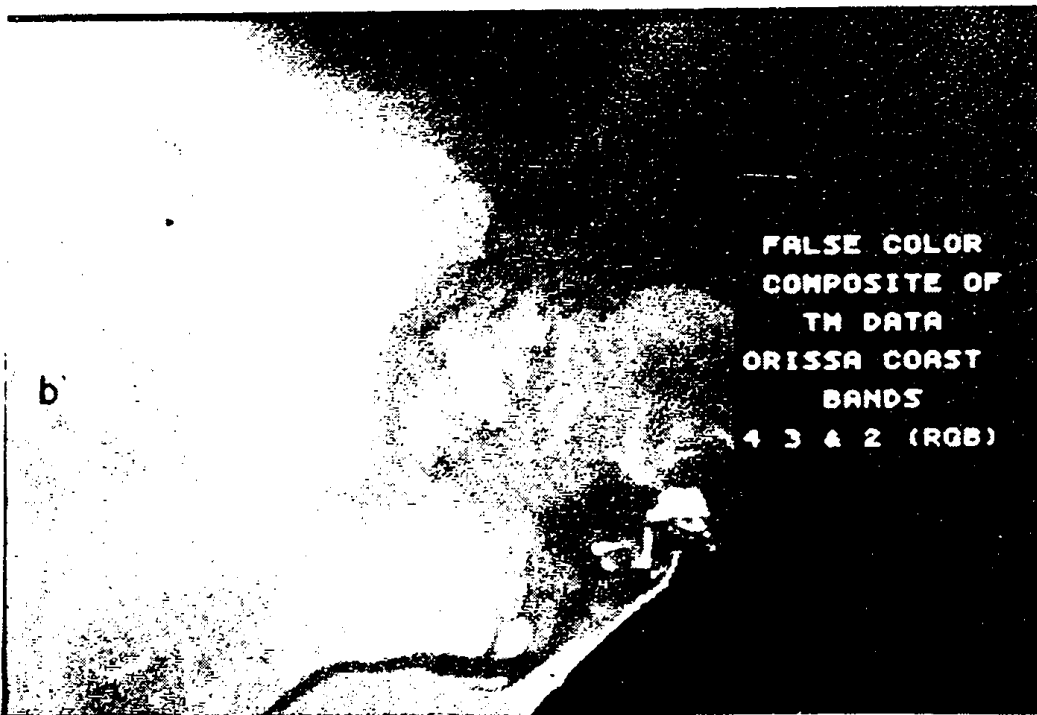


Plate 1b. Satellite imagery of Mahanadi delta front indicating the channel islands, spits and shoals

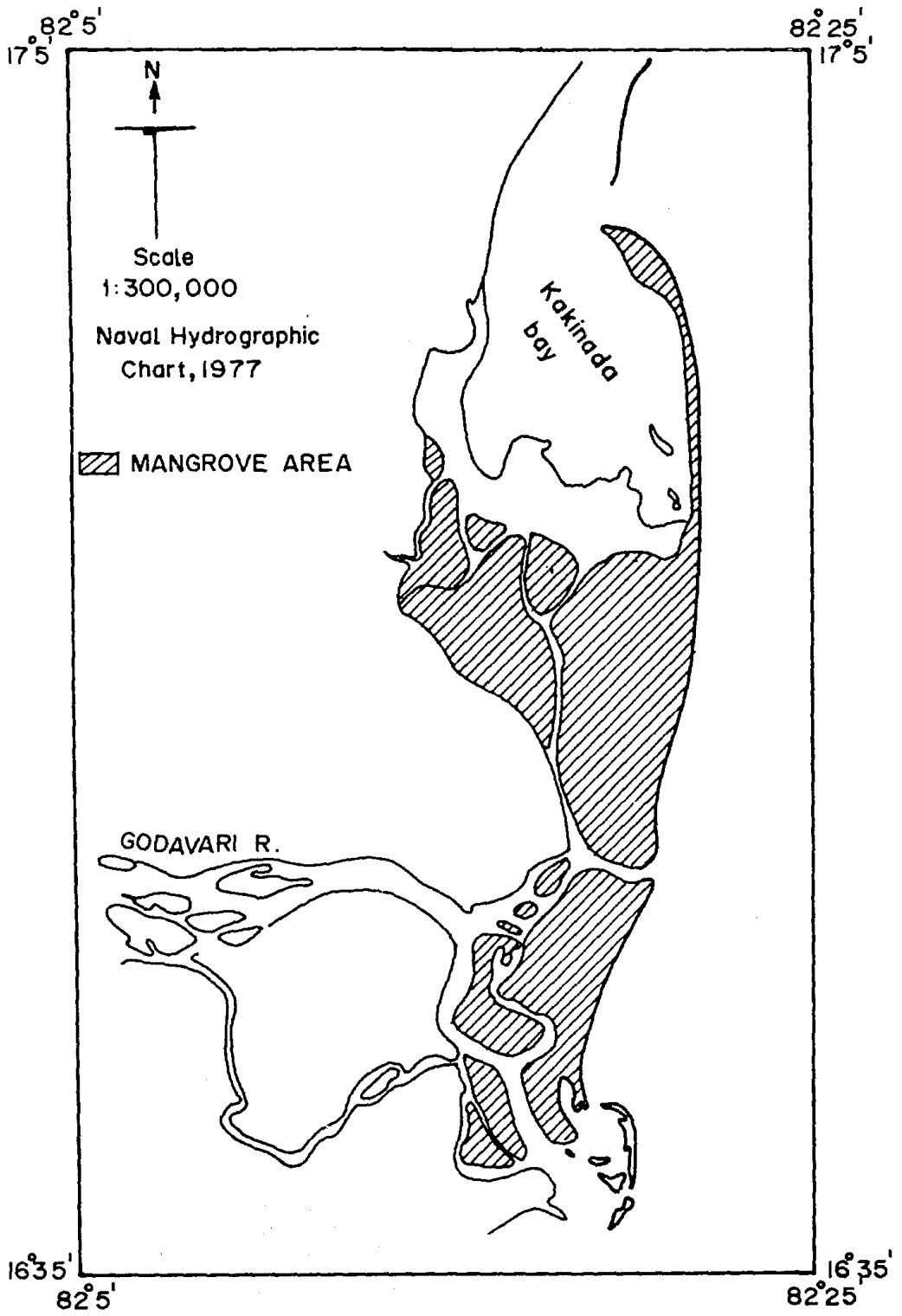
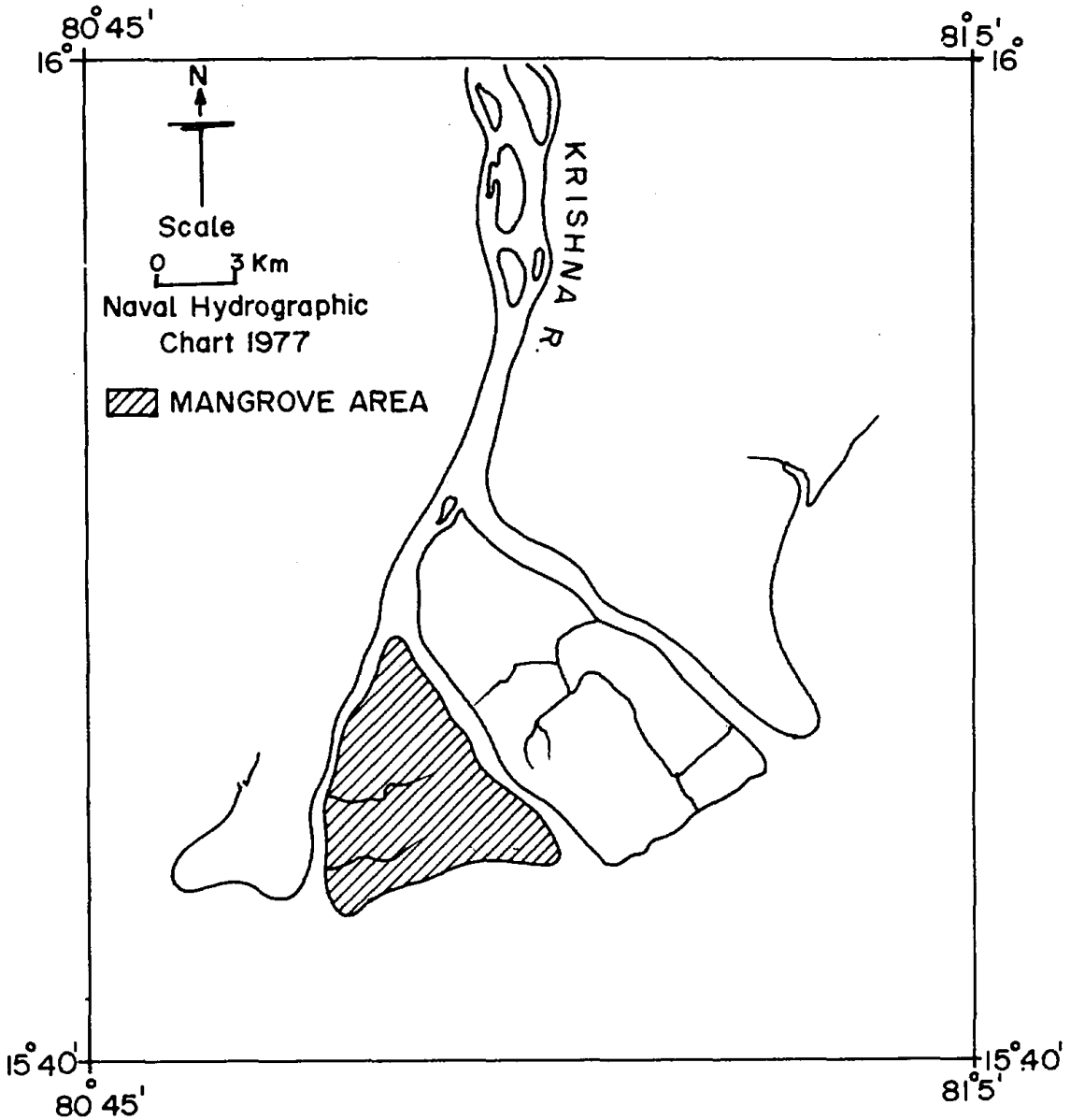


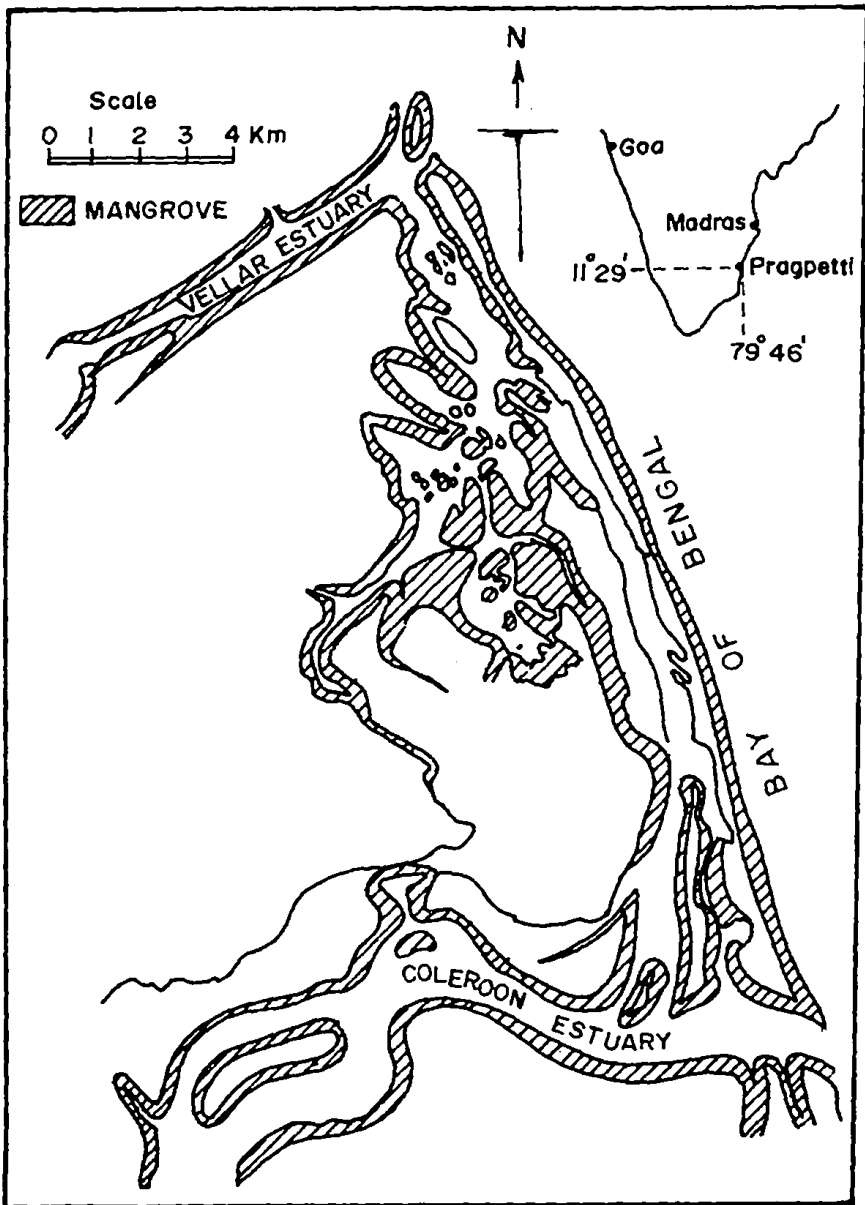
Figure 4a. Mangrove area in Godavari delta



Source: Blasco, 1975

Figure 4b. Mangrove area in Krishna delta

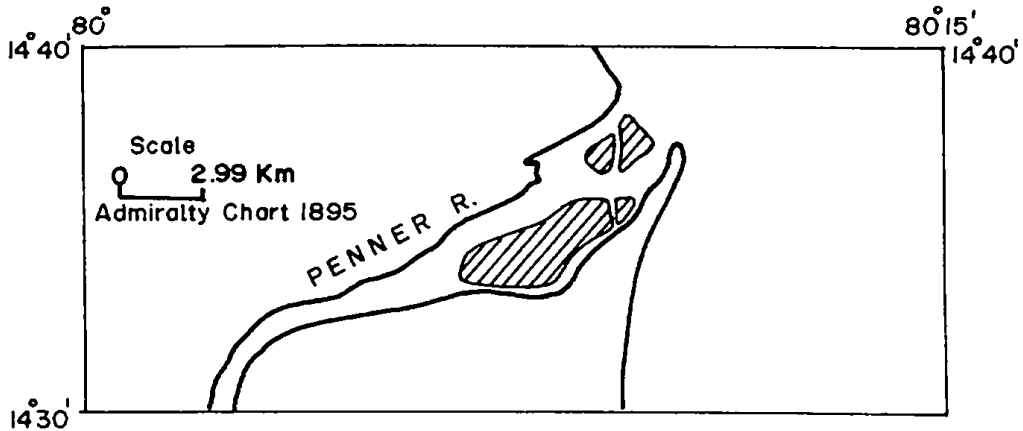
sands, silts and clay to form a delta. The detritus and litter (sudd) in the deltaic environment contributed by various plant communities provide an exposed surface for plant colonization (Ellery *et al.*, 1990). On the other hand, there are areas where sediment accumulation takes place either from coral reefs or from the deposition of carbonate clastics or precipitates. The multiple branching of distributaries result in highly crenulate coastline with shallow bays and lagoons in the deltaic regions. The active distributary where the freshwater discharge is generally high is devoid of any salt tolerant flora. However, abandoned distributary regions in the deltaic plain



Source Blasco, 1975

Figure 4c. Mangrove area in northern part of Cauvery delta

influenced by saline waters called as chenier plains, get established by salt tolerant plants (Thom, 1982). Such deltaic plains are characterised by high degree of morphogenic diversity and subjected to rapid changes in the habitat (Fig. 6). The deltas are either dominated by waves or river currents or tidal processes (Galloway, 1975; Coleman and Wright, 1975). A wave dominated delta possesses a different type of combinations of landform types and process with distinctive sediment properties compared to that of a river or tide dominated delta. The microtopography like land



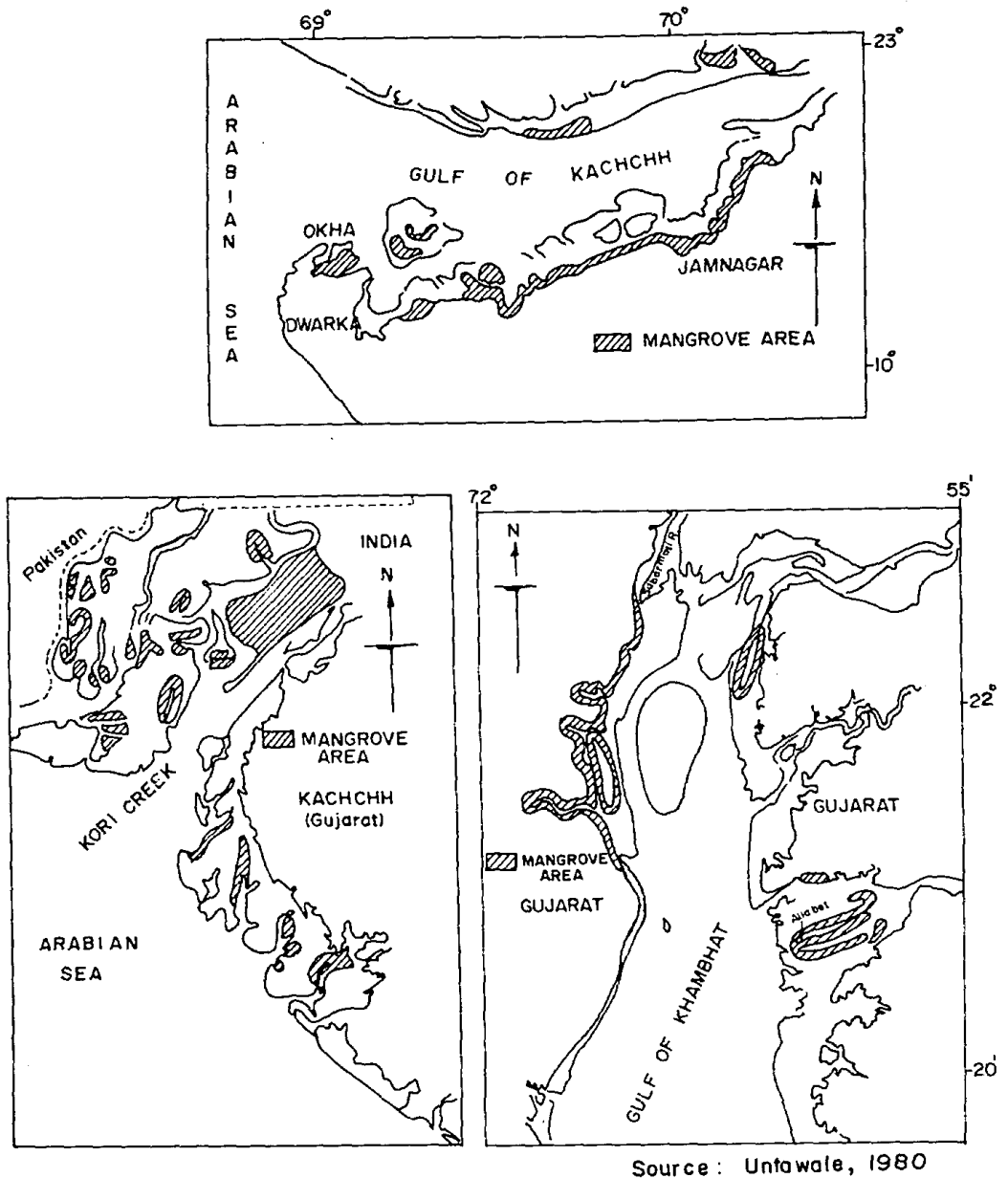
Source: Blasco, 1975

Figure 4d. Mangrove area in Penner delta

surface elevation, drainage and stability in combination with substrate or sediment properties, nutrient input, etc. greatly influence the establishment, growth and distribution of vegetation.

The deltaic regions are generally dominated by salt tolerant flora. Establishment of vegetation in the deltaic plains is very slow and could be identified into various processes like sedimentation, formation, stabilization with vegetation, climax vegetation and terrestrial vegetation (Fig. 7). The freshwater discharge and tidal influence enhances the sedimentation process due to the flocculation which helps in the formation of deltaic plains. The pioneer species like *Porteresia coarctata*, *Myriostachya waghitiana*, *Aeluropus lagopoides*, *Excoecaria agallocha* and *Cyperus* spp establish on the deltaic plains and thus stabilize and further enhance the sedimentation process. The pioneer species differ from region to region. The continuous sedimentation and stabilization process leads to the raising of deltaic plains and formation of intertidal mudflats. The mangrove species like *Rhizophora*, *Avicennia*, *Sonneratia*, etc. establish themselves at the highest high tide mark, start regenerating and reach their climax. The establishment of mangroves and associate species on the newly stabilized islands causes rapid deposition of the sediment and helps in land building. The freshwater plant species may also grow above spring tide mark. The entire process could take more than 50 to 100 years (Fig. 6).

It is considered that the history of the land surface and contemporary geomorphic as well as associated pedogenic processes together determine the pattern of mangrove growth (Thom, 1982). Climatic regime affects the discharge of freshwater and sediments into the salinity regime of estuaries, lagoons and deltas where mangroves grow. The tidal exchange, exposure and inundation of land surface influence the environmental setting of mangrove growth. Similarly, the freshwater discharge which alter the salinity regime, play very important role in the formation of mangroves in the delta regions. The deltaic regions of Godavari, Krishna and Cauvery, which receive relatively poor freshwater discharge, support the growth of highly salt tolerant species like *Avicennia marina*. Similarly, supra-littoral zones of Cauvery and in the Gulf of Kuchchh are dominated by the species



Source : Untawale, 1980

Figure 5. Mangrove area in West Coast of India along Gulf of Kutch, Western Saurashtra and Gulf of Cambay (Khambhat)

of *Suaeda* and *Salicornia*, which are the indicators of high salinity regions. However, the Sunderban regions show the dominance of *Heritiera* and *Xylocarpus* species which grow towards the land due to freshwater requirement. The luxuriant growth of mangroves in Sunderban could be attributed to heavy alluvial sedimentation and freshwater discharge in the deltaic regions. However, due to the tectonic rise of deltaic plain (Deb, 1956) from west to east, the Ganges has changed its course more and more towards eastern side. Therefore, freshwater supply in the mangrove

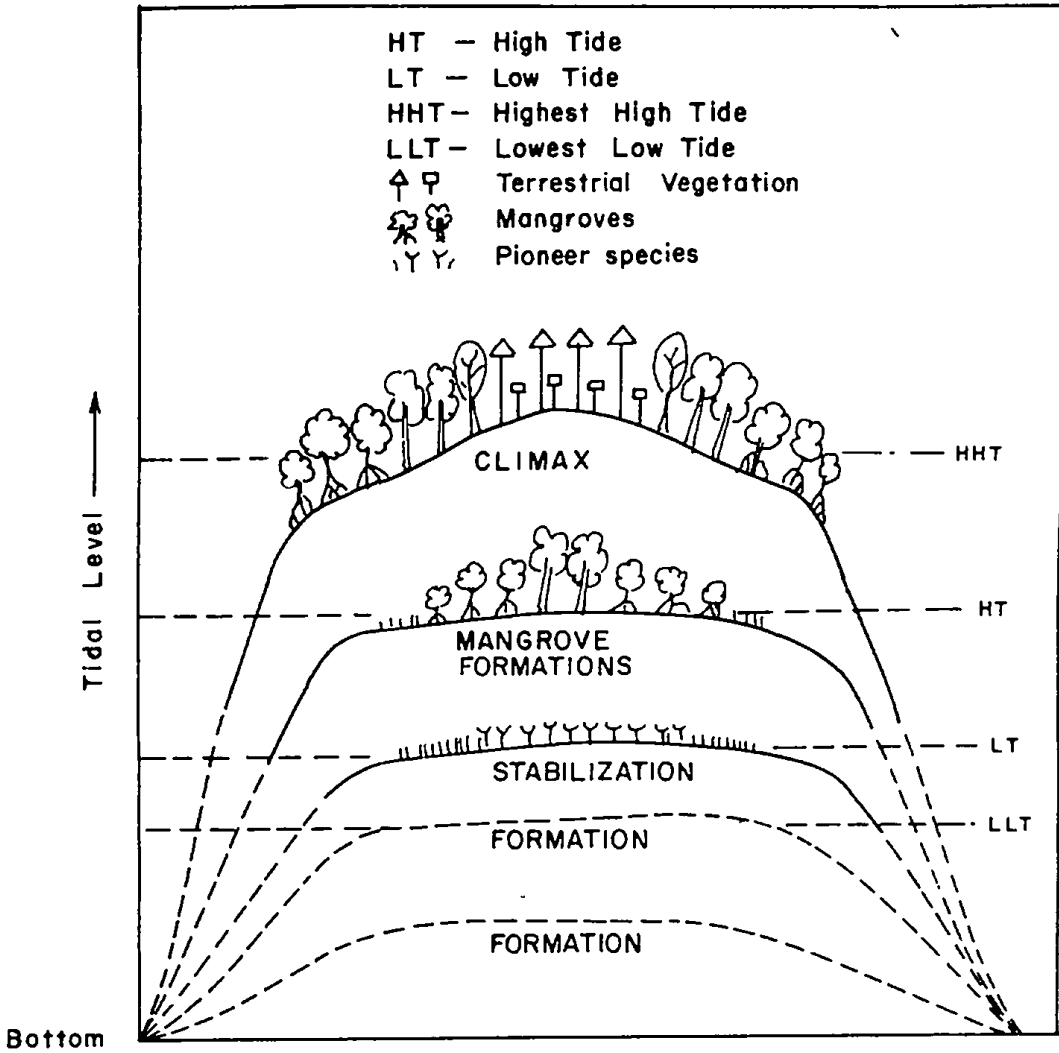


Figure 6. Stages in the formation of mangroves in deltas

regions of India have been reduced causing great damage to the species like *Heritiera*, *Nypa* and *Xylocarpus*.

The composition and luxuriance of mangroves in the Mahanadi delta was similar to the Sunderbans in the past. However, it has been degraded largely due to indiscriminate cutting, erosion, salt penetration and poor freshwater discharge (Rao, 1979). The total of 21,458 ha of mangrove area has been estimated (Patnaik and Choudhury, 1989) from Mahanadi delta which is the second largest formation of mangroves. Poor mangrove cover from other deltas could be attributed to lesser deltaic plains and degradation of mangroves to a greater extent. Various estimates of mangrove areas have been given in the deltaic regions eg. in the Cauvery delta. Sidhu (1963) and Venkatesan (1966) have estimated mangrove area of 2650 ha and 14,897 ha respectively. However, the actual area reported by Blasco (1975) varies between 500-1000 ha and is available at Pichavaram, Muthupet and Chatram (Fig. 4c). Therefore, detailed survey with remote sensing technique is required to assess

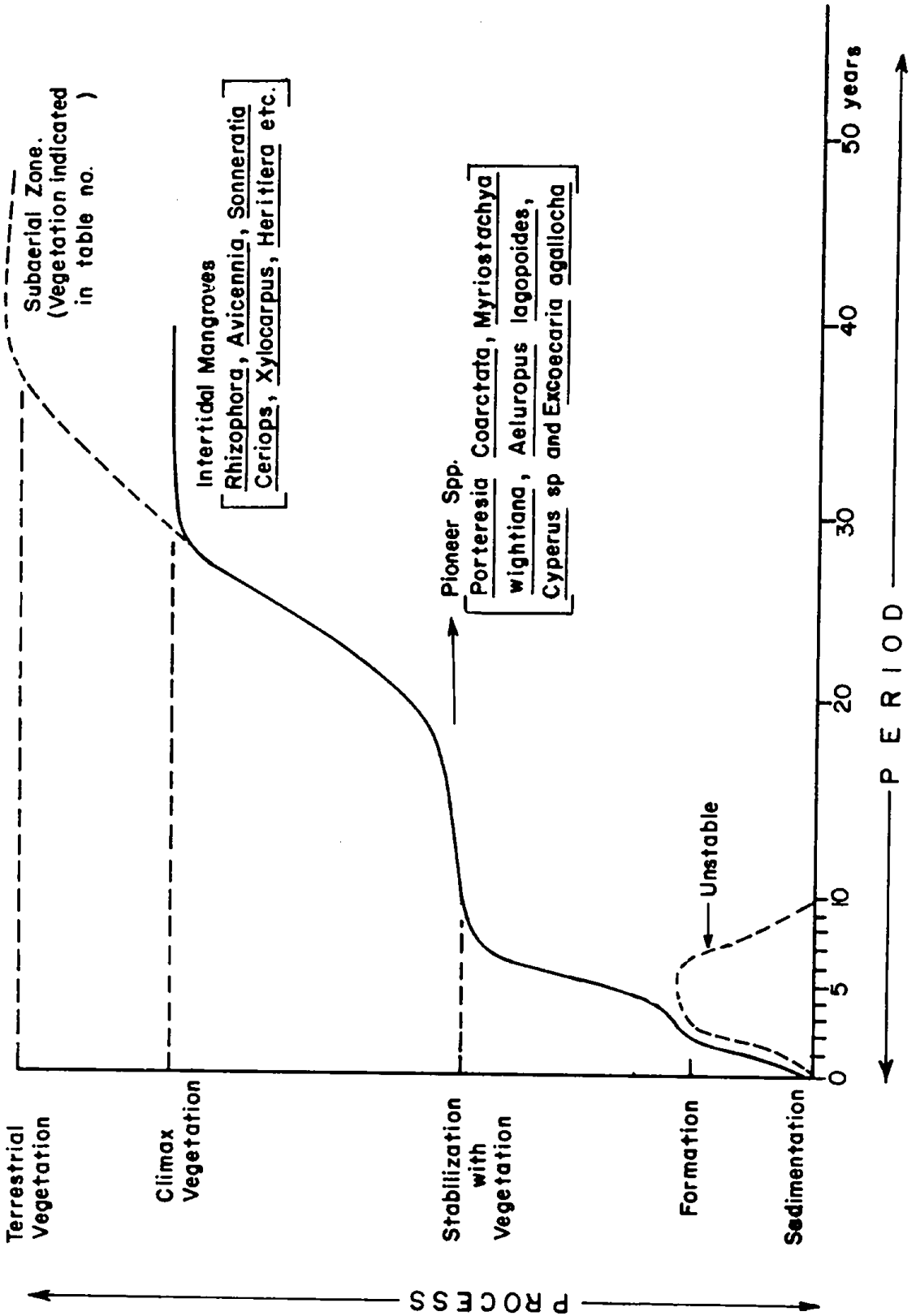


Figure 7. Process variations in deltas along with diversity in species

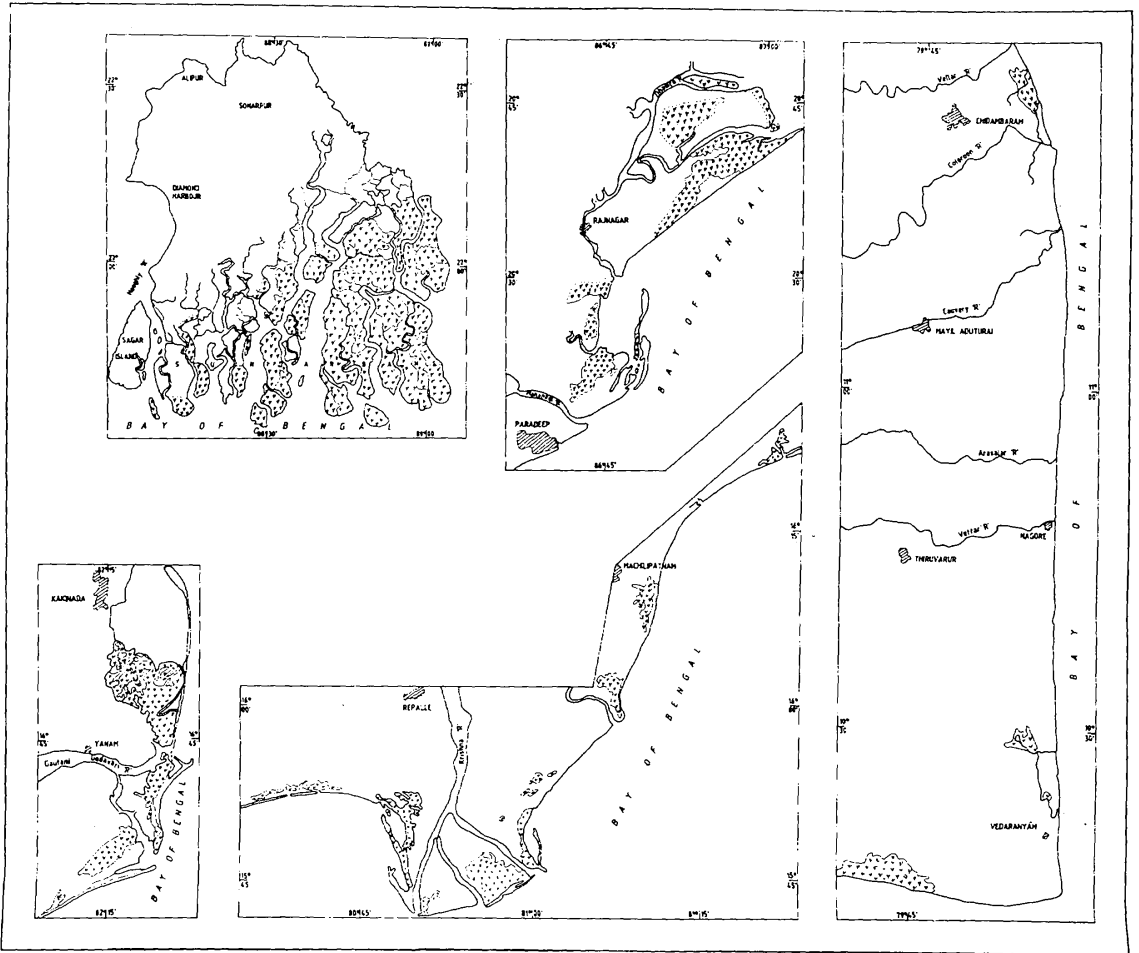


Figure 8. Areal distribution of mangroves in different East Coast deltas, mapped from satellite imagery (1990)

the present status of mangroves in the deltaic regions of Krishna, Godavari, Cauvery and other small deltas along the southeast coast of India.

A pattern of mangroves in the deltaic regions is mainly influenced by topography, salinity and substratum. Gradual slope along the east coast (Fig. 2c) of India helps proper discharge of freshwater, deposition of sediments at the region of confluence, resulting in the delta formation. The deltic plains are composed of higher percentage of fine sand and clay and smaller percentage of silt and coarse sand (Blasco, 1975). The pH of the deltaic soil varies from 6.9 to 8.69 and organic matter ranges from 0.5–2.59% and NaCl from 0.5–3.4% (Blasco, 1975). Most of the mangrove species occur from the polyhaline and mesohaline (Salinity 18–30%), however, species like *Avicennia marina*, *Rhizophora* spp, *Bruguiera* spp., *Sonneratia apetala*, *Excoecaria agallocha*, *Aegiceras* spp, *Ceriops* spp and *Lumnitzera racemosa* having adaptability for wide salinity range, grow in the highly saline zones. Similarly, the high saline soils in supralittoral zones support the growth of stunted *Avicennia* spp and species of *Salicornia* and *Suaeda*. The species of *Xylocarpus*, *Heritiera*, *Kandelia* and *Nypa* grow towards more freshwater influenced regions where tidal influence is feeble. The species like *Aeluropus lagopoides*, *Cressa cretica*, *Heliotropium currasavicum*, *Fimbristylis cymosa* and *Clerodendrum inerme* grow behind the mangroves in the marsh lands that are classified as back mangroves. In general, the deltaic regions of India have been dominated by mangrove vegetation and mainly occur in the tidal zones. The best mangrove formations occur in the deltaic plains of Ganges (Sunderbans) followed by those in Mahanadi delta. Mangroves in other deltaic regions of east coast and in the Gulf of Kuchchh have been reduced to a great extent. The mangrove ecosystems in the tropics are very productive and dynamic in nature and hence are considered to be of great importance (Odum and Heald, 1972). However, these important ecosystems, particularly in India have been totally ignored in the past. The severe degradation of mangroves has reached the critical stage and hence resulted in the ecological imbalance in the coastal regions. Lately, efforts are being made to create an awareness and to conserve mangroves in India. These efforts have to be strengthened further for the conservation and afforestation of mangroves in the deltaic regions, which are most suitable for the growth of mangroves.

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