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The Status of Sundari (*H. fomes*) an indicators species in the Sunderbans

The Lower Ganga River Basin

GRB EMP : Ganga River Basin Environment Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin: Environment Management Plan (GRB EMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Environment Management Plan (GRB EMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin: Environment Management Plan (GRB EMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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1. Introduction

The term “Sundarbans” has been coined from the (i) forests of Sundari (*Heritiera fomes*), or (ii) forests of beautiful plants or (iii) forests of *Samudra* (i.e., Ocean). This entire Gangetic Sundarbans extend over *ca* 14,600 km^2 distributed over both Bangladesh and India, with the latter occupying *ca* 4266.6 km^2 in West Bengal state (Plate 1). In comparison to the Bangladesh part, the Indian component of the Sundarbans has poor forest formation due to higher salinity and biotic interactions leading to different growth pattern and ecological succession. (Blasco, 1975).

Being on the land sea interface, mangroves are always associated with and subjected to saline seawater. However, saline condition is not a prerequisite for their development; rather mangroves choose saline conditions to avoid the competition with the more vigorous terrestrial plants. The Indian Sundarbans can be divided in to three parts *i.e*., **central** and eastern, based on their salinity level. The western part is the least saline due to the freshwater discharge from the Ganga-Bhagirathi-Hooghly rivers; whereas, the central part is most saline due to non-receipt of fresh water from the Ganges owing to heavy siltation since the late 15th century (Chaudhuri and Choudhury, 1994) and the rising sea level (Hazra *et al.* 2002). The rate of sea level rise is 3.14 mm/yr, which is higher than the global and Indian coastline averages of 2.12 mm/yr and 2.50 mm/yr, respectively (Lal and Aggarwal, 2000). The sea level rise and subsequent saline water intrusion into the islands of Sundarbans, they are also vulnerable to extreme climatic events owing to their location below the average Mean Sea Level. Since, the Sundarbans is located in a low-lying floodplain, most of the silt carried out by the Gangetic rivers are lost in the trench of the Bay of Bengal. A large portion of the silt are deposited on the eastern side causing land accretion, particularly in the south-eastern region; and compensatory erosion in the southwestern part, thereby pushing the coastline towards the sea. The coastal geomorphology is regulated by a circulation system driven by high sediment load, coupled with strong tidal and wind actions. The rivers also carry untreated municipal wastes, industrial effluents, agro-chemical residues etc., further adding to the deterioration of the ecosystem.

Mangroves are rich in polyphenols and tannins (Kathiresan and Ravi, 1990). Phenols and flavonoids present in mangrove leaves serve as UV-screen compounds. Flavonoids increase during pre-monsoon period. Pigment concentrations may vary with environmental conditions and seasons. Oswin and Kathiresan (1994) found high level of chlorophyll and carotenoids during the summer but highest level of anthocyanin in the monsoon months. However, depletion of growing stock, post-dispersal predation of seeds by crabs, sporadic flowering, and poor seed set in the remnant mangrove forests have been reported (Robertson *et al.,* 1990). The primary threats to all mangrove species including *H. fomes* are habitat destruction and removal of mangrove areas for conversion to aquaculture, agriculture, urban and coastal development, and overexploitation.

A. Ecology

Kingdom : **Plantae**
Phylum : **Tracheophyta**
Class : **Magnoliopsida**
Order : **Malvales**
Family : **Sterculiaceae**
Genus : ***Heritiera***
Species : ***fomes***

Plate 1: Satellite FCC of Indian Sunderbans

Plate 2: *H. fomes* occurrence in the Indian Sunderbans; a. single canopy; b. multiple canopy; c. in association; d. a twig and e. fruits; Photographs taken during field visit on 8-9 May 2011

H. fomes, Sundari is a mangrove buttressed tree of 10 to 25 m tall with dense, robust pneumatophores about 50 cm height (Plate 2). It is the only *Heritiera* species that produces pneumatophores. The roots do not penetrate deep into the soil, but spread on the surface with numerous stout offshoots and often with narrow ridges forming plant like projections above the soil and also form flat narrow buttress to the basal trunk.

It prefers freshwater and is fast-growing in low-saline environments. The species is commonly found along the tidal creeks and channels of the coastal swamps, and regenerate naturally through seeds (Banerjee and Rao, 1990). The species is found in the upstream estuarine zone in the high intertidal region and adapted best along the seashore. Cluster analysis using the AFLP (Amplified Fragment Length Polymorphism) banding patterns of all the primer combination reveals that *H. fomes* in the due course of evolutionary process might have migrated to land and evolved as a new species (Mukherjee *et al.,* 2003).

Sundari contains 0.25% and 0.09% (dry weight) of chl-*a* and chl-*b*, respectively. Studies have reported that the carbon, polyphenol, tannin and protein content are 0.11%, 39.45%, 21.12% and 29.22% of dry weight, respectively for the species. The chemicals produced from the species can be used for gastro-intestinal disorders (including dysentery, diarrhea, indigestion, colic, acidity, constipation, bloating, lack of appetite, stomachache). Besides this, it can be used to treat hepatic disorders (including jaundice and hepatitis), insect repellent and skin diseases (including eczema, abscess, acne, boils, scabies, itch, infections, dermatitis, rash, sores, scar, warts, etc.). Sundari has been the main timber species and is the primary resource base for 221 small saw mills and 350 pitsaw units in the region (Bangladesh Bureau of Statistics, 1983).

According to **IUCN red list** Conservation Category, *H*. *fomes* is assigned with endangered status. With time, this species may go (locally) extinct as their population is rapidly declining due to various reasons so as Kathiresan (2008a) found the species in only 6% of the sampling sites in India.

The species is now on the extinction threat in West Bengal due to overcutting and increased salinity. Unlike other mangrove species *H. fomes* prefer extremely low saline condition (5 – 15 psu) and hence can act as biological indicator of climate change related to sea level rise. In the highly populated Bengal (India and Bangladesh) the dry season demand for freshwater has increased dramatically; major rivers have been dammed and the downstream effects are becoming apparent with increasing soil salinities and unexplained ‘top dying’ disease is threatening the *H. fomes* population. The first factor is clearly anthropogenic; the second, although aggravated by upstream diversions of Ganga water, is largely due to long-term geomorphic processes.

B. Drivers of Change

Past Alterations

In the past, the Government of India's policies had largely determined the pace, direction, mode and beneficiaries of exploitation in the Sundarbans. Under British rule, there was no state guarantee to the property rights to any person or under-tenants. British land policy in undivided Bengal had created an institutional basis for land clearance. Economic progress, human needs and the revenue demands of the state rested on continued mangrove clearance and reclamation. One model was to empower the energetic landlords, who would invest both energy and capital into reclaiming the waste lands. Timber and fuel wood were another resource tapped for the expanding market. Rice, rather than timber was the choice for the officers to gain from the profitable rice markets in nearby Kolkata (formerly Calcutta). Peace, order, and guaranteed ownership rights on firmly planted lands proved adequate to encourage spread of settlement embanked-rice paddy cultivation for the poor. The Sundarbans is an exception to the general trend of deltaic development in that it is the only area in which a state-organized barrier to agricultural expansion emerged. Wood prices followed a trajectory similar to that of the rice rates with steep ascent of 52% between 1950 and 1980. The pressure of population growth upon resources is evident from the fact that despite one hundred years of cropland expansion, the available cultivated land per capita dropped from 0.22 to 0.08 ha. More strikingly, the reduction in per capita area of all forms of natural vegetation (wetlands, forest, scrub, grassland) declined from 0.27 ha in 1880 to 0.04 ha in 1980.

Salinity Increase

H. fomes can flourish luxuriantly under low salinity conditions; however, it is gradually losing the species owing to increase of salinity level. Based on the physiological studies, Bowman (1917) and Davis (1940) concluded that mangroves are not salt lovers, rather salt-tolerant. But excessive saline conditions retard seed germination, impede growth and development of M~~m~~angroves. When the salinity increases, the species becomes stunted, rare and ultimately disappears. Alteration in growth of mangroves due to difference in salinity between western and central sectors of Indian Sundarbans has been reported by Mitra *et al.* (2004). The effects of salinity on mangroves have been studied in relation to antioxidative enzymes (Takemura *et al.,* 2000; Parida *et al.,* 2004b), leaf structure, rates of transpiration, stomatal conductance and rates of photosynthesis (Santiago *et al.,* 2000; Parida *et al.,* 2004a) and changes in chloroplast structure and function (Parida *et al.,* 2003).

H. fomes prefers an optimum salinity between 2 - 5 psu (Mitra *et al.,* 2004). The adverse impact of salinity on leaf chlorophyll of *H. fomes* may significantly affect the rate of photosynthesis as this pigment is an indispensable raw material for running the process. Various studies have shown that a number of mangrove species grow best at salinities between 4 psu and 15 psu (Connor, 1969; Clough, 1985; Downton, 1982; Burchett *et al.,* 1984 and Clough, 1984) and for *H. fomes*, the preferred salinity range is much lower (Chaudhuri and Choudhury, 1994). At 15 psu the plants become acclimatized to salt after one to two weeks of exposure, but at 20 psu the seedlings could hardly adapt. Salinity exerts its effect on photosynthesis mainly through changes in leaf water status. Clough (1985) stated that the rate of light saturated photosynthesis decreases with increasing salinity of ambient media, attributing this to co-limitation of assimilation rate by stomatal conductance and photosynthetic capacity in response to differences in water status induced by the various salinity treatments. Study reveals that the photosynthetic process may be affected at high saline condition due to decrease in Chl *a* and *b* concentrations in *H. fomes*. The pigments, being the key machinery in regulating the growth and survival of the mangroves require an optimum salinity range between 4 - 15 psu (Downton, 1982; Burchett *et al.,* 1984) for proper functioning.

Industrial Pollution

Oil or gas exploration, petroleum production and accidents by large oil tankers cause significant damage to mangrove ecosystems, causing defoliation of trees, mortality of all sessile and benthic organisms and contamination of many water fowls with minimum recovery period of 10-years (Kathiresan, 2008b). In Indian Sundarbans, several industrial effluents are released in to the adjacent coastal water bodies. For example the presence of Haldia port-cum-industrial complex releases several pollutants of organic load that contains several complex ions and different organic and inorganic compounds. When these compounds are mixed with the coastal water bodies they enter in the sediment through percolation and the pneumatophores contact with the sediment also take up the organic and inorganic compounds. These compounds hamper the circulatory system of the mangroves species such as *H. fomes*.

Disease and Infestation

Top dying of Sundari in the Sundarbans is considered to be the most important of all the diseases and disorder of tree crops in Bangladesh. It has been estimated that about 45 million trees have been affected by top dying in the Sundarbans (Rahman, 1990). This is about 20% of the entire forests in Bangladesh (Hussain and Acharya, 1994). The top-dying disease is believed to be caused by an array of factors *viz*., increased soil salinity due to reduced water flow, reduction in periodic inundation, excessive flooding, sedimentation, nutrient imbalances, pathogenic gall cankers, and cyclone-induced stress. When the salinity increases, the species becomes stunted, rare and ultimately disappears.

Sundari affected by top dying, where death of twigs and small branches gradually reduce the canopy and destroys the growth potential of such trees which may also suffer from death of the top of main stem and be truncated while the remaining portion of the main stem remain healthy. Dead but standing Sundari almost devoid of major branches, may result from infection by one or more sap wood rotting fungi which kill the sapwood and thereby the attacked tree is died. Moreover, Sundari trees are attacked by borers and wood decay fungi. Death of small twigs may be due to the occurrence of gall-cankers. Trees are also seen where only small twigs and branches die and there are no gall cankers. The initial stage of death of twigs and small branches has been seen to be associated with certain insect eating up tender bark of twigs. During October to December, dead twigs and branches have been seen on many hundreds of trees but in no case dying branches were seen. Further observation of January onward is needed to detect the early stage of symptom expression. In other cases, top dying trees are seen to develop very reduced, deformed and bronze colored leaves of very little photosynthetic potential. There are several other symptoms associated with the top dying disease of *H. fomes* that include:

Root rot and resultant die back: A large number of dead Sundari trees are affected by root rot disease. Characteristics symptoms are leaves become gradually discolored pale and light yellow, then yellow and finally fall off the tree.

Sap and heart rot associated with top dying: In general, top dying Sundari trees have a dead and truncated top with accompanied death of twigs and branches to a varying degree leaving a variable extent of healthy canopy. A proportion of Sundari are seen to be dead from top to bottom. Such trees seldom have any live branches. Examination of such dead trees reveals that the bark dies first and is followed by decay and deterioration of the wood. Occasionally both sap wood rot and heart wood rot may occur simultaneously. In other cases even in the absence of any sap wood rot, death and decay of heart wood by a white rot fungus provisionally identified as *Fomes badius* occurs. In this, rot generally destroys the heart wood of the trees, while sap wood remains healthy. Such damage does not cause death of trees, but it weakens the mechanical support of such trees and thereby renders these trees to be more prone to wind damage. Heart rot may occur from the basal part of a tree or it may occur both from the basal part of a trunk and/or from different locations on the main trunk through dead broken branch stubs and then progresses both up and down the trunk.

Dieback of the foliage: In a number of sites where excessive siltation has buried all or a portion of the pneumatophores, Sundari in particular and other trees in general have been seen to produce leaves of very diminished size, light bronze in color, having a general pale appearance. Such trees can add very little new growth. Quite often such branches are seen to die and ultimately most of the affected trees die or show rapid death from top to downward. Top-dying of Sundari appears as a decline and dieback of the foliage and twigs of a part of the crown, but ultimately the main stem becomes affected and may also be truncated having a variable extent of the crown. Top-dying of Sundari and dieback of the foliage and twigs of a part of the crown appears as a decline. In case of older trees, one or more of the major branches may die and gradually other branches die and ultimately the crown is substantially reduced (Rahman, M. A. Methodology of Pathological Research in Mangrove Forest unpublished).

Hence, the important causes that can be attributed to the top-dying diseases are: (i) soil salinity, (ii) burial of pneumatophores, production of reduced number of it creates reduced soil aeration affecting metabolism in the root system, (iii) deficiency of micronutrients and presence of high level of calcium, (iv) greater opening in the canopy, *Loranthus* infestations, higher dbh (Diameter at breast height) classes are associated with severity of top-dying disease, (v) Once top-dying starts a number of fungi degrade wood of the tree, and (vi) insect infestation of sapwood and wood decay fungi has linear positive association.

Invasion

Biological invasions are now considered one of the main threats to world's biodiversity. Impact of these invasive or associated species on Sundarban mangroves are that they (i) compete with indigenous plants for light, nutrients and moisture; (ii) impede natural regeneration; (iii) cause physical damage to the native species and (iv) change water quality or characteristics and habitat for fish and other aquatic organisms. Invasive species spread into natural vegetation due to disturbance. 23 invasive species belonging to 18 families and 23 genera are present in Indian Sundarbans (Biswas *et al.,* 2007). Among these identified species, 3-species are highly invasive, 6 are moderately invasive and the remaining are potentially invasive. However, *H. fomes* is positively associated with *Derris trifoliata, Hoya parasitica* and *Micania scanden* in the Sunderbans (Biswas *et al*., 2007).

Extreme Weather Events

The *Sundarban*s is already affected by climate change and extreme weather events such as tropical cyclones and storms. Mangrove forests protect all types of coastal communities from the fury of extreme weather events by means of their mere presence by providing the best shelterbelt. Tropical cyclones and storms are more common in the Bay of Bengal, severely affecting the eastern coast as compared to that of the western coast. According to Koteswaram (1984), there were about 346 cyclones that include 133 severe ones in the Bay of Bengal, between the years 1891 and 1970. These cyclones with tremendous speed hit the coastline and inundate the shores with strong tidal wave, severely destroying and disturbing coastal life.

Tsunami-induced human death and property loss were also behind mangroves and sand dunes. The mitigating effect of mangroves depends on their response to two physical processes of tsunami - (i) wave attack, and (ii) towing flow. Mangrove's response to wave attacks depends on its vegetation characteristics, whereas the response to towing flow relies on 'drag force' caused by the mangroves, resulting in prevention of coastal erosion. Thus the protective role of mangroves depends on: (i) vegetation characteristics such as, density, height, species composition, density of forest, diameter of mangrove roots and trunks, and elevation of habitats, as well as status of ecological degradation of the forests; and, (ii) tsunami wave characteristics such as wave height, wave period, and depth of water. Protection and restoration of mangroves, coastal forests and sand dunes would mitigate the impacts of not only tsunamis, but also storms and sea level rise.

C. Management Practices

H. fomes is the single most important species of the Sundarbans, but the dominance of *Heritiera* forest is decreasing. As a pure crop and in mixture with *Excoecaria agallocha*, the species occupies ca. 18.2% and 62.4% of the forest area respectively (Anon, 2001). The species necessitates mass vegetative propagation, an alternative to seed propagation, for perpetuation of the species and their re-establishment in the area (Hartmann and Kester, 1989). Few studies dealt with the effect of auxins (IAA, IBA & NAA) on rooting of the pre-girdled stem cuttings and air-layers and the biochemical changes during initiation and development of roots in *H. fomes.* Extensive physical and biological changes in last 50 years have led to artificial assemblage of *H. fomes*, *Sonneratia apetala* etc., species owing to economic needs and environmental change (Snedaker, 1982). There are reports of development of management plans for coastal plantations targeting to achieve many objectives *viz*., (a) to continue the establishment of coastal forest plantations and initiate management of existing ones for their timber value, (b) to protect and preserve areas of environmental value relating to conservation of biodiversity resources, (c) to integrate people's participation and development, (d) to enhance and promote recreational and tourism potential etc. (Canonizado, 1999). In addition to the forest department, some NGOs and local people's groups are now engaged in forest management activities using the following key management strategies.

Adoption of holistic management approach: The Sundarbans have been under systematic management for *ca.* 130 years. In the past, a sustained yield principle under the selection system was applied and main emphasis was given to two or three timber species. Recently, emphasis has been put on ecosystem management and timber felling is now banned. Salvage felling and enrichment planting has started to restore forest health (Siddiqi, 2001). However, continuous pilferages of valuable species are a major threat to sustainability (Naskar, 1999). Integrated regional development plans are necessary to increase the supply of freshwater to the Sundarbans through excavation of rivers and revision of treaties with India.

Biodiversity conservation and enhancement: Mangrove plantations are offering a new habitat to the wildlife of the Sundarbans. In addition, some parts of the mangrove forest and plantations are declared protected areas under a different status *e.g*., wildlife sanctuaries, national park and ecologically critical areas.

People's participation in forest management: Under the Coastal Greenbelt Project (CGP), a people oriented participatory forestry program was targeted to improve the socio-economic condition of the rural poor, improve the role and status of women in rural enterprises, diversify and supplement farm income, substitution of locally produced coconut for improved oil and enhance the environmental quality including the restoration and/or protection of critical mangrove habitat (Canonizado, 1999).

Modeling for optimizing plantation design: The mangrove plantations are playing an important role in reducing the impact of these cyclones and accompanying surges. It is essential to maintain the shelter belt, but as yet, no fixed width has been determined. In Indian Sundarbans, modeling studies are being carried out to find the optimum plantation width and the number of rows to increase protective efficiency.

D. Discussion

H. fomes is one of the most important endangered/threatened species in Indian Sundarbans. Due to durability and hardness of wood, this species is very much useful for boat building and several domestic purposes as well as for furniture making. But, these days, it is occasionally found in the tidal swamps of the Sundarbans, especially in the western zone, where the salinity level is high up to 25 ppt and human interference is more. The trees of *H. fomes* are being exploited indiscriminately for its timber value, since long. Only a few plants of *H. fomes* are found in the eastern part of Indian Sundarbans in association with other species. But most of the *H. fomes* plants are noted for scanty growth and the sizes of those trees are not as big as the normal tree. Inside the ridge of tidal forest zones in the Sundarbans tidal forest some of the *H. fomes* are also found. Their growth is more vigorous than the river side trees. The differences in growth experienced may be due to higher salinity towards the river side forest than the inside higher level ridge forest area; and more human pressure on the river side trees.

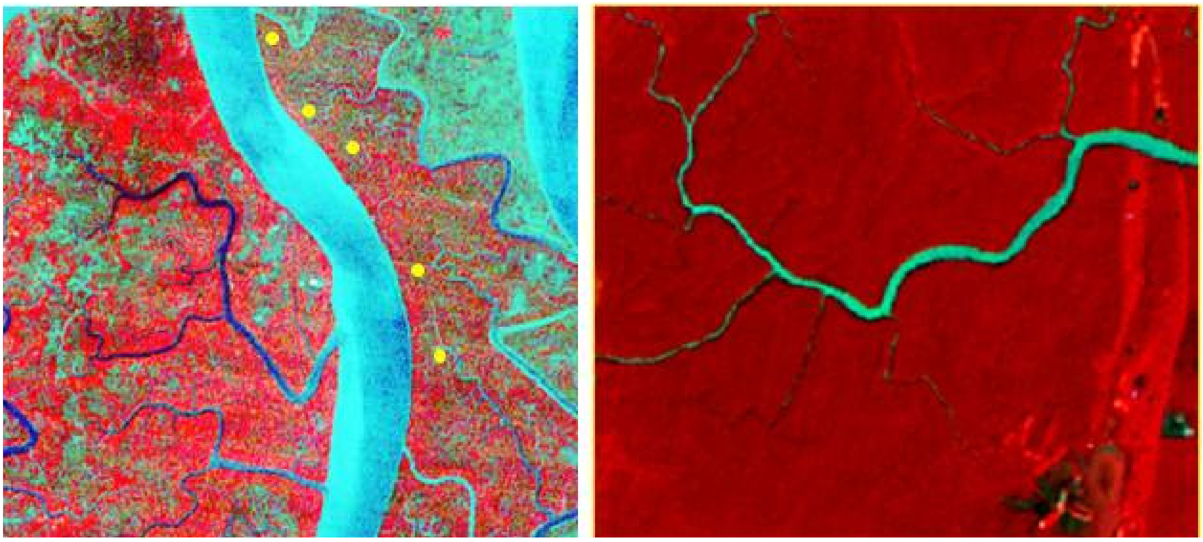

Plate 3: ***H. fomes*** **as seen on satellite image (LH) found in scattered patches in the Sundarbans, West Bengal; luxuriant growth in Dangamala region of Bhitarkanika WL Sanctuary, Orissa (RH)**

During field visit to the Indian Sunderbans, the senior author had to search for, to see the presence of the species; whereas luxuriant growth was evident in Bhitarkanika wildlife sanctuary (Orissa), which is also revealed from the satellite data (Plate 3). It emerged from all the above gathered evidences that the species *H. fomes* is approaching fast extinction. And if the *Sundarbans* name has been coined from the forests of *Sundari* (*Heritiera fomes*), then perhaps the world`s largest mangrove forest may need a name change in future days?

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