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Analysis of problems for worldwide mangroves

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Abstract: Mangroves supports a diverse fauna and flora, approximately one million people of Bangladesh and India depend on it directly for their livelihood, and also it provides a critical natural habitat which helps protect the low lying country and its population from natural catastrophes such as cyclones. Despite this role, mangroves particularly Sundarbans has been facing tremendous problems, including that of dieback (top-dying), human destructions, deforestations, illicit fellings, miss-management of the main tree species (*Heritiera fomes*) which is affecting millions of trees. The cause of this dieback is still not well understood unknown. The present work has investigated one of the possible factors that might be causing this problems like top-dying, namely the concentrations of various chemical elements present in the sediments, particularly heavy metals, though other chemical parameters such as the pH, salinity, moisture content of the sediment and nutrient status were also assessed. Tree height and trunk diameter were determined as indications of tree growth, counts of seedlings and saplings were made to assess regeneration success, and the intensity of top-dying within the sampled plots was recorded on a rank scale. However, the present results have showed that Sn, Exchangeable K, soil pH, Pb , Zn and Ni could be directly linked with top-dying disease of *Heritiera fomes* (Sundri) in Sundarbans, probably particularly by weakening the vigor of the trees and people and allowing other factors such as pathological agents to attack the plants and surrounding people in Sundarbans, Bangladesh (Awal, 2014).

Keywords: Status of World Mangroves, Chemical Contamination, Causal Factors, Heavy Metal Concentrations, Sundarbans, Top-Dying

1. Introduction

Coastal lands cover 6% of the world's land surface (Tiner, 1984). Coastal and wetlands everywhere are under threat from agricultural intensification, pollution, major engineering schemes and urban development, (UN-ESCAP 1987; 1988). Mangroves in Asia including Bangladesh, India, and East Africa previously contained a much fuller range of species (Seidensticker, and Hai, 1983; Khan, 1997). In the Southeast Asian region, species diversity of mangroves was previously much higher, where approximately two-thirds of all species and 70% of the major vegetation types with 15% of terrestrial species in the Bangladesh-India-Malayan realm have already been destroyed (Ellison, 1998, 2000). The Indo-Pacific region is known for its luxuriant mangroves. Some earlier estimates of the distribution of mangroves include Bangladesh, Australia, Burma, Brunei, Fiji, India, Indonesia, Kampuchea, Malaysia, Pakistan, Papua New Guinea, Peninsular Malaysia, Philippines, Sabah, Sarawak, Sri lanka, Thailand, Vietnam (Government of India, 1990). The distribution of mangroves in the Indo-West Pacific bio-geographical region is outlined in Macnae (1968).

The mangrove zone of Bangladesh is about 710 km long including several tiny islands (Rahman, *et al.,* 2003). In the present day the Indo-Malayan mangroves are confined to Sundarban reserved forests, mainly in Bangladesh. According to Miller *et al.* (1985, 1981), this forest had been affected by human settlement, human destruction, heavy metal contaminations in soil and water, illicit felling, poaching, encroachment and agricultural activities during and under both the Bengal Sultanate (1204-1575) and the Mughal Empire (1575-1765).

But, at the arrival of British rule in 1765, the Sundarbans forests were double their present size and significant exhaustion of the growing stock led to dwindling by 40% - 45% between 1959 and 1983 (Chaffey *et al.,* 1985).Representing 2.5 percent of the world's mangrove forest (Saha, 1991), the Sundarban forest is still the largest natural single tract of mangrove forest and habitats in the world (Christensen, 1984; Seidensticker and Hai, 1983; Hussain and Karim, 1994) with 10, 029 km^2 area. The total area of the part of Sundarban in Bangladesh is now about 6,017 km^2 (Imam, 1982; Christensen, 1984; Chaffey *et al.,* 1985), which arose due to the eastward shift of the Ganges (Blasco, 1977; Naskar 1999; and Bakshi, 1954; Thom, 1982). *Heritiera fomes* (Sundri) is the predominant tree species, supporting about 65% of the total merchantable timber (Chaffey *et al.,* 1985, and Siddiqi, 2001).

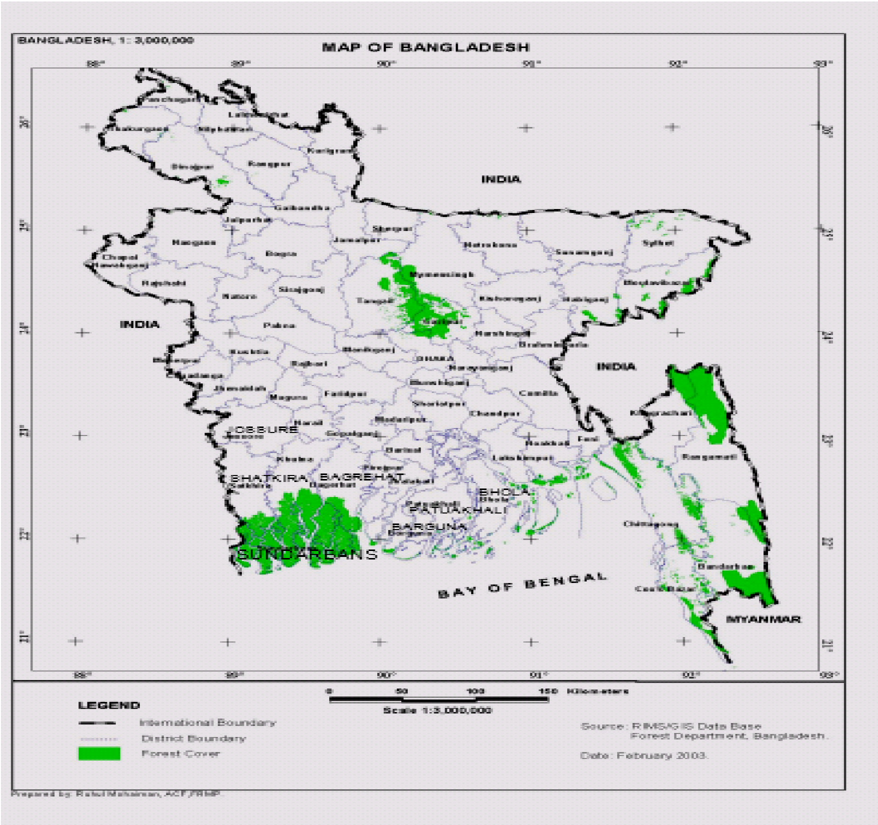

Figure 1.0. *Map showing the administrative districts of Bangladesh, including the location of the Sundarbans (the shaded area in the south-west of the country).*

Due to over-felling, principally of Sundri and *Excoecaria agallocha* (Gewa) for timber and industrial raw materials, the overall loss of mangroves area in Bangladesh had exceeded 300,000 cubic meters annually (FAO, 1982). The Chakoria Sundarban in eastern Bangladesh, which has now been almost completely depleted for aquaculture (ADB, 1995), cleared by 34% between 1975 and 1990-91, and in Sundarbans the amount of *Heretiera fomes*, declined from 31.6 to 21.0% of the total number of trees between 1959 and 1983 (Chaffey, 1985). Thailand's mangrove forests, where more than half of the total area (some 208 220 ha) was lost, and Bangladesh's Chakoria Sundarban mentioned above which disappeared between 1961 and 1993, are two notable examples of such mangrove forest decline.

Land reclamation and other coastal developments have also been responsible for the destruction of wildlife habitats and natural resources, as well as some fine natural coastlines in the Republic of Korea (Government of Republic of Korea, 1994). The total management resource in Thailand has shrunk from an estimated 368,100 ha in 1961 to 196,643 ha in 1986-87 (FAO, 1982). Such mangrove areas are under various threats from human-intensification, disturbance and exploitation. In respect of non-wood forest products, the importance of bark tannins has declined in many Asian countries, but some mangrove tannin is still used in India and Bangladesh for leather curing and for fishing-nets curing in Sri-Lanka (FAO, 1982). Through tourism to coastal ecosystems in the Maldives, fish stocks had shrunk and also have been polluted by the combined effects of agricultural run-off and siltation, urban sewage, and industrial pollutants (Government of Maldives 1994). A large number of species of fauna and flora have vanished from the global mangroves (Seidensticker and Hai, 1983). In the U.S.A, and Australia also, mangroves are being adversely affected by both nearby developments and pollution problems (Peters *et al.,* 1985).

In South America, mangrove forests extend from northern Peru on the pacific coast and from Brazil's southern state of Rio Grande do Sul on the Atlantic coast. The mangroves of the Americas continue north along both sides of the Central American isthmus. The 3,900 km Pacific coast had over 340,000 ha of mangrove forests, with a higher floristic diversity than the Caribbean community (Jimenez, 1985). Aridity and the cold Humbolt current limit the southern extension on the Pacific side to about 6 degrees south, whereas higher rainfall and warm currents along the southern coast of Brazil permit mangrove growth to about 28 degrees south. In Honduras, between 80,000 and 120,000 cubic meters of mangrove are estimated to be used for firewood annually. In Nicaragua, according to the permits granted, 9,000 cubic meters a year are collected for firewood (Jimenez, *et al.,* 1985), and according to the researchers, the El Salvador harvest is approximately 30,000 cubic meters a year (Miranda, 1998). Buffington (1987) reported that California had lost 91% of its wetlands, the Louisiana delta had been losing 104 km^2 each year recently prior to that date and the national loss rate for wetlands in the 1970s was 185,000 hectares a year (Tiner,1984). Coastal biological resources have been depleted by commercial fishing, including poison and blast fishing (Jones, 1992). In addition, pollution from shipping, in particular oil, and in some areas the discharge of toxic wastes, had adversely affected the marine environment (UNESCAP 1988). Since only about 1% of total global mangrove area is under some sort of protection status, but, there is still grave danger of further massive losses (Awal, 2007, 2009, 2014). Large undisturbed forests still remain in remote areas, however (Snedakar *et al.,* 1977, 1984). Mangroves also penetrate some temperate zones, but there is a rapid decrease in the number of species with increasing latitude (Chapman, 1976). For the above reason, on average, one species of flora or fauna is believed to become extinct worldwide every day (Awal, 2007). It is also believed that today mangrove forests comprise 15.8 million hectares, or 0.6% of all inland forests in the world. This is roughly less than half the original mangrove forest cover, and is fast declining further at an assumed rate of 2 to 8% per year (Peters et al., 1985).

1.1. The Sundarbans Mangrove Forest Location and Extent

The Sundarban mangrove forest is located mainly at the southern portion of the Gangetic delta bordering on the Bay of Bengal of Bangladesh *(Figure 1)*. It occupies a flat deltaic swamp rarely exceeding 0.9 to 2.1 m above the sea level and most of the area is under water during the high spring tides of the monsoon and the major portion of land is a low plain with maximum 10 m height above mean sea level (FAO, 1994). Sundarbans is subdivided into 8 blocks (Rahman, 2003) and further subdivided into 55 compartments (*Figure 2*), varying in size from 4000-16,000 ha (Tamang, 1993), depending on the height classes & stocking conditions of the forest trees. The forest lies just south of the topic between 21º38´- 22º30´ North latitudes and 89º0´-90º0´East longitudes. Within the total areas of the Sundarbans, *Heritiera fomes* constituted 63.8% among the total tree vegetation (Chaffey *et al.,* 1985).

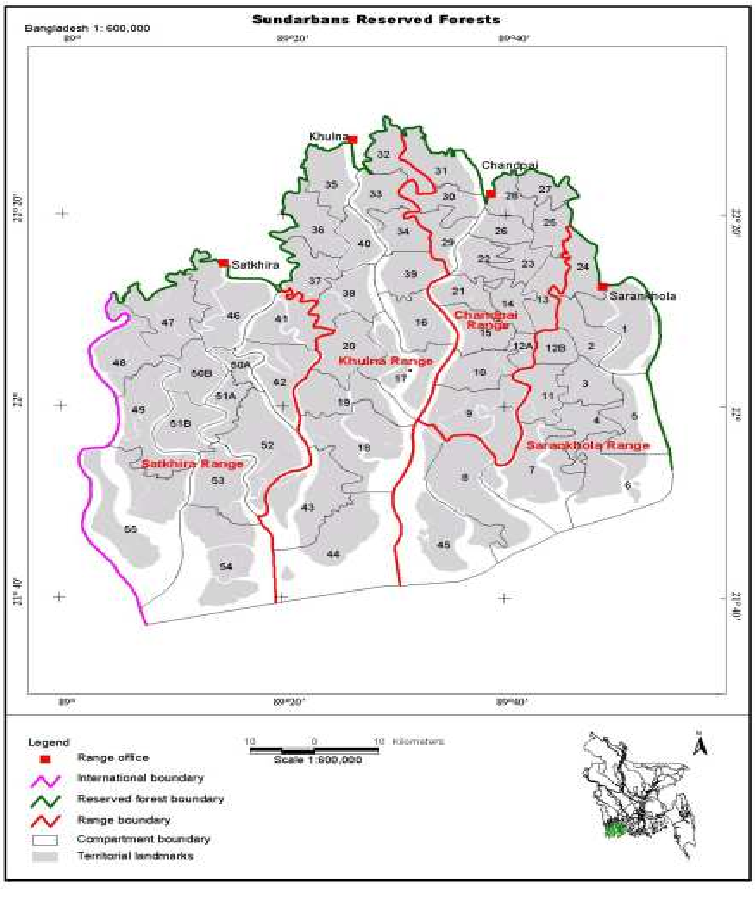

Figure 2.0. *Shows compartment numbers and Ranges of Sundarbans Reserved Forest.*

1.2. Climate of Bangladesh Sundarbans

The climate of Bangladesh is sub-tropical and tropical with temperature ranging from an average daytime low of 15ºC in the cold season to a high of 35ºC in the hot season (Statistic of Bangladesh, 2006). Mean annual rainfall varies from about 1,800 mm at Khulna, north of the Sundarbans, to 2,790 mm on the coast (Choudhury, 1968). Relative humidity is high (80%) in Sundarbans, and annual mean relative humidity in this forest varies from 75%-80%. There is a six month dry season during which evapotranspiration exceeds precipitation. Conditions are most saline in February-April, the depletion of soil moisture being coupled with reduced freshwater flow from upstream (Awal, 2007). Temperatures rise from a daily minimum of 2- 4°C in winter to a maximum of about 43°C in March and may exceed 32°C in the monsoon with the average being about 24ºC in January and 35ºC in June (Imam, 1982). Storms are common in May and October- November and may develop into cyclones, usually accompanied by tidal waves of up to 7.5m height (Alam, 1990; Christensen, 1984; Seidensticker and Hai, 1983).

1.3. Hydrology and Tides

A large part of the Sundarban remains above tidal level during the lean season, while only a part is flooded during the spring high tides and a small part in the South and West is tidally flooded throughout the year. However, the whole of the Sundarbans becomes submerged during high monsoon tides. The depth and duration of tidal inundation depends on factors including: (1) the distance from the sea and the main river; (2) local relief; (3) the general elevation of the area; and (4) the load content of the inundating water. These factors also influence the ecological conditions of a site within the Sundarbans. The Sundarbans are criss-crossed by a network of interconnecting channels (Islam, 2003) and the main rivers are the Baleswar, Passur, Sibsa, Kobadak, Jamuna and Raimangal. The Baleswar and Passur rivers are linked with the Ganges through the Gorai-Modhumati, and the Arial khan rivers. The Sibsa and Kobadak rivers are not connected with the main flow of the Ganges during the lean season. The Baleswar, washing the eastern fringe of the Sundarbans, receives the bulk of the Ganges water while the Passur shares only a few cusecs during the lean season (Own observation, 1993-97).

1.4. Conservation Value of Sundarbans

The future of Sundarbans is as directly dependent on the health of her wetlands, as is the future flora and fauna. Considering the limitations of the current planning process in Bangladesh, it is possible that within a few short decades, as water tables fall, rivers run dry and lakes shrivel, water–riots will become the order of the day. It may also be the case that wars on the subcontinent will more likely be fought over water than oil. And until uncontrolled development is restricted, the threat of floods and droughts due to loss of mangrove systems will continue to be present (Sahgal, 1991). Coastal lands include some of the most productive of ecosystems with a wide range of natural functions, but are also one of the most threatened habitats because of their vulnerability and attractiveness for ‘development’. The first global conservation convention, the Ramsar Convention, focused solely on coastal lands and wetlands, and it has recently been strengthened and elaborated with regard to the wise use of all coastal areas such as Sundarbans.

By the 1970s, the majestic royal Bengal tiger *(Panthera tigris)* population in the Sundarbans had declined to an alarmingly low level due to forest degradation since tiger habitats are *ipso facto* high grade forests, and the deer *(Axix axis)* has also dwindled recently (Ghosh, 1988; Hai and Seidensticker, 1983; Seidensticker, 1986).

Water birds serve as another example of decline. With their dependency on patchy food supplies, they must integrate resources over large areas; their nesting and roosting sites vitally require protection (Personal observation, 1993-97). Generally, the diversity of species in the Sundarbans was quite high, but the present status regarding population, habitat, and food of wildlife in Sundarbans in Bangladesh is threatened (Personal observation, 1993-97). The various factors that threaten the Sundarbans are outlined in the following section.

1.5. Salt Production in Sundarbans

In many regions of Asia with a seasonally dry climate, large areas of mangrove were cleared in early times for solar salt production. Today there are still areas diverted entirely to salt pans. Elsewhere salt production is rotated with shrimp farming in the wet season, as in the Sundarbans (Nuruzzaman, 1990). In addition to the physical loss of mangroves through coastal industrialization, there are also concerns over environmental effects from pollution, Burns *et al.,* (1993) noted that there were 157 major oil spills in tropical seas between 1974 and 1990. Deep mud coastal habitats may take 20 years or more to recover from the toxic effects of such oil spills, although aquaculture operations impact on the environment has increased recently (Phillips, 1994).

1.6. Altered Pneumatophores

Chaffey (1985) reported that reduction in the number of lenticels on the pneumatophores might be associated with top-dying of Sundri. Accordingly, a study was carried out in which the numbers of lenticels were counted under a magnifying lens on 90 sq. cm area of the pneumatophores of nine top-dying and nine healthy Sundri trees, selected randomly from relatively fresh water zone at Burigoalini. Actually, the results indicated that there was no relation between the number of lenticels on the pneumatophores and the top-dying.

1.7. Entomological Causes

As the heart rot fungi decay the wood and beetle larval tunnels increase, the commercial value of the wood is largely diminished (Chowdhury and Baksha, 1983). A study of the state of health of the cable, anchor, and nutrition roots of healthy and top-dying Sundri trees was conducted at Sutarkhali. The results showed no significant difference in the root of healthy and top-dying trees (Singh, 1986, Chaudhury, 1968; and Gibson, 1975).

Chowdhury (1973) observed plenty of *Chrysocroa* species in the twig crotches of dead and dying Sundri trees in the compartment Nos.26, 28, 29, 30 and 31 at Mara-Passur in adjacent areas. The role of *Chrysocroa* species in the initiation of top-dying of Sundri was subsequently studied and reported by Chowdhury and Baksha (1983). For the study, three diseased trees at various stages of attack and one healthy tree were selected at random in each of compartments 31, 32 and 46 representing relatively fresh water, moderately saline water and highly saline water zones respectively. The trees were felled and split thoroughly from top to bottom. The position of the dead branches, larval tunnels and the portions damaged by heart rot were recorded. There were in all 19 dead branches of which the relative positions of 15 branches were from the sites of the larval tunnels and heart rot. Heart rot was observed in 11 out of 12 trees. According to them, it became obvious that larval tunnel and /or heart rot did not have any contiguity with the dead branches. Even the tissues at the base of these branches were found to be healthy and the entrance holes of the larvae were healed up. They concluded that *Chrysocroa species* did not have any role in the initiation of top-dying of Sundri (Chowdhury and Baksha, 1983).

1.8. Pathological Causes

Pathological studies on top-dying of Sundri were conducted by Rahman *et al.* (1983, 1986). Based on these and other studies conducted so far (reviewed in Rahman *et al.,* 1986) there does not appear to an association between pathological factors and top-dying. According to Rahman et *al.* (2001), a precise description of symptoms of any plant is important for further study leading to disease prevention. The same is true in case of top-dying of Sundri as well.

Therefore, trees were labelled in each of the damage categories (Rahman *et al.,* 2001). After that the labelled trees were observed to identify the symptoms of top-dying on the various branches at the time of recording within the selected plots. Subsequently, observations at monthly intervals were recorded of the symptoms of top-dying on the branches and progressive changes were recorded for 12 months. In this way Rahman *et al.* (2001) tried to identify the first symptom expression and its progressive changes over time. But there is a big gap between primary and secondary causes of infection and symptoms for each particular Sundri tree. There is no scientific proof that pathogens are causing this top-dying of Sundri. Many of the scientists had made technical comments about pathological studies, but they did not find any scientific base for the correlation between pathogens and top- dying. Previous research had tried to find out the causal agents of top-dying of Sundri, and tried to determine the infection-biology of the causal factors (pathogens) for top-dying of Sundri (Hartung *et al.* 1998; Chowdhury and Baksha, 1983, 1986; Rahman *et al.* 1983). Rahman *et al.* (2001) also tried to find out the biotic and a-biotic factors responsible for aggravating the top-dying disease of Sundri. However, they failed to find out the real cause of top-dying of Sundri.

Hartung *et al.,* (1998) reported their findings about the putative biotic disease agents of top-dying of Sundri in the Sundarbans. For the study, they collected 20 samples of wood, bark, and leaves from compartment 19, 22, 26, 32, and 39 in 1997. This study was conducted for the isolation of bacteria, and eight types of bacterial colonies were recorded. The color of bacteria colonies were white, yellow, red, white-yellow, yellow-white, yellow-brown, grey-white, shiny-white, etc. There was no yield of bacterial colonies from wood tissues taken from un-affected Sundri trees (3 samples). Samples of affected-dead-standing Sundri (2 samples), 4 unaffected wood samples of other tree species (2 from gewa, 1 from Passur, and 1 from Goran) were taken. Out of the 6 to 8 types of bacterial colonies, two isolates have been identified as *Arthrobacter nicotianae* and *Pseudomonas* species due to their sequence homologies in a PCR assay. Both the species of bacteria were isolated from samples of severely top-dying affected living Sundri trees. The bacterial species showed phytopathogenic ability in a bioassay. The authors concluded a close association of phytopathogenic bacteria with top-dying disease of Sundri (Hartung *et al., 1998*). But a thorough search of literature does not reveal any association of *A. nicotianane* with any other tree disease problem anywhere in the world (Awal, 2007). Moreover the data presented do not provide enough evidence of consistent association of *Pseudomonas* species with top-dying of Sundri wood.

1.9. Gall Cankers

Occurrence of cankers on top-dying Sundri trees has been recorded by Curtis and (1933), and Chowdhury (1973). It may be noted that the cankers on apparently healthy trees could be an early stage of deterioration and death of twigs or branches. Rahman*et al.,* (1983) reported that a fungus identified as *Botryosphaeria ribis* was consistently isolated from Sundri canker.

An early stage of gall canker develops on Sundri saplings. To investigate the proper cause of canker, the fungi were isolated from the bark and woody tissues of Sundri Canker samples following standard phytopathological method (Booth, 1971). One fungus was isolated as 'BFRI 230' and identified as *Botryosphaeria ribis*, and occurred consistently. A number of other fungi were obtained only sporadically and hence disregarded.

The distribution and severity of perennial canker development on healthy and dying twigs, branches and stems of Sundri were studied at Sutarkhali Sarbotkhali, Kalabogi and Mankiduania (Rahman *et al*., 1983, 1986). It was found that there were top-dying trees which had virtually no canker. The results suggested that there existed an association between top-dying of Sundri and twigs and branches with gall canker in nearly 50% of the top-dying Sundri trees surveyed, but in some trees the top-dying condition was independent of gall canker development. There is therefore no conclusive link between the canker and top-dying.

1.10. Destruction of Sundarbans

Mangroves in Asia including Bangladesh, India, and East Africa previously contained a much fuller range of species (Seidensticker, and Hai, 1983; Khan, 1997). In the Southeast Asian region, species diversity of mangroves was previously much higher, where approximately two-thirds of all species and 70% of the major vegetation types with 15% of terrestrial species in the Bangladesh-India-Malayan realm have already been destroyed (Ellison, 1998, 2000). The Indo-Pacific region is known for its luxuriant mangroves. The mangrove zone of Bangladesh is about 710 km long including several tiny islands (Rahman, *et al.,* 2003). In the present day the Indo-Malayan mangroves are confined to Sundarban reserved forests, mainly in Bangladesh.

2. Methodology

In this section the various field and laboratory methods used in this study will be discussed as below:

2.1. Field Sampling Methods

The Sundarbans Reserved Forest is located at the south west corner of the Ganges River Delta close to the Bay of Bengal, mainly on the sea-shore line, river banks, channels, and small creeks. The location of the Sundarbans within Bangladesh has been shown in *Figure 1.0.*

2.1.1. Site Selection and Location of the Study Area

General reconnaissance of possible sites was made by visiting all the possible regional areas before categorizing and selecting plots for sampling. It was decided to sample from the Chandpai area which is the mostly human accessible and ecologically polluted area (in *Figure 2.0)*. Of the three chosen compartments, the nearest compartment to Mongla port is compartment 31, with comparatively modest human activities, but which nonetheless involve clear-cutting of natural vegetation, replanting with other species rather than mangrove or other native species, all types of soil erosion, and construction activities present. Within each of the three compartments, detailed observations of the regeneration and sampling of soil and water took place within three 20 m x 20 m plots, chosen to reflect a range of top-dying intensities (High, medium and Low for that area). The sampling was conducted in a randomized block design, in that a plot was sited within a particular top-dying intensity block, but the precise location of that plot was randomized so as not to bias the detailed data collection. Thus in total nine plots were sampled, representing a range of top-dying intensities. Intensive field data collection was made among these nine selected plots (*in Figure 3.0)*. Observations were performed from observation towers during low and high tides, also traversing the forest floor and vegetation on foot, as well as using a speed boat, trawlers, country-boats, and a launch as required to gain access.

Figure 3.0. *Photograph showing the Sundarbans forest trees and understory vegetation. The adult trees behind the author are of Heritiera fomes. The forest floor shows dead leaves from trees affected by top-dying.*

All sampling was accompanied by Deputy Rangers, Foresters, and Forest guards armed with a rifle from the local office, Chandpai range, Bangladesh Forest Department, to prevent a fatal

Fieldwork was performed in October, 2003 to March, 2004. Locations of sampling points were determined using a Global Positioning System with a precision of 5-10 m. For one typical plot, in compartment 31, the altitude was recorded as 4.4 m above sea level.

2.1.2. Vegetation Recording Methods in the Field

Within each of the nine 20mx20m plots, each adult tree was assessed for three parameters. The diameter at 1 m height was recorded (in cm) by using a tree diameter-measuring tape or slide calipers depending on girth. The tree height to the top of the crown was determined mainly by ocular estimation but some heights were checked by using Clinometers at a set distance of 20 m to test the accuracy of such ocular estimations.

Finally, the status of the tree in respect of the amount of top-dying was assessed by using a four point qualitative scale of intensity, namely; not affected, little affected, moderately affected or highly affected by top-dying. This was later expressed as a semi-quantitative or rank scale of 0 to 3 respectively, so that a median rank value could be calculated and used as an index of top-dying intensity in that plot. After that, the total number of seedlings (individuals of the tree species <1 m tall), and saplings (young trees >1 m tall with a diameter of trunk of < 10 cm), were counted within the plots. Care was taken to ensure that trees, saplings and seedlings were not counted more than once or missed in the counting process. After recording, adult trees were marked with white chalk to segregate those marked trees from other trees, seedlings and saplings; red paints were applied to all seedlings and saplings as they were recorded.

2.1.3. Soil and Water Sampling Methods

As stated above, from the three selected compartments, a total of nine plots of 20m x 20m were selected. From each of these plots, seven soil samples were collected; one from the centre of the plot, four (one each) from all the corners, and two from the middle sides of the plot. Therefore a total of 63 soil samples were taken. Also nine water samples were collected from nearby rivers, creeks or channels, one from the area of each of the sampled plots. Soil samples were collected from 0-30 cm soil depth by using a stainless steel spatula and steel cylinder (d=5.25 cm), and all soil samples were kept in sealed plastic bags. Water samples were collected directly in pre-cleaned plastic-containers. Marking and labelling was performed with a detailed description of the selected sampling site on both the soil-containing plastic bags and water containers, and preserved in portable coolers until arrival at the laboratory at Dhaka University for initial chemical analysis. This field sampling method followed the W.H.O, U.K, and E.P.A systems of standard laboratory and field sampling principles, rules and regulations. Rainfall for the area during sample collection was not notably different from the respective monthly averages for the Sundarbans of recent years; there was no heavy intensity of rainfall within one month before sampling.

Any evidence of changes was recorded, sometimes obtained through asking local people and forestry staff, or from personal observations. In particular, any soil erosion and diversion of the river's position or of new channels and creeks observed during the data collection period were recorded, as were signs of siltation changes.

2.1.4. Questionnaire Survey of Local People

In order to establish the views of local people about the incidence and causes of top-dying, a questionnaire was prepared for asking peoples either individually or in groups. This survey was done among people living or working in the 17 Sub-Districts of Sundarbans, making a distinction between those living within and outside of Sundarbans. They were asked whether they had seen the top-dying disease of *Heritiera fomes* (Sundri) in Sudarbans for a long time, either through living within the Sundarbans or through visiting Sundarbans for their daily work, for their professional work such as forestry officials, for fishing or for collecting wood as wood cutters, for seasonal honey collection, or other purposes. Groups were made up among targeted people in all locations and from all categories mentioned above, based on age, profession, and also for their sharp memory. In this way, 50 questionnaires were filled up through interview, mostly of groups and sometimes of individual people. The justification of selection of people for the questionnaire survey was that the targeted people were familiar with the top-dying problem in Sundarbans, and are related through their professions with Sundarbans directly and indirectly. The questionnaire started by establishing that the respondents were familiar with top-dying, and went on to seek their views and information on what changes they had observed and whether they had noticed possible causes. This was possible because, most of the interviewees are living within the Sundarbans for their daily activities. So, this survey was performed to receive their indigenous response and knowledge towards top dying and its present conditions, and their ideas about what leads to top-dying, as well as questions about tree regeneration and human health in Sundarbans (Awal, 2014).

3. Results

These results are indicated as follows: if one number (all values in ppb) is given it is a mean, otherwise if a range is given they are the minimum and maximum; the number is followed by the type of material from which the data come, with no text indicating it is from sediments (the most common material reported in the literature); finally, the number in brackets indicates the numbered reference source, the sources being indicated in the legend. Besides attempting to establish whether the element concentrations are elevated or not, it is valuable to explore whether there is any marked spatial (as opposed to random) variation in the concentrations found *(table 1)*.

Table 1.0. *Mean (±1 S.E.) and extreme heavy-metal elemental concentrations (ppb) in Sundarbans, together with comparisons with values from other published sources. An asterisk denotes a value below the limits of detection. Comparable data could not be found for all elements.*

Values from this study					**Values reported elsewhere**
Element	**Minimum**	**Mean**	**S.E.**	**Maximum**	**(Data refer to sediments unless otherwise stated; number within brackets indicates source in footnote)**
Al	0.89	16332.44	854.17	37570.00	420 – 585 (soil,[1]); 8089000 – 46100000 ([1]); 500 (spring and well water,[2])
As	*	4.56	0.24	10.06	3150 – 6830 ([7])
B	0.55	19.20	2.14	103.80	2600 (spring and well water,[2])
Ba	0.59	52.41	2.37	141.80	300 (spring and well water,[2]); 141 (coastal soils,[5])
Bi	*	0.40	0.02	0.74	
Cd	0.15	0.55	0.03	1.62	0.52 – 0.92 (soil,[1]); 300 – 13520 ([1]); 43 – 147 ([4]); 0.8 (coastal soils,[5]); 11 – 65 ([7])

Values from this study					**Values reported elsewhere**
Co	5.93	31.31	5.65	143.60	0 – 7.9 (ocean water,[3]); 3800 – 26000 ([1]); 10.6 (coastal soils,[5]); 5540 – 15500 ([7])
Cr	3.11	15.72	3.39	114.90	7 (spring and well water,[2]); 1480 – 8560 ([4]); 41.2 (coastal soils,[5]); 12.8 (water,[6]); 33200 ([6]); 19500 – 46100 ([7])
Cu	1.85	10.52	1.71	43.76	12.2 – 16.6 (soil,[1]); 12940 – 85600 ([1]); 22 (spring and well water,[2]); 22 – 37.2 (ocean water,[3]); 2270 – 14730 ([4]); 23.1 (coastal soils,[5]); 3.8 (water,[6]); 18200 ([6]); 6950 – 31600 ([7])
Fe	25.82	173891.10	9883.85	248200.00	634 – 820 (soil,[1]); 8080000 – 52000000 ([1]); 63 (spring and well water,[2]); 6.2 – 131.5 (ocean water,[3]); 38.5 (water,[6]); 7110000 ([6])
Hg	*	6.41	1.47	83.30	66 – 180 ([4]); 1.8 (water,[6]); 6320 ([6])
Mn	0.70	436.80	14.69	697.00	4980 – 438000 ([1]); 25 (spring and well water,[2]); 1.8 – 40.8 (ocean water,[3]); 3738 (coastal soils,[5]); 7.4 (water,[6]); 412000 ([6])
Mo	0.20	1.62	0.46	26.15	24 (spring and well water,[2])
Ni	7.58	76.08	18.84	1127.00	10800 – 37400 ([1]); 3 (spring and well water,[2]); 0 – 12.1 (ocean water,[3]); 24.5 (coastal soils,[5]); 15900 – 44600 ([7])
Pb	0.32	19.30	0.98	34.19	1.0 – 1.76 (soil,[1]); 1460 – 10400 ([1]); 2 (spring and well water,[2]); 3440 – 15590 ([4]); 74.0 (coastal soils,[5]); 2.3 (water,[6]); 12800 ([6]); 8046 – 15700 ([7])
Rb	0.18	36.37	1.65	76.94	
Sb	*	0.09	0.05	2.93	30 – 94 ([7])
Sc	*	6.05	0.37	8.98	
Se	*	0.17	0.05	1.43	
Sn	*	0.61	0.16	9.68	219 – 654 ([7])
Sr	0.18	27.77	0.89	44.17	2200 (spring and well water,[2])
Ti	4.61	475.39	26.26	1350.00	72 – 341 ([7])
V	0.09	32.93	1.14	51.65	13 (spring and well water,[2]); 18500 – 46900 ([7])
Y	0.03	6.60	0.34	16.69	
Zn	2.30	73.60	2.23	112.50	35.0 – 56.2 (soil,[1]); 120 - 62200 ([1]); 2.4 – 20 (ocean water,[3]); 72.5 (water,[6]); 43200 ([6]); 24300 – 76000 ([7])

[1] Balasubramanian, 1999. [2] Bond, R G & Straub, C P (eds), 1973 [3] Braganca & Sanzgiri, 1980. [4] IUCN Reports 1987. [5] McGrath & Loveland (1992). [6] Sarkar, S.K. et al. 2003 (Premonsoon data from the mouth of the Ganga estuary near Gangasagar used). [7] Zöckler, C & Bunting, G 2006.

4. Discussion

The mangroves in half of these countries, as well as those of other regions, have since been destroyed through various pollution problems and population pressure (Peters *et al*., 1985). The country's food security and public health will be in danger if the water and wetlands are destroyed at the present rate (Awal, 2009). Unplanned natural resources management and environmental contamination in Sundarbans are fast destroying the surface, vegetation, water, and underground fresh water sources (Awal, 2014). Data were summarized by calculating means and standard errors, and by noting minimum and maximum values, for comparison with other data reported in the literature *(table 1)*. The spatial variability in the data was assessed by calculating two-factor analyses of variance with replication, where the factors used were the broad-scale variation between compartments, the smaller-scale variation between plots within the same compartment, and the interaction between these two sources of variation. The concentrations of the various trace metals determined by ICP-MS from our Sundarbans soils are given in *(table 1)*. For completeness, the minimum and maximum values are given, as well as the mean and the standard error, in order to facilitate comparisons with other published information and to indicate the extent of variability between the different samples in the results (Awal, 2007). It is clear that due to destruction of natural resources and contaminations of soil, water for some elements the variability is considerable; for example, nickel has a maximum value many times larger than the mean, while for iron the mean and maximum are more similar but the minimum is substantially smaller.

In particular, the metal values from sediments are likely to be much higher than those from soils, and indeed one author (Balasubramanian, reported by Swaminathan, 2000) found sediment values to be often at least one thousand times higher than values for equivalent soils. The concentration values for the various trace metals recorded in Table 1 are believed to be amongst the first published for soils from the Sundarbans, and as such provide baseline data for comparison with other future studies in the area (Awal, 2007). It has therefore not been possible in many instances to find appropriate comparators from the literature in order to help assess whether the data show elevated concentrations from those expected in such soils. The comparatives information from the literature presented in *(table 1)* is all from the same general region, but includes values from water (from ocean, springs or wells), from coastal soils (but not within the main mangrove areas), and particularly from mangrove sediments, as well as a few from mangrove soils. All comments based on these other sources must therefore be judged on the basis of the differences between the materials in the results likely to be obtained. A further complicating factor in interpreting these results is the high degree of variability in concentrations between different samples shown by many elements, as indicated in *(table 1)* by the high standard error values and by the results highlighted for some elements in *(table 1)*. For most of the elements tabulated there are either no comparisons in the literature, or the results from our study do not appear particularly elevated compared to other results. Perhaps surprisingly, given the problems that have been identified with elevated concentrations of arsenic (As) in groundwater in Bangladesh (e.g. Nickson *et al*., 1998; Chowdhury *et al*., 2000), this element was not notably high in the soils studied here. However, there were other metals which may be elevated in their concentrations. Two results appeared particularly elevated, namely those for mercury (Hg) and for nickel (Ni). In considering the result for mercury, it is recognized that the ICP-MS method of testing the soils is not the most appropriate one for obtaining an accurate determination of mercury concentration because of the potential for cross-contamination of samples from earlier ones due to retention of the element within the instrument. The problem was reduced by the use of gold-wash solution rather than nitric acid in preparation of the calibration standards. Nonetheless, the elevated concentrations of mercury in these mangrove soils can only be considered as an indication until confirmation of these values by further work involving a different analytical procedure can be completed. There is likely to be considerable geographic variation in the extent of pollution problems in the different parts of the Sundarbans, associated both with the proximity to local polluting sources such as Mongla port and with the extent to which the area is influenced by the Ganges river, which is strongly polluted (Sarkar *et al*., 2003). This was indeed found *(table 1)* as there were significant differences between different areas in the Sundarbans with regard to at least some of the elements studied, and others were probably not significant only because of the large amount of variability between different samples within individual compartments. It is therefore perhaps not surprising that the values reported by Zöckler and Bunting (2006) were lower than ours, since their study was in the east of Bangladesh away from the Ganges and other main sources of pollutants. Also, the choice of sites in the present work emphasised areas likely to be polluted because they were near to human activity and hence more accessible. Even so, and allowing for the fact that sediment data is the only comparator medium, the data from the literature suggest that the Sundarbans is not yet as polluted as some other mangroves from the region, such as in Pakistan (e.g. IUCN, 1987).

Clearly, further work is required to confirm and extend the results reported here. The indications of potentially elevated heavy metal concentrations is a matter of concern, and a higher general pollution load is likely to contribute to the increase in top-dying observed in the Sundarbans (Rahman, 2003; Chaffey, *et al*.,1985; Chowdhuy,1984; Gibson; 1975). A likely mechanism of influence might be that greater concentrations of the trace-metals weaken the resistance of the tree to attack by pathogenic fungi. The relationship between individual trace metals and the amount of top-dying will be explored further in a separate article. It is also worth noting that local residents and those who work in the Sundarbans quite frequently reported health problems, of which problems of the skin were the most common (data from a questionnaire, included in Awal, 2007). It is possible that the high concentration of nickel (Awal, 2007), which can cause skin conditions, is leading to such complaints. Such health issues are therefore also a cause of concern and need further confirmation and elaboration.

5. Conclusion

The overall conclusions from the results presented in this section are that the selection of sites has not produced clear statistical differences in the amount of top-dying evident; probably because of the way the data were collected. However, it is believed that there is notable variation between plots and compartments, and certainly this seems to be reflected in the ability of the trees to regenerate. However, the link between top-dying and the size of the trees is not clear, with tree height and diameter not being directly related consistently to amount of top-dying, although moisture content of soil was inversely related. Since the great majority of trees present in all plots is the species *Heritiera fomes*, this means that the comments above are essentially referring to the response of this species rather than that of any others. So that, the Sundri, by contrast, prefers largely fresh water in which it resembles the mesophytes, but the species is adapted to the wet swampy condition of the Sundarbans by virtue of its leaves having partly xerophytic adaptations and plentiful pneumatophores which help cope with the saline swamps of the Sundarbans.The vegetations need sound ecological balanced to survive but due to deforestations, illicit fellings, hunman destruction are responsible for the heavy metal contaminations in soil, water and vegetation(Awal, 2007, 2009, 2014).

Comparing figures in the *(table 1)*, it would suggest that about two thirds of the elements have concentrations which are elevated compare to other reference sources in the Sundarbans. This would be consistent with the evidence that heavy metals were having an influence on top-dying intensity (Awal, 2007, 2009, 2014). The elements Pb, Sn, and Zn were highlighted earlier in this discussion, and although not all of them quite reached statistical significance (Awal, 2007), the positive trend linking two of them to top-dying suggests a likely mechanism of influence, namely that greater concentration of the heavy-metal weaken the resistance of the tree to attack by the pathogenic fungi (Awal, 2007, 2009, 20014). This might well be a process that other elements contribute to as well (Awal, 2007, 2009, 2014), but has not been picked out by the analysis as showing a link because of the variability between samples inherent in the data (Awal, 2007). In this respect, the anomaly of the negative relationship indicated for Sn is harder to explain (Awal, 2007), but a possible process might be an antagonistic response of Sn and another element (Awal, 2007), so that when Sn is less abundant the other element can have a stronger (deleterious) effect on the trees (Awal, 2007), thus allowing more top-dying to occur (Awal, 2007).

A further point is that variations in soil pH from site to site (shown to be significant) will also have a marked effect on the bio-availability of some of these heavy metals (Awal, 2007), and thus perhaps influence top-dying (Awal, 2007).Therefore, we need to protect our global mangroves at any cost.

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