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TREE DIVERSITY AS AFFECTED BY SALINITY IN THE SUNDARBAN MANGROVE FORESTS, BANGLADESH

ASHFAQUE AHMED[*], ABDUL AZIZ, AZM NOWSHER ALI KHAN, MOHAMMAD NURUL ISLAM, KAZI FARHED IQUBAL[1], NAZMA[1,2,3] AND MD SHAFIQUL ISLAM[3]

Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

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Abstract

A botanical expedition to the Sundarban Mangrove Forests (SMF) in March, 2010 was made to study the tree diversity and their abundance as affected by salinity gradient. In six quadrats of 25m × 25m each, distributed in all four Ranges, a total of eight tree species were recorded. A maximum number of five species occurred in relatively low saline sites. Tree zonation dynamics of the forests along salinity gradient revealed an increase in the number of *Ceriops decandra* (goran), a salt tolerant plant in the north-eastern parts of the SMF which was dominated by *Heritiera fomes* (sundri), a freshwater loving plant in 1960's. Highest importance value index (IVI) was recorded for *C. decandra*, which was present in all sites, except Moroghodra, a freshwater zone in Nalianala (Khulna) Range. Comparison of the Landsat images of Nalianala and Chandpai Ranges during 1989, 2000 and 2010 revealed a decreased tendency of dominance of *H. fomes* in the two Ranges but increased tendency of *Bruguiera sexangula* (kankra), *Excoecaria agallocha* (gewa) and *Sonneratia apetala* (keora). Total tree cover in 2010 decreased by about 3% from that of 1989. The changes in the tree composition have been attributed to increased salinity. The changes in the physiography and tree composition of the two Ranges between 2000 - 1989 were considerable.

Zonations and patches of the mangrove plant composition resulted from complex gradients of hydro period (Chapman 1976) and soil conditions, such as nutrient limitation and abiotic stressors, e.g. salinity and sulfide (Nickerson and Thiobodeau 19853). Generally members of Rhizophoraceae dominate most mangrove forests of the world but Sundarban Mangrove Forests (SMF) are dominated by *Heritiera fomes* Buch.-Ham. (Sterculiaceae) and *Excoecaria agallocha* L. (Euphorbiaceae) (Hussain and Karim 1994). The physico-chemical properties of soil and species diversity have been determined by Nazrul-Islam (2003). Using Thematic mapper (TM) Landsat images and GIS techniques the changes in plant cover of the SMF (Giri *et al*. 1997) and and newly accreted islands and coastal areas have been studied (Ahmed *et al*. 2010). The present study is aimed at studying the variation of tree species composition and diversity directly in the field in relation to salinity of soil, and also studying changes that have taken place over a period of about 21 years by analyzing remote sensing data for Nalianala (Khulna) and Chandpai Ranges of the SMF.

The Botanical expedition to the SMF was carried out from 26 to 29 Mach 2010. A total of six sites were considered distributed in all the four Ranges (Fig. 1). A 25 × 25 m plot (quadrat) was studied about 10-15 m inland from the shore for each site following Chen and Twilley (1999) except Kotka (S3), where the plot was considered about 500 m inland from the shore because of destruction of the forest in the periphery by Sidr. All the tree plants within each plot were counted. Phytosociological analysis was done according to Curtis and McIntoch (1950). The Shannon-Wiener diversity index (H) was calculated as described by Krebs (1989).

[*]Corresponding author. <aashfaque67@yahoo.com>. [1]Department of Environmental Science, State University of Bangladesh, Satmasjid Road, Dhanmondi, Dhaka, Bangladesh. [2]Present address: Local Government Engineering Department (LGED), Agargaon, Dhaka, Bangladesh. [3]A Part of MS thesis.

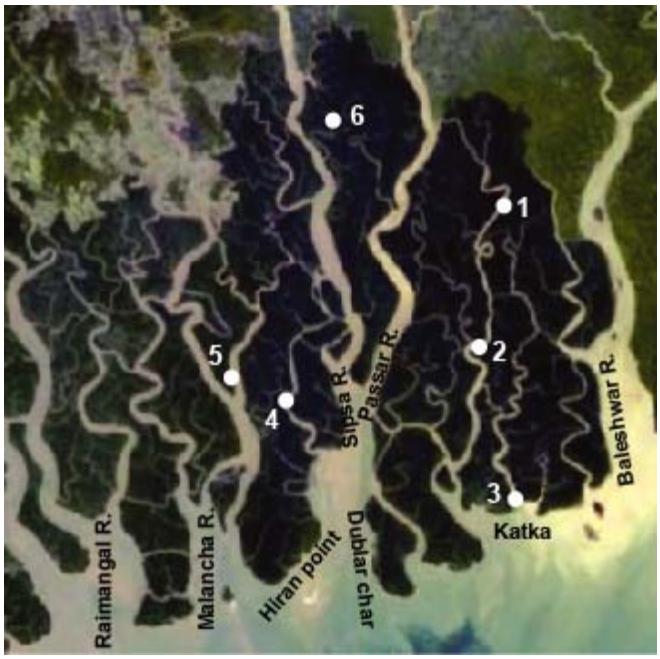

Fig.1. Satellite image of the SMF in February 2010, showing sampling sites. The darker colour towards the north-east indicates denser forests.

Remote Sensing and Geographic Information Systems were used to explain changes in Nalianala (Khulna) and Chandpai Forest Range. Landsat TM data of 12 January 1989 and Landsat ETM+ of 26 November 2000 and 2010 (http://glcf.umd.edu) were rectified and geo-referenced to the World Geodetic System 1984 and projected to the Universal Transverse Mercator (UTM) map projection system and were compared. The image processing was done using Erdas Imagine 9.1 software produced by Leica Geosystems. The images were downloaded as individual bands 1, 2, 3, 4, 5, 6 and 7 respectively and stored separately. The data obtained from LANDSAT images on the SMF are raster data which were converted into vector data. Soil samples from each plot were collected in polyethylene bags from 0-10, 10-20 and 20-30 cm depths and five replicates were taken. To determine salinity, 20 g soil in 50 ml distilled water was stirred homogeneously and was allowed to settle down. Salinity of the soil extracts were measured using hand refractometer.

Tree plant species recorded from the six sites of the SMF and their phytosociological analysis are listed in Table 1. A total of 8 species such as *Aglaia cucullata* (Roxb.) Pellegr. (Amoor), *Avicennia officinalis* L. (Bain), *Bruguiera sexangula* (Lour.) Poir. (Kankra), *Ceriops decandra* (Griff.) Ding Hou (Goran), *Excoecaria agallocha* L. (Gewa), *Heritiera fomes* Buch.-Ham. (Sundrai), *Sonneratia apetala* Buch.-Ham. (Keora) and *Xylocarpus mekongensis* Pierre (Pussur) were recorded. On an average *C. decandra*, *H. fomes* and *E. agallocha* were dominant tree plants. *H. fomes* and *E. agallocha* were found in all sites though the number varied from site to site, lowest in Kotka and Arpangachia (polyhaline zones) (Nazrul-islam 2003). *C. decandra* was found in all sites except near Moroghodra (a freshwater zone). The maximum Importance Value Index (IVI) was recorded for *C. decandra* (Table 1) followed by *H. fomes* and *E. agallocha*. Depending on the site of mangroves along the salinity gradient of an estuary and with distance inland from shore, the properties of mangrove communities vary within an environmental setting (Chen and Twilley 1999).

Table 1. Phytosociological analysis and Shannon-Wiener index of tree diversity (H) of the Sundarban Mangrove Forests (IVI = Importance value index. * indicates overall diversity of six sites of SMF).

Name of species / Shannon-Wiener Diversity index	Sites							IVI
	S1	S2	S3	S4	S5	S6	Total	
Ceriops decandra(Goran)	226	50	698	127	525	0	1626	99.14
Heritiera fomes (Sundri)	606	100	4	105	10	550	1375	84.48
Excoecaria agallocha (Gewa)	207	150	569	126	75	18	1145	74.07
Aglaia cucullata (Amoor) (Syn. *Amoora cucullata*)	10	3	0	0	0	17	30	13.11
Xylocarpus mekongensis (Pussur)	0	0	1	0	2	4	7	11.58
Bruguiera sexangula (Kankra)	0	0	1	0	0	10	11	08.38
Avicennia officinalis (Bain)	0	0	0	0	0	9	9	05.08
Sonneratia apetala (Keora)	0	3	0	0	0	0	3	04.16
Shannon-Wiener Diversity index (H)	1.46	1.59	1.04	1.58	0.68	0.66	1.68*	

The single most important tree *H. fomes* which constituted 31.6% in 1959 (Forestal 1960) was reduced to 21.01% in 1983 and was again substituted by *E. agallocha*, which increased to 29.7% and the changes has been attributed to increased salinity (Chaffey *et al*. 1985). A maximum number of 5 tree species were found at Moroghodra, Nalianala Range (S6) and the area was dominated by *H. fomes* (Fig. 2, Table 2). Of the six study sites only this site was found to be inundated daily during March 2010. The lowest number of 3 tree species such as *C. decandra* followed by *E. agallocha* and *H. fomes* was found in Patcosta (S4), situated in polyhaline zone. Maximum species diversity was found in Tek (S2) and Patcosta (S4). Lowest diversity was found at Moroghodra (S6) and Arpangachia (S5) which was due to the dominance of *H. fomes* and *C. decandra* respectively (Table 1). *C. decandra* was dominant at S5 because of its salt loving nature, while *H. fomes* was dominant at S6 because of low saline environment (Fig. 2). Both the *C. decandra* and *E. agallocha* were dominant at Kotka at Sarankhola Range having highest soil salinity (Fig. 2) which also resulted in lowest number of *H. fomes*, a fresh water loving plant.

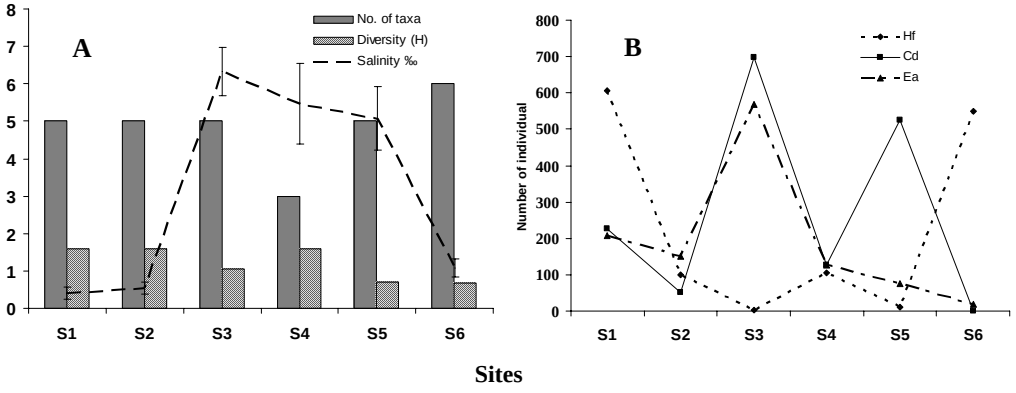

Fig. 2. Effects of salinity on the number of taxa and diversity (A) and on the number of *Heritiera fomes* (Hf), *Ceriops decandra* (Cd) and *Excoecaria agallocha* (Ea) (B) per 25 m × 25 m quadrat in the SMF. Abbreviations: S1 = Tambulbunia, S2 = Tek, S3 = Kotka, S4 = Patcosta, S5 = Arpangasia, S6 = Moroghodra. n = 5, vertical bars = ± 1SEM.

The Landsat images and GIS data on the changes of forest cover over 20 years (1989 through 2000 to 2010) at Nalianala (Khulna) and Chandpai ranges also revealed increased cover by *B. sexangula* (kankra), *E. agallocha* (gewa) and *S. apetala* (keora) and decreased cover of *H. fomes* (Fig. 3, Table 2). Total tree cover in 2010 decreased by about 3% from that of 1989. The changes

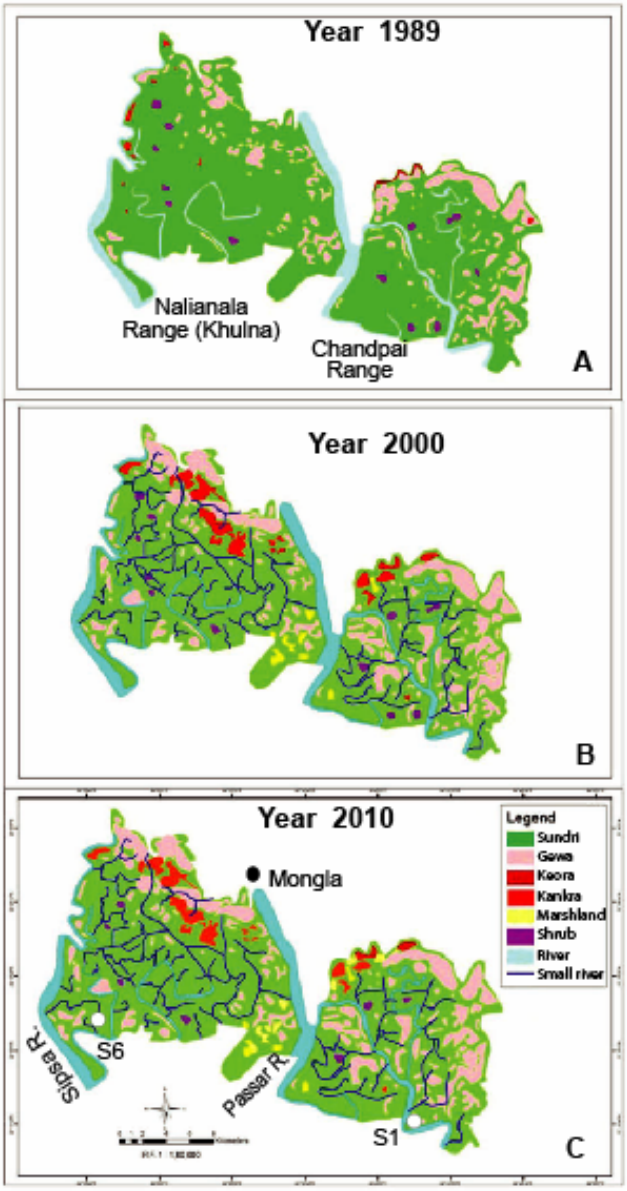

Fig. 3. Landsat TM and Landsat ETM+ images showing changes in species composition of forests of Nalianala (Khulna) and Chandpai Ranges over 21 years: 1989 (A), 2000 (B) and 2010 (C) in SMF. Forest cover by the Trees at different times are given in Table 2. Sites 1 and 6 in Chandpai and Nalianala Ranges are shown by circles.

in the physiography and tree composition of the two Ranges between 2000 - 1989 were considerable. It has been estimated that during first 10 years' time (1989 – 2000), total forest area has increased slightly (by 26.50 hectares). This increase in the land surface might have resulted in the increase in grass (*Porteresia coarctata*) cover. But by the next 10 years total surface area of forest land decreased Forestal (1960) obtained 211 sundri per ha in 1959 where as Chaffey *et al*. (1985) obtained 125 sundri per ha in 1983 and were attributed to increased salinity of SMF over

Table 2. Changes of forest cover (area in hectare) in 1989, 2000 and 2010 as determined by GIS technique at Nalianala (Khulna) and Chandpai ranges of the SMF (values in parenthesis are in percent). Maps of three time periods of the two Ranges are given in Fig. 3 A-C.

Classes	Forest cover by tree			Changes of forest cover		
	1989	2000	2010	1989-2000	2000-2010	Overall
H. fomes	23027.77	19308.51	16407.65	– 3719.26 (16.15)	– 2900.86 (15.02)	– 6620.12 (28.75)
E. agallocha	15184.45	15828.41	16200.42	+ 643.96 (4.24)	+ 372.01 (02.35)	+ 1015.97 (06.69)
B. sexangula	190.55	1906.06	3025.85	+ 1715.51 (90.00)	+ 1119.79 (58.75)	+ 2835.30 (1487.96)
S. apetala	43.78	81.69	108.58	+ 37.91 (86.59)	+ 26.69 (32.67)	+ 64.80 (148.01)
Marshy	-	386.67	585.21	+ 386.67 (100)	+ 198.54 (51.35)	+ 585.21 (100.00)
Shrub	569.55	463.27	366.99	– 106.28 (18.66)	– 96.28 (20.78)	– 172.56 (30.29)
Water	4726.56	5580.98	6008.96	+ 854.42 (18.08)	+ 427.98 (07.67)	+ 1282.40 (27.13)
Total areas	44301.33	44327.83	42,703.66	+ 26.50 (0.059)	– 1624.17 (03.66)	– 1597.67 (03.61)

the years. The Bangladesh part of SMF was divided into freshwater and moderately saline zones by Curtis (1933) but after about 50 years or over 11 years of Farakka barrage operation, Chaffey *et al*. (1985) divided the SMF into three ecological zones viz. freshwater (north eastern part), moderately saline (middle southern part) and saline (Southern part) water zones into more or less equal proportions. After about 10 years from 1983 Karim (1994) found about 60% in the western part as saline (polyhaline), and about 35% mesohaline and less than 5% oligohaline zones eastwardly. Zonation is likely the mangrove ecosystem's response to external factors rather than a temporal sequence induced by the plants themselves. Changes in salinity might also be responsible for the spatial distribution of plant communities.

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