Spatial Configurations of Floral Species of Sundarbans Mangrove Forests in Bangladesh With Reference to Geomorphological and Hydrological Considerations

Thesis Submitted for the Degree of

Masters of Philosophy

IN

GEOGRAPHY AND ENVIRONMENT

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2006

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CERTIFICATE

This is to certify that Mr. Md. Ashaduzzaman has completed the M.Phil. Thesis entitled *"Spatial Configurations of Floral Species of Sundarbans Mangrove Forests in Bangladesh With Reference to Geomorphological and Hydrological Considerations "* under my supervision and it is his own original work.

04-09-06

(Prof. Dr. Mohammad Abdur Rob)

(Supervisor)

With Best of my Respects and Regards
Dedicated to
My
Beloved Parents,

JANAB MD. GOLAM AKBOR
AND
BEGUM REZIA AKBOR

ACKNOWLEDGEMENT

I take this opportunity to express my sincere and grateful thanks to Professor Dr. Mohammad Abdur Rob, Department of Geography and Environment, University of Dhaka, Bangladesh, whose kind and valuable guidance was available at every stage of the present work. The meticulous care he has taken in going through each of the chapters of the thesis is known only to me. Far from being official and formal, the treatment he has accorded is personal, cordial and humane. I earnestly believe that the work would have been incomplete but for his unfailing encouragements and stimulating guidance.

I also wish to express sincere regards to Dr. K. B. Sajjadur Rasheed, Professor, Geography and Environment, University of Dhaka, for his valuable advice and suggestions.

Then my regards are due to Professor Dr. Amanatullah Khan the former Chairman, Geography and Environment, University of Dhaka and Professor Dr. Khondoker Moudud Elahi, Geography and Environment, Jahangirnagar University, for valuable suggestions at different stages of this thesis.

Much regards and gratefulness are due to Professor Dr. AQM Mahbub, the existing Chairman, Department of Geography and Environment, University of Dhaka for his kind co-operation and help.

I am particularly grateful to the Forest Unnayan Adidaptar (Mohakhali), River Research Institute (Faridpur), Survey of Bangladesh, Space Research and Remote Sensing Organization (SPARRSO) and Department of Geography and Environment, University of Dhaka for help and co-operation in this study by providing important data, information, maps, other materials and allowing me to utilize these in my studies.

Most respectfully, I mention the affections and encouragements of my parents and parents-in-law in the course of this study. I express my hearty gratitudes to them.

This note of acknowledgements would not be completed if I do not say a few words regarding the secrifice and service of my loving wife Mrs. Sayma Khanam (Bonny) whom I always found beside me with an inspiring smile and helpful attitude throughout the course of analysis of data, writing of the chapters, and typing the thesis.

I finish this note of acknowledgements remembering the sweet disturbances of my son ***Sami*** and daughter ***Fairuj*** during the entire course of studies for this thesis. All of their disturbances always turned into stimulating inspirations to me.

Ashaduzzaman.

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ABSTRACT

This thesis involves and in depth investigations into the critical appreciation's of the relationship between some ecological parameters in the Sundarbans Mangrove Forests in Bangladesh. In this thesis aspects have been taken to examine the spatial configurations of the major floral species of the Sundarbans in respect to the morphological and hydrological considerations. This work is almost new and pioneering initiative in the area of environmental studies of the Mangrove ecosystem. For the present study 3 distinct patches of the forests have been selected i.e. compartment-35 (Paikgacha area), compartment-45 (Dublar char area), compartment-46 (Shamnagar area) have been selected as study areas. Scientific statistical sampling methods were followed in selecting these areas. In order to achieve the objectives of the study extensive investigations through analysis and interpretation of topographical sheets, hydrographical charts, aerial photographs and satellite imageries were made on the different aspects of the vegetation conditions, physiographical situation and hydrological influence in study areas.

The findings of the present study reveals that the geo-morphological particularly the land-levels of the forests are very gentle-sloping. However there are varied elevations in different forested zones in the Sundarbans. At the same time the hydrological condition-especially the volume of discharge, quality of water viz. salinity intrusions and tidal effects etc have been influencing the distribution, composition and quality of the floral species in the study areas in the Sundarbans. The results of the statistical tests (X^2 tests, F-tests, K-S tests, H-tests etc.) suggest that there are some positive and a few negative relations in the role of the physical parameters like Physiography and hydrology on the floral situation in the Sundarbans.

The findings of the present study reveals that, although the Sundarbans is a viable and complex coastal ecosystem, it has been undergoing a progressive geological change characterized by the abandonment of Ganges spill rivers and reductions in freshwater inflow in the west. The eastern Sundarbans remains a relatively low salinity environment due to discharge of the Ganges-*Brahmaputra* river system. However, the continuing geo-morphological change together with man-made reductions in freshwater availability are presumed to be causing a change in the species distribution and dominance in the Sundarbans. The study reveals that the fallout of the Farakka Barrage of the distributaries of the Ganges that create a maze of estuarine creeks of the Sundarbans have greatly effected the hydrological as well as the geo-morphological situation of the Sundarbans region. As a result a noticeable change has been marked in the floral distribution of the forest and the ultimate resultant is a destined decay in the plants and vegetation domain in the Sundarbans—the Largest Mangrove Forest of the World.

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ABBREVIATIONS

BIWTA : Bangladesh Inland Water Transport Authority
BWDB : Bangladesh Water Development Board
MPO : Master Plan Organization (Dhaka)
RRI : River Research Institude
SPARRSO : Space Research & Remote Sensing Organization of Bangladesh
GSB : Geological Survey of Bangladesh
DL : Danger Level (of rivers)
LB : Left Bank
RB : Right Bank
MSL : Mean Sea Level
g : gram
m : meter
cm : centimeter
Km^2 : Square kilometer
km : kilometer
m^3/sec : Cubic meter per second
sq. km : square kilometer
SRF : Sundarban Reserved Forest
SW : South West
FD : Forest Department
SLR : Sea Level Rise
FAP : Flood Action Plan
cft : cubic feet
kg/m^3 : kilogram per cubic meter
lbs. : pounds
BFRI : Bangladesh Forest Research Institute
ODA : Overseas Development Authority
m-ohs : micro mohs/sec.
BADC : Bangladesh Agricultural Development Corporation
SWMC : Surface Water Modeling Center
SRF : Sundarban Reserve Forest

Chapter -1

Introduction

Chapter -1
Introduction

1.0 Geographical Background and significance of the Study

The *Sundarbans* are the largest mangrove forests of the world. These forests are distributed in the southern deltaic coastal and estuarine tracts of south-western part of Bangladesh and south-eastern part of West-Bengal, India. In Bangladesh, The *Sundarbans* occupy the tidal portion of the estuarine delta. These estuaries are essentially the lower reaches of the distributaries of the Ganges. Morphologically these estuaries are deeper and wider land experience regular pulsation of the tidal influxes daily. Different studies reveal that this area was under the sea about 2,500 years ago.*(Rob -1999, Bagchi-1948)*. The total area of the *Sundarbans* in Bangladesh is 5772.85 square kilometres. 70% of the land surfaces of the *Sundarbans* is forested. The rest 30% covers rivers, canals, mud-flats and creeks. These forests cover about 40% of the total forested surface of Bangladesh. *(Hussain-1994)*

The *Sundarbans* is famous for its rich biodiversity of both floral and faunal species. The Bangladesh area of the *Sundarbans* offers habitation to 425 species of wildlife, which include 49 species of mammals, 315 of birds, 53 of reptiles and eight kinds of amphibians. More than 120 species of fish are also available in the different rivers in and around the *Sundarbans* area. *(Das-1982 ; Hussain-1994)*

Around 4.0 million people of the south western part of Bangladesh depend upon the resources of *Sundarbans*. Out of them around 0.5 million are directly dependent on the various resources of the forests. These people enter the *Sundarbans* about everyday from its surrounding villages under the five *Upazillas* (police station) to catch fish-fry, collect honey and to gather wood and for some other primary economic activities.

The *Sundarbans* is not only the world's largest Mangrove forest, some part of it has been declared as "The World Heritage Site" in 2000. Some 1,39,700 hectares area of the Sundarbans (east, south and west) have been brought under as the world Heritage site by the UNESCO. The Mangrove forests of Bangladesh home the world's most beautiful cat species- the *Royal Bengal Tigers*. The *Sundarbans* is located in the estuary of the river spanning an area about one million hectares in south-west Bangladesh in the District of Bagerhat, Khulna, Satkhira and Barguna. On the other hand, small area of the *Sundarbans* is located in Cox's Bazar district at Chokoria, Sonadia Island and Naf rivers area.

1.1 Mangroves: Some Conceptual Aspects

Mangroves are the most typical saline water forest formations of sheltered coastlines in the tropics and subtropics where they are best developed in river deltas, in the lee of coral reefs or islands, and along broad and gently sloping shores. The *Sundarbans,* World's largest mangrove forests occur in the coastal estuarine portion of the Ganges Delta which is distributed both in Bangladesh and India. The *Sundarbans* consist of trees and bushes growing below the high water level of spring tides. Their root systems are regularly inundated with saline water, although it may be diluted by freshwater surface runoff from the upstream areas. The term "Mangrove" is applied to both the ecosystem as such and to individual trees and shrubs. Ecologically, mangrove forests are characterized by a very low floristic diversity compared with most inland forests in the tropics. This is because few plants can tolerate and flourish in saline mud and withstand frequent inundation by tidal seawater. Most of the faunal species found in mangroves also occur in other environments such as beaches, rivers, fresh water swamps or in other forest formations near water. Found worldwide in tropical and subtropical areas, mangrove swamps provide excellent nesting and feeding areas for a variety of marine fish, invertebrates, and birds. Mangroves are trees that have the common trait of growing in shallow and muddy salt water or brackish waters, especially along quiet shorelines and in estuaries. (*Hussain-1994* ; *Rob -1997*).

Mangrove forests can be seen in the tropical coasts of Asia, Africa, North America, South America, and Oceania (Table-1.1).

Table-1.1 Continent-Wise Distribution of Mangrove Forest Land Area in the World

Continent	Area (Sq. Km)	Percentage (%)	Country	Area (Sq. Km)	Country	Area (Sq. Km)	Country	Area (Sq. Km)
Asia	56788	34.73	Bangladesh	4143	Philippines	2400	India	3565
			Indonesia	25000	Cambodia	100	Vietnam	3200
			Srilanka	40	Brunei	70	Malaysia	6700
			Pakistan	3450	Mayanmar	8120		
Africa	32587	19.93	Angola	500	Libya	400	Gambia	600
			Benin	30	Madagascar	3207	Zaire	200
			Cameroon	2730	Mozambique	850	Kenya	450
			Gabon	2500	Sierra Leone	1000	Senegal	4400
			Guinea	2600	Nigeria	9730	Tanzania	960
			Guinea-Bissau	2430				
North America	22150	13.55	Cuba	4480	Jamaica	70	Trinidad Tobago	40
			Dominical Rep.	90	Haiti	180	U.S.(Florida pirico)	1780
			El. Salvador	360	Mexico	6600	Costarica	390
			Guatemala	500	Panama	4860	Belize	750
			Honduras	1450				
South America	34060	20.83	Brazil	25000	Peru	280	Ecuador	1960
			Colombia	3070	Surinam	1150	Venezuela	2600
Oceania	17900	10.95	Papua N.Ginea	5530	Frence Ginea	550	Australia	11620
			Fiji	200				
Total	163482	100.00						

Source: *Man, Land and Sea- Coastal Resource use and Management in Asia and the Pacific-1998.*

Mangrove, common name applied to several kinds of tropical flowering plants. Some mangrove roots extend above the water. These specialized vertical branches, called pneu matophores, act as aerating organs. Botanically, the mangroves can be categorised into 3 Different families i.e.

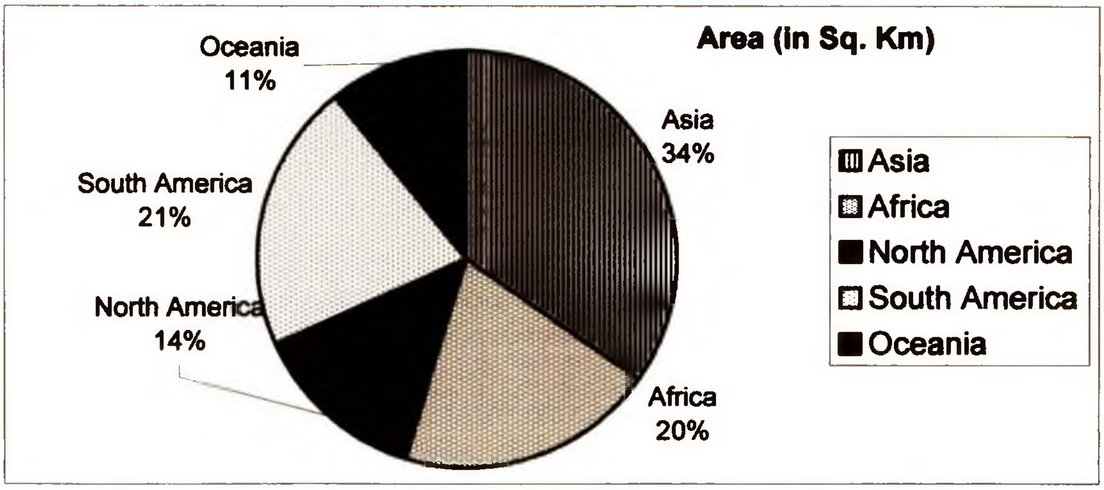
- *Red mangrove* - The most common and most important species, the red mangrove, is so named because of its reddish wood. The red mangrove belongs to the family Rhizophoraceae and is classified as Rhizophora mangle.

- *White mangrove* - The white mangrove and button mangrove belong to the family Combretaceae.

- *Black mangrove* - The black mangrove belongs to the family Verbenaceae and is classified as Avicennia germinans. The black mangrove is a member of the verbena family.

Red, white, and button mangroves occur in southern Florida and in other tropical areas. *(Encarta Encyclopedia - 2002).*

Graph- 1.1 Global distribution of Mangrove Forests (Area in sq. km)

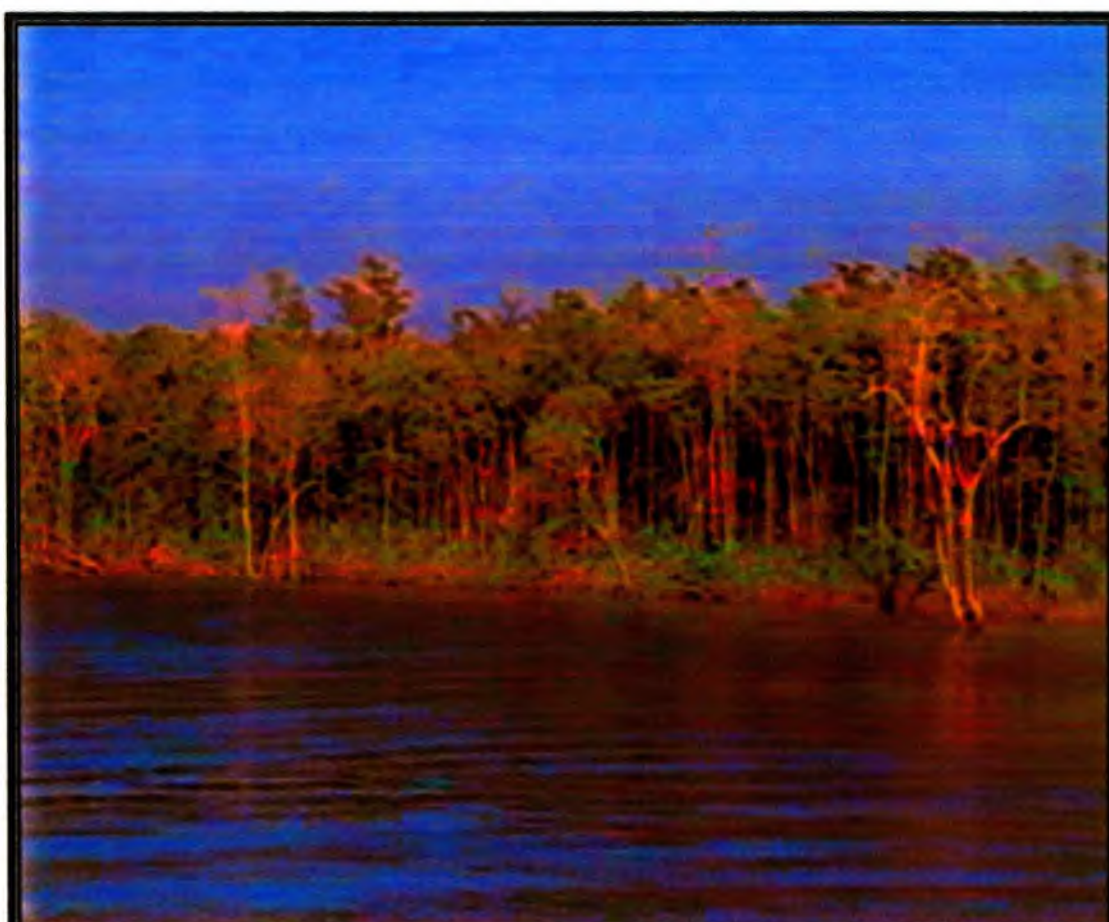


Source: *Man, Land and Sea- Coastal Resource use and Management in Asia and the Pacific-1998.*

Mangrove forests are vital for healthy coastal ecosystems. "Rainforest by the sea," the mangroves are estimated to over an area of 22 million hectares *(0.22 m. Km²),* dominating the majority of the subtropical and tropical coastal lines around the world. Estimates are that there are some 16 million ha *(.16 m. Km²)* of mangrove forests Worldwide (FAO-1994a). There are two distinct bio-geographic zones of mangroves in the world: those of West Africa, the Caribbean and America; and those of the east coast of Africa, Madagascar and the Indo-Pacific region. While the first contain only ten tree species, mangroves of the Indo-Pacific are richer, containing some 40 tree species *(excluding palms)*.

The Mangrove forest are scatered in different littoral or coastal areas of different countries of the world viz. Bangladesh, India (West Bengal), Mayanmar, Thailand, Bureni, Cambodia, Indonesia, Malayasia, Phillipines, Sri Lanka, Vietnam, and Singapore. Most of these Swamp-forests are developed in the deltaic and estuarine tide-dominated environments. Some mangroves can be observed even in the tropical humid areas of Florida of the USA and in the coastal fringes of Pakistan (*i.e. Sind*).

Photo-1. The Sundarbans : The World's Largest Saline Water Coastal Mangrove Forests In Bangladesh



1.1.1 The *Sundarbans*

The *Sundarbans* Forest of Bangladesh is located on an old delta formation of the River Ganges and is characterized by a species -rich tidal forest. The *Sundarbans* forest is situated in the south west corner of Bangladesh between latitude 21°27'30"N to 22°30'00"N and longitude 89°02'00"E to 90°00'00"E in Khulna, Satkhira and Bagerhat districts. The Sundarbans is bounded by the Harinbhanga-Raimangal-Kalindi Rivers and the Indian Sundarbans in the west. The Bay of Bengal in the south and the Baleswar river in the east and to the north, there is a sharp interface with intensively cultivated land of Satkhira, Khulna and Bagerhat districts. These cultivate lands are also intersected by a network of tidal rivers, canals and streams.

1.1.2 Area of the *Sundarbans*

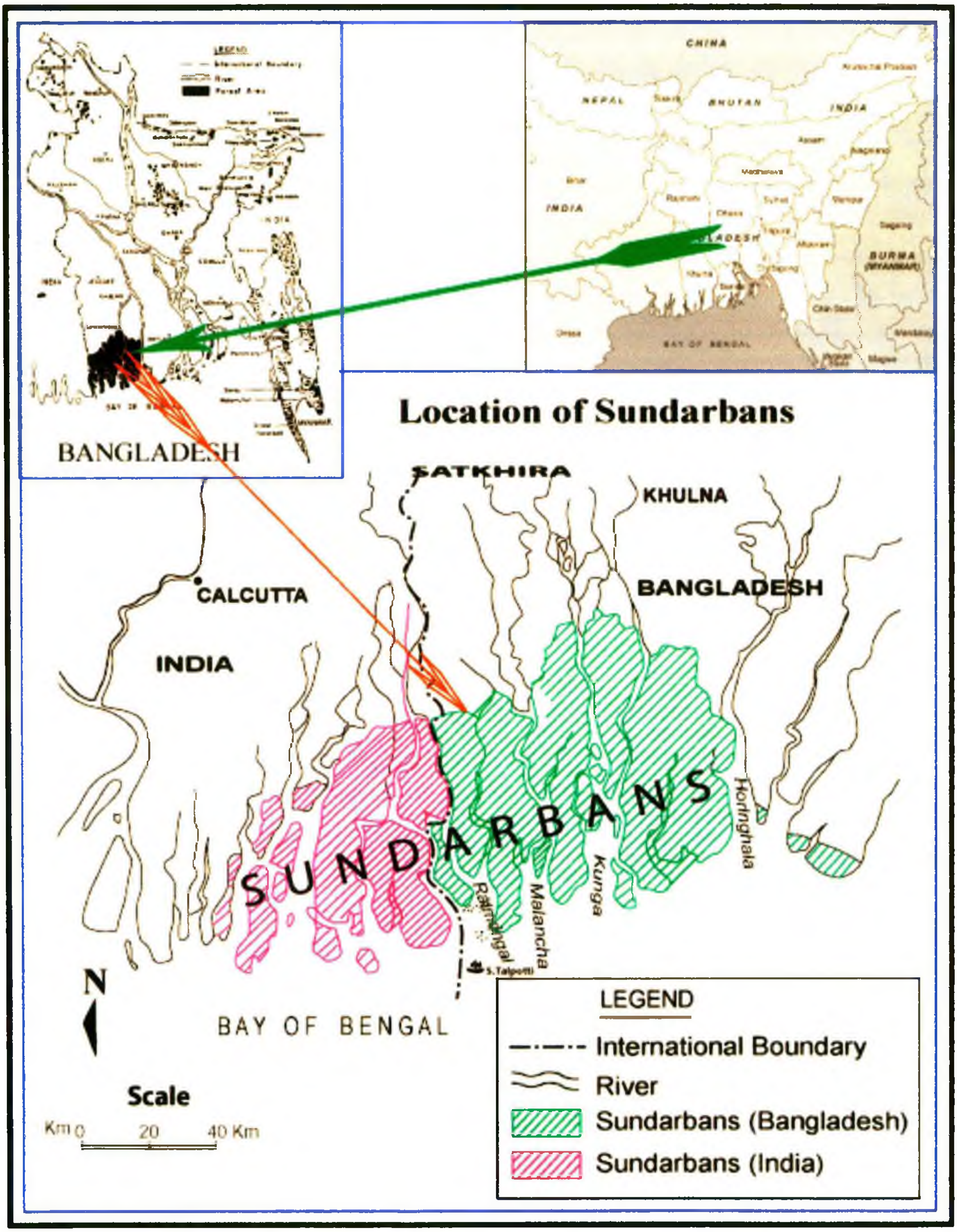
The *Sundarbans* of Bangladesh along with adjacent Indian portion comprises the World's largest Mangrove or tide dominated coastal saline water forests. As a whole at present the Mangrove forests of Sundarbans cover a total area of about 10,000 sq. km.(*about 7,731.1 sq. km forest area*) of which in Bangladesh these occur is about 5770 sq. km (*about 4,142.80 sq. km forest area including Sundarbans*) in the south western portion of Bangladesh (*Hussain-1994 ; Sundarbans study group- 2000 ; & Rob-1999).*

Table-1.2 List and Area of Mangrove Forest in Bangladesh & India

Bangladesh Mangrove Forest			Indian Mangrove Forest		
List	Area (acres)	Area (Sq. Km)	List	Area (acres)	Area (Sq. Km)
Sundarbans (Ganges Delta)	1006500	4073	West Bengal (Ganges Delta)	494000	2000
Chokoria Sundarban (Cox's)	21000	85	Andaman & Nicobar Islands	247000	1000
Sonadia Island (Cox's)	2000	8	Bombay Region	49400	200
Naf River (Cox's)	2500	10	Kathiawar Saurashtra & Kutch Coast	49400	200
Total Mangrove Area	**1032000**	**4176**	Mouth of Godavari & Krisna	24700	100
			Cauvery Delta	3700	15
			Mouth of Mahanandi	12400	50
			Total Mangrove Area	**881000**	**3565**

Source: *Man, Land and Sea- Coastal Resource use and Management in Asia and the Pacific-1998.*

Fig – 1.1 : Geographical Location of the Sundarbans Mangrove Forests



***Source** - Modified and edited after, Man, Land and Sea- Coastal Resource use & Management in Asia & Pacific-1998*

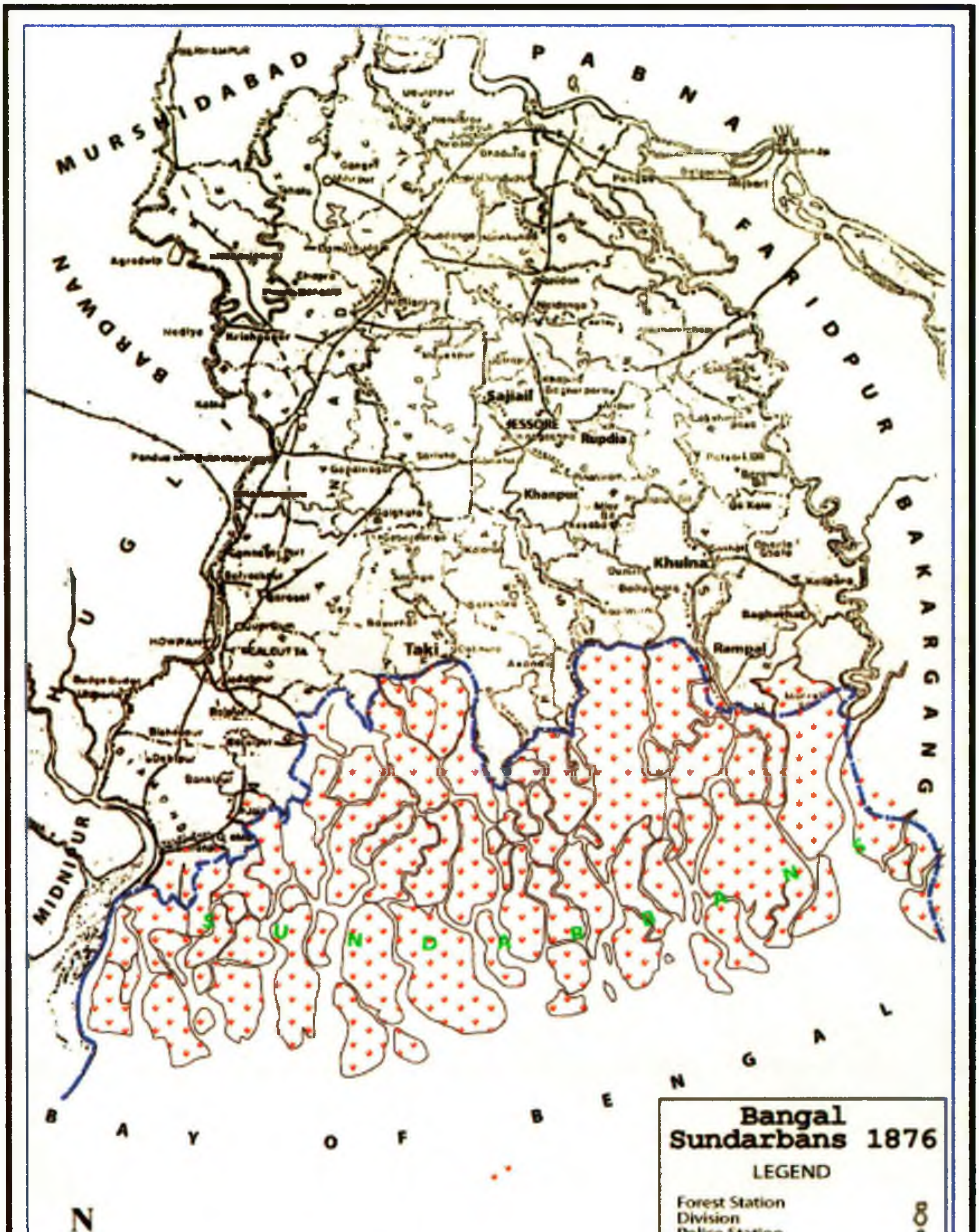
1.1.3 Origin and Evolution of the *Sundarbans*

Various explanation are given to the derivation of the name *Sundarbans*. The most popular brief is that it is the named after "*Sundri*". The principal tree found on it. It is also believed to be derived from the words "*Sundar ban*" meaning beautiful forest, "*Sundar band*" meaning beautiful embankment "*Samundar or Samudra ban*" meaning sea forest.

The genesis and evolution of the Mangrove forests of the *Sundarbans* are related to the origin and transformation of the deltaic lands of the lower portion of the Ganges-Brahmaputra basin. Geologically, the Sundarbans are of recent origin. Studies revealthat only a few thousand years ago the whole deltaic area of today's the *Sundarbans* was under the sea-water and the estuarine islands of this swamp- forest represent the outcome of a specific phase of the delta- building activity by the net work of the Ganges system.

The *Sundarbans* forest have been exploited by man for many years. The area was first mapped by the Surveyor General of the 1760s following accession by the East India Company in 1757 from the Mughal Emperor, Alamgir 11 (*Hunter-1876*). Prior to the 18th century when progressive land clearing was initiated along the northern boundaries of the forest, Sundarbans occupied a land area of approximately,31,65,000 acres (*12,81,000 hectors*) or about two times the size of the present forested land area (*Curtis-1933*). land clearing for agriculture and thus the reduction of area of forest land ,continued until 1828 when the British Government assumed proprietary rights to the forest ;however large scale forest destruction continued for another 40 years or more. The first restriction on the leasing of forest , land for clearing and bundling was initiated in 1875 in the Khulna district and over the next few years the majority of the remaining forest lands were declared to be reserved. The first forest management working plan came into being in 1893-94. From then until 1904, occasional destructive leasing led to deforestation on only some 17,560 acres (*7,109hectors*) then apparently stopped (*Choudhury-1962).*

Fig-1.02 : The Presidency Division comprising the District of 24 Parganas, Nadia & Jessore of Bangal Sundarbans Forest Area in 1876



Source- Modified and edited after, The Statistical Accounts of Bengal Sundarbans – W. W. Hunter

In the late 20th century, questions are being raised concerning the economic value of retaining the Sundarbans as a production forest and wildlife reserve versus the value of economic benefits that might be realized through site-conversion to agricultural land.

1.1.4 Climate of *Sundarbans*

The *Sundarbans* occurs in the southwestern coastal region of Bangladesh and very naturally experime a tropical warm rainy monsoon climate. The eco-climatic condition of the estuarine region of the deltaic part of the Bengal is ideal for the deltaic part of Bengal for the growth of mangrove vegetation, the typical woody jungles that fringe muddy saline shores and estuarine tracts of tropical and sub-tropical regions.

The *Sundarbans* is located at the tropic of cancer and at the northern limits of the Bay of Bengal. The coolest temperatures occur during December to January, and the warmest at the end of the dry season during May to June.

- *The pre monsoon season* ***(March to May):*** This season has the height temperature and evaporation rates with occasional heavy thunderstorm and nor-western.
- *The Monsoon season* (June to September): The monsoon brings high rainfall, humidity and cloud cover. Sediment load and water levels of rivers also increase due to heavy rainfall in upper catchment areas.
- *The Post Monsoon* (*October to November*): This season is hot and humid, but sunny with heavy dew fall at night with occasional thunder storms, cyclone and storm surges.
- *The Dry Season* (*December to February*): This Season is characterized by cool, dry and sunny weather with low precipitation and low tidal levels.

Table-1.3 Climate of the *Sundarbans*

Area/ Stations	Location		Rainfall (mm) Annual	Humidity % Average	Temperature (°C) Average		
	Latitude	Longitude			Mean max.	Mean Min.	Average (monthly)
Khepupara	21°59′ N	90°14′ E	2269	83	30.3	22.3	26.3
Khulna	22°51′ N	89°34′ E	1851	82	31.3	21.4	26.4
Mongla	22°20′ N	89°30′ E	1962	82	30.8	22.5	26.6
Satkhira	22°43′ N	89°05′ E	1737	76	32.0	21.6	26.8
Indian Sundarbans	21°32′ N- 22°40′ N	88°05′ E- 89°00′ E	1628	--	-	-	26.5

***Source:** Bangladesh Meteorological department (1984-93).*

**Depending on the distribution of rainfall, temperature and humidity four main seasons can be recognized.*

1) Rainfall - The rainfall is typically in monsoon, dry during November to April but rain from May to October. Monthly rainfall varies from a dry season low of a few millimeters in December to a wet season maximum of about 600 mm in July. The rainfall in the *Sundarbans* region decreases from east to west. About 80% to 85% annual rainfall occurs here during the monsoon season from May to September. However particularly rainy season starts about the middle of June and ends about the end of middle of September.

Table-1.4 Some Meteorological data of the *Sundarbans* (1986-1995 average)

Parameter	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Monthly Temp. (°C)	Khulna	19.8	22.4	27.1	29.5	29.5	29.4	29.0	29.0	29.2	28.2	25.0	20.7	26.6
	Satkhira	19.4	22.3	27.0	29.8	30.1	29.7	29.0	29.0	29.0	28.1	24.5	20.2	26.5
Mean Monthly Rainfall *(mm)*	Khulna	12.7	28.4	35.4	88.6	190.3	347.7	345.6	342.5	244.0	141.7	33.9	1.6	1822.4
	Satkhira	19.8	33.3	35.8	91.0	124.9	331.2	370.0	329.6	297.9	132.5	31.4	10.8	1808.2
Mean Monthly Humidity *(%)*	Khulna	73	71	70	75	78	87	89	88	87	83	78	75	80
	Satkhira	70	67	65	70	74	83	87	88	86	82	75	71	77
Mean Wind Speed *(Knots)*	Khulna	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0	4.0
	Satkhira	5.0	5.0	6.0	6.0	6.0	5.0	5.0	6.0	5.0	5.0	5.0	4.0	5.3
Mean Sunshine *(Hours)*	Khulna	8.2	8.2	8.4	8.8	7.7	4.6	3.5	4.7	4.5	7.4	8.0	8.1	6.8
	Satkhira	7.9	8.2	8.5	8.9	8.0	4.3	3.6	4.7	5.1	7.6	7.9	8.0	6.9
Mean Monthly Evaporation *(mm)*	Khulna	62	73	111	131	129	96	77	82	74	77	72	64	1049
	Bagerhat	60	83	121	131	123	98	73	72	75	92	84	67	1079

***Source-** Integrated Resource Development of the SRF vol-1, 1998.*

*2) **Temperature-*** Like other part of the South-Western Bangladesh in Sundarbans the average temperature also is higher (average 26° C). The high temperature begins about the middle of March & ends about the middle of June. The cold weather commences at the beginning December to February. The mean annual maximum is 31.1° C at Satkhira to the west of the Sundarbans and 29.4° C at Patuakhali in the east of the Sundarbans.

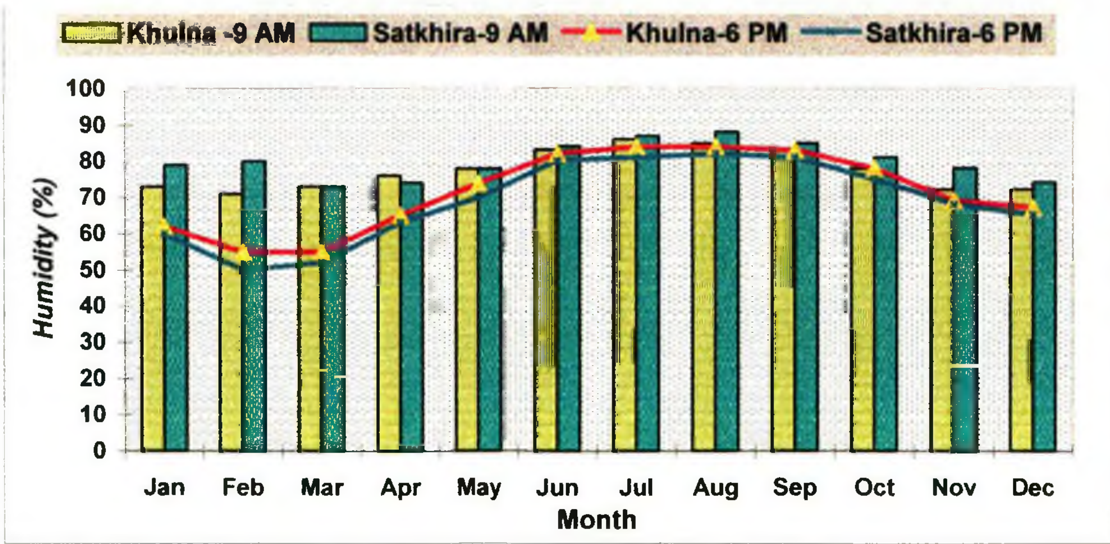
*3) **Relative Humidity*** Mean annual relative humidity various form 70% at Satkhira to 80% at Patuakhali June to October are the months with high humidity. Humidity is lowest in the winter season because rainfalls very low.

Table-1.5 Relative Humidity (%) is 9 AM (Morning) and 6 PM (Evening) at Khulna & Satkhira

Name of the station	Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Khulna	9 AM	73	71	73	76	78	83	86	85	83	78	72	72	**77.5**
Satkhira	9 AM	79	80	73	74	78	84	87	88	85	81	78	74	**80.1**
Khulna	6 PM	62	55	55	65	74	82	84	84	83	78	69	67	**71.5**
Satkhira	6 PM	60	50	52	63	70	80	81	82	81	75	68	65	**68.9**

Source: *Integrated resources development of SRF. Vol-1. 1998.*

Graph- 1.2 Relative Humidity (%) at Khulna and Satkhira District



Source: *Integrated resources development of SRF. Vol-1. 1998.*

4) Wind: The southwesterly monsoon starts about March to September. The monsoon wind blow from the south with sustained force from March to October. The prevailing winds are from the north and northeast in January.

5) Cyclones: Violent cyclone storms crop up frequently from the middle of May to June due to north coastal winds Severe cyclone may also occur in October and early November. Both the storms and tidal surges can cause serve damage to forests and human settlement.

1.2 Geomorphology of the *Sundarbans*

The *Sundarbans* landform represents the fluvial delta building deposits of the Ganges river. The present delta is a tide/wave dominated coastal delta. The strong bi-directional tidal currents present the formation of a classical prograding delta and instead from elongated tidal and sub-tidal shoals separated by numerous active channels *(Thom-1982)*. Inland directed tide and waves tend to retain sediments on the continental shelf where they contribute to the formation of shoals. Whereas active delta-building processes continue to the east of the Sundarbans. At the present time, there is a salinity gradient that increases from east to west through the abandoned spill rivers and waterway.

In the *Sundarbans,* the large channels or "*Khals*" that are oriented north-south are interconnected by numerous cross-channels creating a large number of islands .Within the *Sundarbans*, accretion on the islands occurs up to an elevation which is slightly above mean high tide level. At most high tides flooding does not extend far inland since the time during which sea level is above the land elevation is short *(UN-1978)*. Sedimentation may therefore reach a higher level near the larger channels than further inland where there may be depressions. Some of these depressions *("beels")* are poorly drained. The *Sundarbans* islands do not have pronounced levees due to the absence of coarse sediments. The banks are therefore steep and rise to a flat plateau that forms the surface of the islands.

The *Sundarbans* is presumed to be formed by deposition of silt brought down by the rivers Brahmaputra and Ganges from the Himalayas along with their network of tributaries forming an watershed area of 10,90,000 Sq.Km. Previously it was a depression in the coast which was ultimately filled up by thick sediment of recent Pleistocene origin. Whatever might be cause, it has been estimated that present day *Sundarbans* came into existence about 4,000 years ago. The Bengal Basin tilted east ward on the 12th century because of geotectonic movement *(Ali- 1998)*. This affected the course of the main river flow in recent geological past resulting in the reduction of fresh water supply to western river. This has given rise to accretion at river mouth, increase in salinity followed by subsequent change in biotic community.

1.2.1 Geology and Tectonics of the Delta

1.2.1.1 Geology of *Sundarbans* Forest

The Geological history of the area began probably from the early Pleistocene *(about 1 million years ago)* when due to wide scale glaciating the whole of the area at present occupied by the delta including quite a considerable area of the Bay of Bengal was dry. The history of the delta formation began from the tertiary period. The stream and rivers washing the southern faces of the entire Himalayas carries the materials to the inland sea for deposition. The delta began to from near the mouth of the Ganges and the Brahmaputra and were gradually emerged out of the sea once again and with the extension of the land or delta southward the rivers adjusted their beds and continued to the sea. The rivers are carrying enormous quantity of sand, silt and other debris and depositing them here. This the history of the delta formation of this region. Ferguson in his famous paper on recent changes in the delta of Ganges (*1863, p.331*) referring to the ages of delta of the Ganges says that not even 5000 years have elapsed since the delta has been formed *(Mujibur-1995)*.

1.2.1.2 Tectonics of *Sundarbans* forests

The broad Gangetic delta has been formed by the combined discharges of the Ganges, Brahmaputra and Meghna river and lies entirely with in the Bengal Basin bounded on the north and west by the Indian shield, on the east by the Arakan Yoma anti-clinorium and on the south by the submerged delta in an abyssal plain in the Bay of Bengal (*Daniel Sokol, personal communication).* It is an active delta which reveals a long history of the progressive creation and abandonment of distributaries. The *Sundarbans* lies wholly, on the delta created by the Ganges throughout its delta-building spill rivers.

Although the western portions are moribund, the Gangetic delta remains a dynamic system which can be characterized by a wide range of physical and biological changes induced for the most part by large scale geological process. Prior to the 16th century, the main course of the Ganges flowed by the Calcutta, India, through water courses now known as the Bhagirathi and the Hugely. At that time, all of the major delta building spill rivers (except the Jalangi, Matabhanga and Gorai) issued from the left bank of the Ganges and not from the right bank as they do presently *(Snedaker- 1984).*

1.2.1.3 Formation of land in *Sundarbans*

Geomorphology of the region is the result of ancient and contemporary geological and tectonic activity together with past and current operation of the drainage system. The *Sundarbans* landforms have developed due to the continual deposition of the weathered materials carried by the part of the deltaic plains of three mightily river the Ganges Brahmaputra and Meghna. It has a complex drainage pattern made up of inter connected rivers, cross channels, estuaries heavy seasonal rainfall and inputs of water and sediments from on of the worlds.

A historical account of the changing dynamics of the Ganges reveal that during and towards the end of Pleistocene the Ganges and its tributaries were building deltas to the west of Calcutta. The course of the Ganges gradually migrated eastward. The Ganges appears than to have build a delta in the Jessore area. While extending it later into the Sundarbans *(Mpo- 1985)*. At that time, the early Meghna and Brahmaputra rivers would have built their delta in the east in the greater Barisal region.

Sometimes in the 15th or 16th Century the river shifted eastward and probably Gorai rivers, and the Bagirathi-Hoogly system was reduced to the status of a right-bank distributary. At that time a number of formerly left bank spill channel became right-bank distributaries. However in 1762 and 1782 two major earthquake occurred and following a particularly large–flood in 1787, the Teesta, a major left bank tributary was diverted to the east and confluence with the Brahmaputra rather than the Ganges. A few years later the Brahmaputra itself avulsed westward to meet the Ganges near Goalanda and from a very large combined river the Padma. This change seems to have taken place over decades and completed by about 1830.

This sequence of events in the building of the Ganges delta is the major determinant of the landscape of which the *Sundarbans* forest system and their biota has developed. The resulting configuration is a complex of an innumerable islands of varying shape and size separated from each other through a complex drainage pattern made up of inter connected river, cross channels and estuaries. The rivers Kumar, Nabaganga, Chitra, Bhairab and Kabadak that were once active tributaries of the Ganges become the major Des-tributaries of the Ganges and followed through the *Sundarbans* through a complex network of dis-tributaries of their own. Each of those deltaic landforms are delta was formed by tributary streams are characterized physiographic features of such delta building process.

1.2.2 Physiography of *Sundarbans*

The *Sundarbans* is a deltaic swamp. To the north of the inclined towards the sea at a slope equivalent to 0.03m, vertical distance per km of horizontal distance. Generally the height land is that immediately adjacent to the watercourses, where sediment is deposited when these overflow their banks. The low-lying areas are drained by a network of small creeks, which follow into the main watercourses on the ebb flow of the tide.

The *Sundarbans* forests occupy the tidal plain of the Ganges delta. The tidal plain is an area of enormous sedimentation subsequent subsidence caused by compaction and the structural dawn warping. The tidal action has redistributed the alluvial sediments leading to the development of almost the perfect plain with a slope of 0.025 feet per mile. The tidal action has also caused the development of cracker board pattern of drainage. The east west streams which join the north south following distributaries of the Ganges are locally called 'Bharaini' and act as important arteries of transportation. The levees are very low and almost flat, and go under water during high tides. The inter stream areas are shallow saucer like depressions *(Nafis & Karim- 1959).*

Table-1.6 Major Physiographic Areas of Bangladesh and the Sundarbans *(After Phillipson, 1985)*

Description	**Area (Km^2)**	**% of total Area**	**Cumulative total (%)**
River, Canals Streams	8300	*5.75*	*5.75*
Estuarine, Blackish water	1828	*1.27*	*7.03*
Floodplain	112010	*77.76*	*84.79*
Wetlands (Beels and Haors)	2930	*2.03*	*86.82*
Freshwater Ponds and Tanks	794	*0.55*	*87.37*
Artificial Lakes	906	*0.63*	*88.00*
Hill Areas	17286	*12.00*	*100.00*
Total Bangladesh	**144054**	***100.00***	***100.00***
Forest (Managed by FD in Bangladesh	14610	*10.1 (% of total area of Bangladesh)*	
Reserved Forest (RF)	11777	*80.6 (% of total Forest area)*	
The Sundarbans RF & area including Sandbar	4142.6	*28.35 (% of total Forest area)*	
SRF Marine Zone	1603.2	--	
River, Canals, Stream and Channels	1874.1	*12.83 (% of total Forest area)*	
Total Area of Sundarbans (SRF) Excluding Zone **Including Marine Zone**	**6016.7** **7620.0**	***51.1 (% of RF in Bangladesh)*** ***64.7 (% of RF in Bangladesh)***	

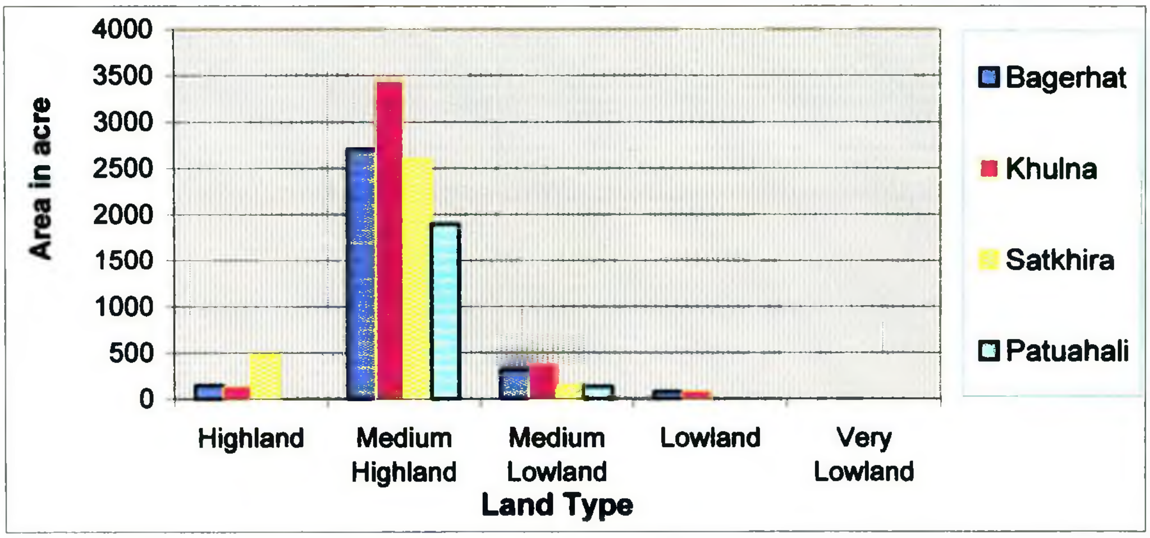
Source: Hassan & Acharya, 1994.

Table-1.7 District Wise Distribution of Agricultural Land Types in 1996

Zila	Highland	Medium Highland	Medium Lowland	Lowland	Very Lowland	Total
Bagerhat	148.3	2703.6	309.5	76.8	0.0	**3238.2**
Khulna	135.5	3445.3	372.6	79.2	0.0	**4032.6**
Satkhira	465.7	2598.0	144.0	0.0	0.0	**3207.7**
Patuakhali	00	1897.6	132.5	0.0	0.0	**2030.1**
	749.5	**10644.5**	**958.6**	**156.0**	**0.0**	**12508.6**

Source: *Statistical Year book of Bangladesh, 1998*

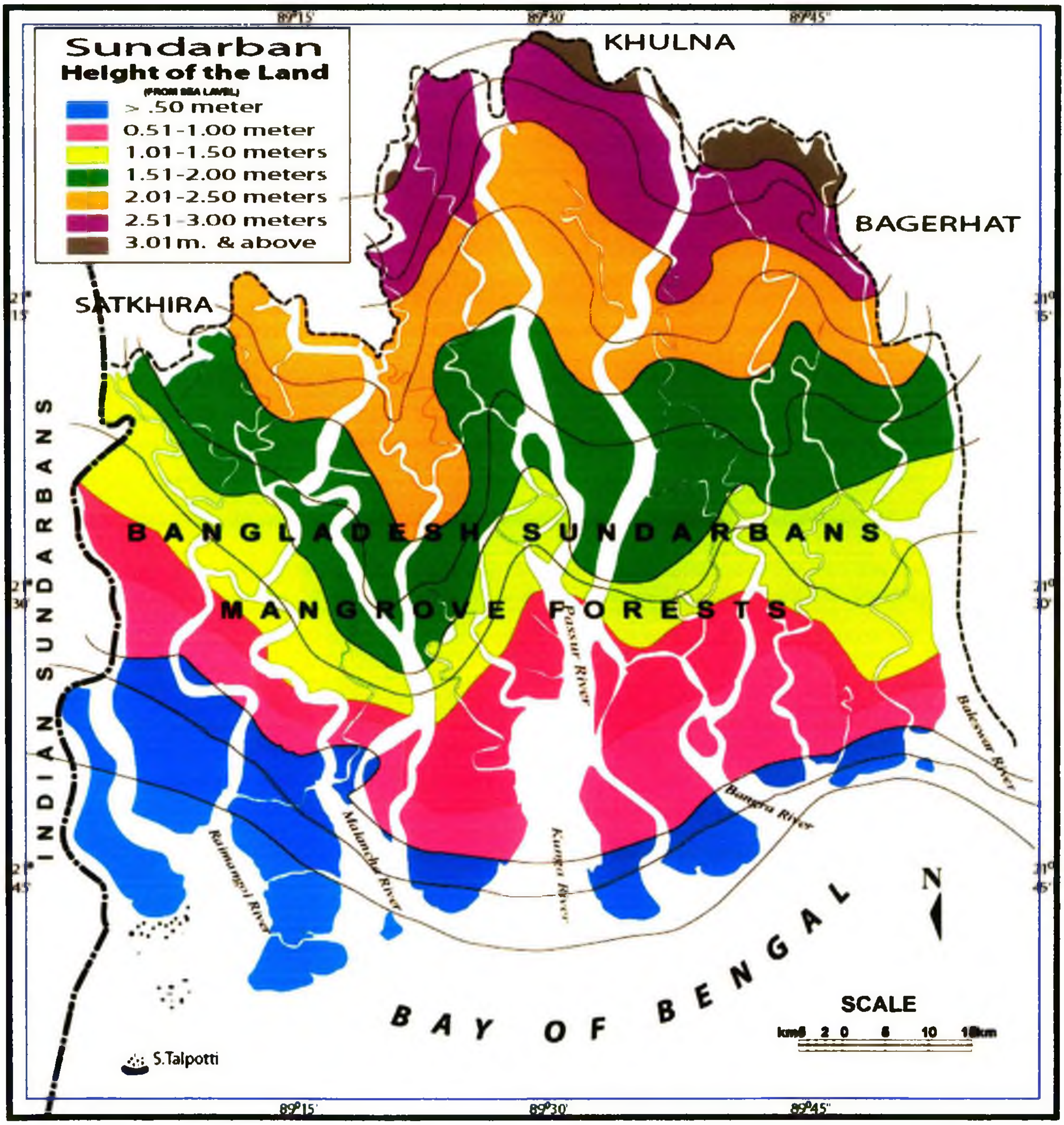
Graph-1.3 Distribution of Agricultural Land Types in 1996



Source: *Statistical Year book of Bangladesh, 1998*

The forest is flat and elevation is hardly three meters above mean sea level. The entire area are intersected by a complex network of streams and rivers varying considerably in width and depth at comparatively recent period, all these rivers were connected with Ganges; now however the only one which is direct influence, is the Baleswar. Which is responsible for freshwater supply in the eastern part of the Sundarbans. A number of rivers named Passur, Sipsah, Arpangasia, Malancha and to a slight extent Jamuna and Raimangal have indirect connected and they receive overflow of the Ganges during rains.

Fig-1.03 : Physiographic Units area (height of land) of Coastal *Sundarbans* in Bangladesh



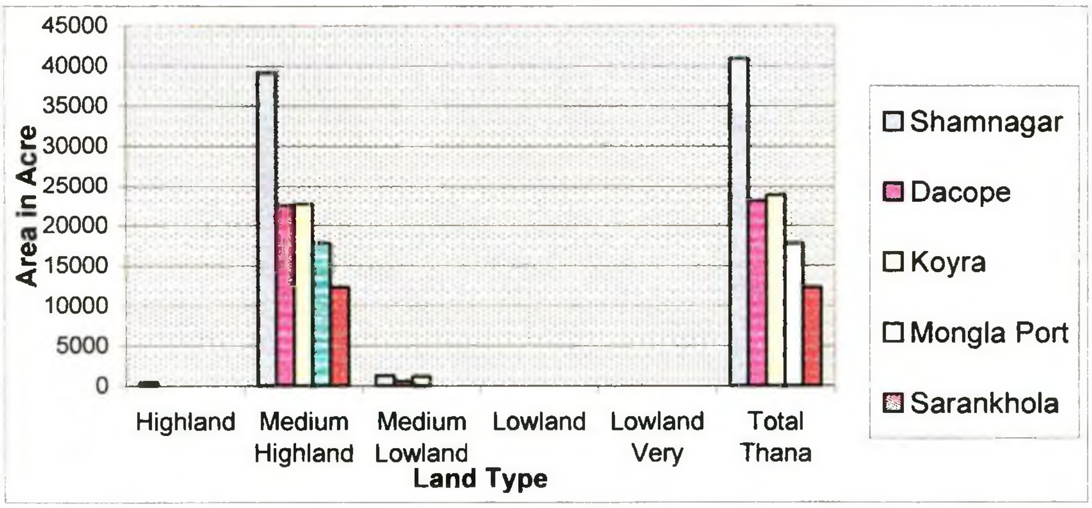
Source- Modified and edited after, Department of Soil Salinity, Govt. of Bangladesh

Table-1.8 Distribution & extent of different land types in the Sundarbans Regions of Bangladesh *(in hectares)*

Thana/Upazila	Highland	Medium Highland	Medium Lowland	Lowland	Very Lowland	Thana Total
Shamnagar	443	39166	1285	0	0	**40894**
Dacope	0	22534	567	0	0	**23101**
Koyra	14	22688	1148	0	0	**23850**
Mongla Port	0	17782	0	0	0	**17782**
Sarankhola	0	12283	0	0	0	**12283**

Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh -Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

Graph- 1.4 Distribution & extent of different land types in the Sundarbans Regions of Bangladesh *(in hectares)*



Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh -Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

1.3 Hydrological and Drainage system of the *Sundarbans*

1.3.1 Hydrological System of the *Sundarbans*

Tidal inundation regulates the hydrology of the area based on the frequency of tidal inundation, especially during the May- October period, the *Sundarbans* can be divided into four hydrological zones *(Seidnesticker and Hai. - 1983)*

1) *Area inundation- by all tides:* Poor oxygenated new accretion occupying the mouth of the big rivers and along the sea coast.

2) *Area inundated by normal high tides:* This zones includes the greater part of the *Sundarbans.*

3) *Areas inundated only by spring high tides:* This zone includes the northern part of the *Sundarbans.*

4) *Areas inundated by the monsoon high tides:* Levees located in the north east part of the *Sundarbans.*

A huge quantity of water flows through Bangladesh into the Bay of Bengal. It is estimated that in an average year, 870 million acre-feet of water flow into the country from the neighboring countries-India, Nepal, Bhutan and China. Bangladesh is a delta of three mightily rivers systems, namely the Ganges the *Brahmaputra-Jamuna* and *Meghna*. The Sundarbans are criss-cross by a network by interconnecting channels. The main rivers are *Baleswar, Passur Sibsa, Kobadak, Jamuna* and the *Raimangal* - *Baleswar* and *Passur* are linked with Ganges through the *Gorai-Madhumoti* and the *Arial khan*. The *Sibsa* and *Kobadak* are not connected with the main flow of the *Ganges* during the lean season. A large part of the Sundarbans 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.

Hydrologically, the *Sundarbans* is regulated mainly by high local rainfall during the monsoon (1600mm from May to October) and by the tidal inundation's. It may be remembered that 4000 cusec of the Ganges water, released at Farakka during the lean season, flow to the sea through the Padma-Meghna *channels*. Only a small part of it flows through the *Gorai- Modhumoti channel* to the *Baleswar* and *Passur* rivers.

1.3.2 Drainage System of the *Sundarbans*

The *Sundarbans* are showed that two big channel. The Passur gets its apply of fresh water from the *Gorai* and a minor portion of this water enter into the *Sipsah channel*. Both these channels eventually meet to from the *Kunga estuary*, a very broad channel. Tidal action is prominent in both these channels. Therefore, the Chandpai and the Sarankhola Ranges lying to the east of the *Passur* are influenced by fresh water.

The *Arpangasia* is another broad rivers, but having no link in the upstream with freshwater carrying channels is saline. So it is also the *Kalindi-Raimangal* rivers on the extreme west.

Gorai-Madhumoti-Baleswar is a freshwater Rivers, which flows by the extreme east of the *Sundarbans* and the *Kalindi-Raimangal*. Which lies to the extreme west of the Bangladesh *Sundarbans* is a saltwater river. The salinity of the *Sundarbans* is thus distributed from west to east.

1.4 Soil of the *Sundarbans*

Geologically, *Sundarbans* is of recent origin. Only a few thousand years ago the swamp forest was under the sea. According to C*howdhury (1968)* the soil is a silty-clay-loam and sub-soil consists of alternate layers of clay and sand, which at greater depths are compacted with shale and sandstone. PH in the soil is between 5.4 and 7.8. Water is mainly saline. There are 120 islands in the *Sundarbans* area of which some 58 are inhabited. Soil in the *Sundarbans* is very fertile. But the degree of salinity is not constant in the soil and water of this forest. The degree of salinity varies form year to year and from season to season.

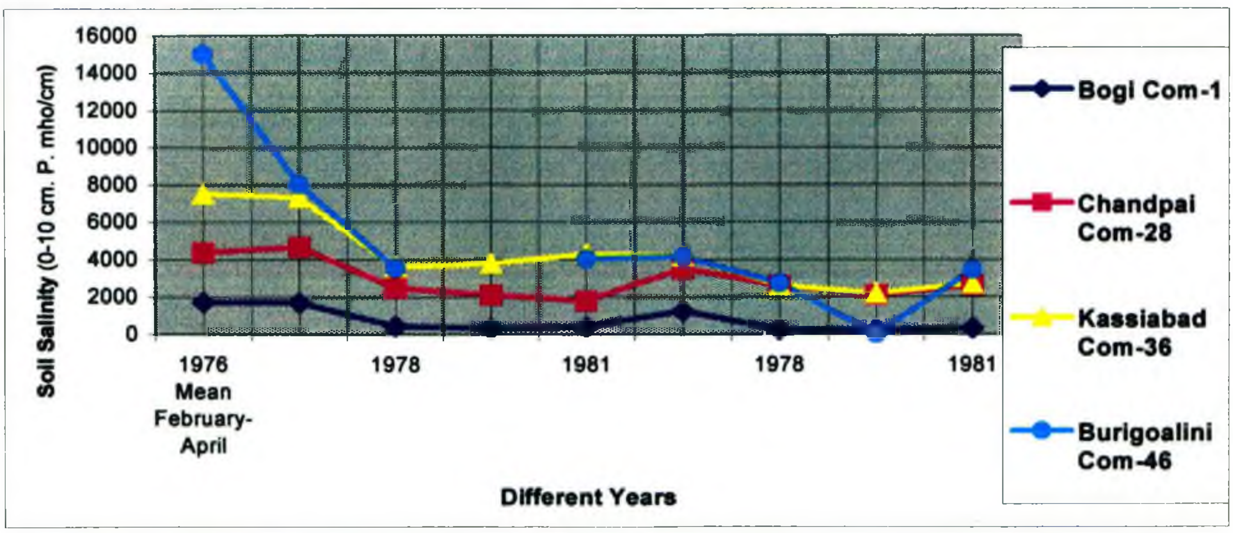
In the eastern part of the forest, where the rivers supply fresh silt each year, the top dressing is soft and fertile; in the western *Sundarbans*. Where there is no fresh water supply of silt each year, even the surface soil has settled down to a hard mass and the ground much less suitable for tree growth. Soils of the *Sundarbans* are unreclaimed, partly ripended or un-ripended and gray in color. The alluvium on the riverbank in the eastern part is slightly saline in the east or northeast and moderately saline in the west or southwest parts.

Table-1.9 Soil salinity at four stations

Station	Compartment	Forest Type	Pure Heritiera *(Sundri)*.Class	Soil Salinity (0-10 cm, P.mho/cm}										
				Max 1976-81	Min 1976-81	Mean February-April					Mean August-October			
						1976	1977	1978	1979	1981	1977	1978	1979	1981
Bogi	1	Fresh Water	35%	1800	150	1700	1670	420	310	400	1230	220	200	300
Chandpai	28	Fresh Water	67%	6200	500	4365	4650	2470	2080	1780	3500	2600	2100	2600
Kassiabad	36	Fresh Water	25%	7500	1000	7500	7300	3600	3770	4270	4170	2600	2170	2700
Burigoalini	46	Saline Water	0%	15000	1900	15000	8000	3530	0	4000	4120	2710	0	3430

Source: *Soil salinity from Shafi (1982), Vegetation from Baten (1968) & channel Salinity measurement by Rabanal* (FAO,1984).

Graph-1.5 Soil Salinity in Sundarbans at Four stations in different years



Source: *Soil salinity from Shafi (1982), Vegetation from Baten (1968) & channel Salinity measurement by Rabanal* (FAO,1984).

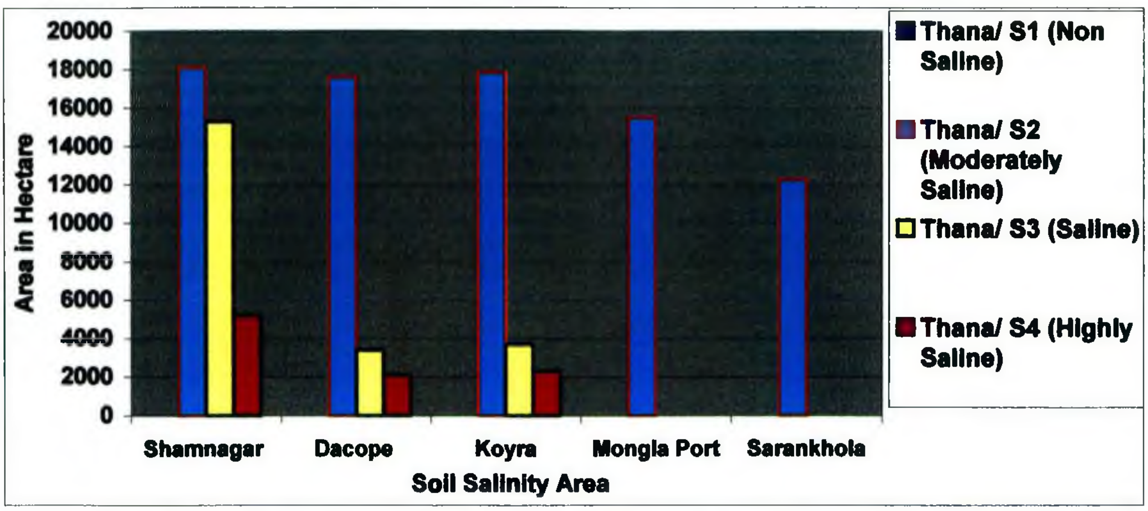
The soil salinity at the northern fringes of the *Sundarbans* has been recorded since 1977 at Bogi, Chandpai and Burigoalini by the Bangladesh forest institute. The Salinity trend and soil increases from Bogi (north east) towards Burigoalini (north west) but remains less than 6m mhos/cm even the driest months (April-May) as mentioned by *Hassan and Razzaq (1981).*

Table-1.10 Distribution and extent of different categories of soil salinity in the *Sundarbans* regions of Bangladesh *(Hectare)Integrated Management of Ganges*

Thana/ Upazila	Salinity categories				Upazila total
	S1 (Non Saline)	S2 (Moderately Saline)	S3 (Saline)	S4 (Highly Saline)	
Shamnagar	0	18,100 (46.93%)	15,270 (39.57%)	5,200 (13.48%)	38,570 (100%)
Dacope	0	17,600 (76.19%)	3,400 (14.72%)	2,100 (9.09%)	23,100 (100%)
Koyra	0	17,840 (74.83%)	3,700 (15.52%)	2,300 (9.65%)	23,840 (100%)
Mongla Port	0	15,500 (100%)	0	0	15,500 (100%)
Sarankhola	0	12,280 (100%)	0	0	12,280 (100%)
		81,340 (71.73%)	**22,370** (19.75%)	**9,600** (8.47%)	**1,13,290** (100%)

Source: *Salinity problem and crop intensification in the coastal regions of Bangladesh: Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka, BARC.*

Graph-1.6 Different categories of soil salinity in the *Sundarbans* regions *(Hectare)*



Source: *Salinity problem and crop intensification in the coastal regions of Bangladesh: Z.Karim, S.G. Hussain, M.Ahmed-1990. Dhaka, BARC.*

1.5 Vegetation of the *Sundarbans*

Forest of the total area of the *Sundarbans,* some 3,80,340 hectares comprises classified forests and about 26,807 hectares unclassified forests (*Quamrul, 2001*). Among the different floral species of the *Sundarbans* Mangrove forest Sundry (*Heritiera fomes*), Gewa (*Exoecaria agallocha*), Goran (*Ceriops decandra*) and Keora (*Soneratia apetala*) are major. Sundri is the most important floral species in this forest, which covers about 52.7% of the vegetation area and constitutes about 64%of the standing tree volume (*Rahman, et.al.1996*). Other minor species of the forest are Passur (*Xylocarpus mekongensis*), Baen (*Avicennia officialis*), Kankra (*Bruguiera gymnorrhiza*), Golpatta (*Nypa fruticaus*), Dhundul (*Xylocarpus granatum*), Hantal (*Phoenix paludosa),* Ora (*Sonneratia caseolaris),* Amur (*Amoora cucullata*) etc.(*Hussain-1994, Hossain-1998 and Latif-1992).*

Table-1.11 List of Common important plants of the *Sundarbans*

Vegetation	Forest type	Scientific Name	Family Name
TREE AND SCRUBS	Sundri	*Heritiera fomes*	Sterculiaceae
	Gewa	*Excoecaria agallocha*	Euphorbiaceae
	Passur	*Xylocarpus mekongensis*	Meliaceae
	Dhundul	*Xylocarpus granatum*	Meliaceae
	Amur	*Amoora cuculata*	Meliaceae
	Goran	*Ceriops decandra*	Rhizophoraceae
	Kankra	*Bruguiera gymnorhiza*	Rhizophoraceae
	Garjan	*Rhizaphora mucronata*	Rhizophoraceae
	Baen	*Avicennia officinalis*	Avicenniaceae
	Keora	*Sonneratia apetala*	Sonneratiaceae
	Ora	*Sonneratia caseolaris*	Sonneratiaceae
	Golpata	*Nypa fruitcans*	Palmae
	Hantal	*Phoenix paludosa*	Palmae
	Khalshi	*Aegiceras comiculatum*	Myrsinaceae
	Kirpa	*Lumnitzera racemosa*	Combretaceae
	Shingra	*Cynometra ramiflora*	Leguminosae
	Karanja	*Pongamia pinnata*	Leguminosae
	Bhola	*Hibiscus tiliaceus*	Malvaceae
GRASSES	Nol gash	*Eriochloa procera*	Gramineae
	Ullu	*Saccharum cylindricum*	Gramineae
	Hogla	*Typha elephantina*	Gramineae

Source: *Integrated Management of Ganges floods plain and Sundarbans Ecosystem BRAC, July 1998*

Forest of *Sundarbans* has been divided into three (3) zones according to degree of salinity of water in the surrounding water, courses and composition of vegetation. These are-

1. **Fresh water forest vegetation.**
2. **Moderately salt water forest vegetation.**
3. **Salt water forest vegetation**

1.5.1 Fresh water forest vegetation

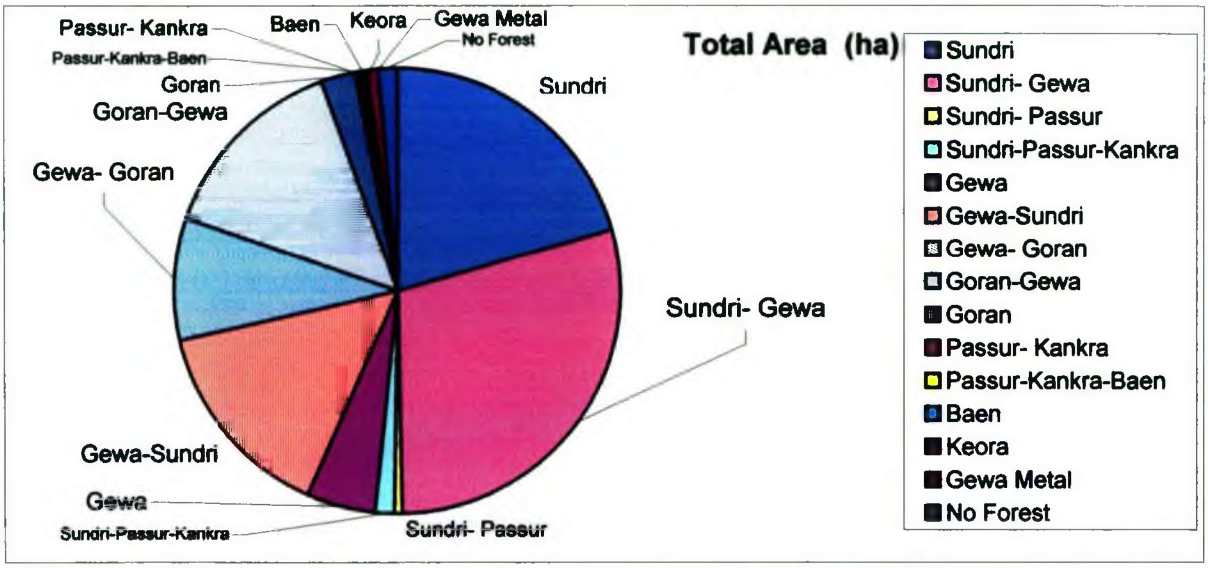
North and east of a line from Kobadak forest station to the mouth of Katka khal on the coast. The river creeks in this zone are fresh or only slightly saline during the rainy season. Sundry (*Heritiera*) is the dominant species. It is mixed with varying amounts of Gewa. The proportion of Sundri decreases towards west and south and Gewa correspondingly increases. Passur and Kankra occur the more frequently flooded areas.

Table-1.12 Sundarbans Forest type of Vegetation and Salinity distribution (Area*(ha)* of Salinity unit and % of total Land)

Forest Type	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area	% of total Sundarban Land
	Area (ha)	% of S. Land	Area (ha)	% of S. Land	Area (ha)	% of S. Land	(ha)	
Sundri	62518	*15.57*	20518	*5.11*	62	*.02*	**83098**	***20.69***
Sundri- Gewa	54947	*13.68*	61165	*15.23*	403	*.10*	**116515**	***29.01***
Sundri- Passur	1109	*.28*	590	*.15*	241	*.06*	**1940**	***0.48***
Sundri-Passur-Kankra	5985	*1.49*	441	*.11*	0	*0*	**6426**	***1.60***
Gewa	1297	*.32*	14251	*3.55*	3921	*.98*	**19469**	***4.85***
Gewa-Sundri	20093	*5.00*	26285	*6.55*	12603	*3.14*	**58981**	***14.68***
Gewa- Goran	6	*.00*	12288	*3.06*	23715	*5.90*	**36009**	***8.97***
Goran-Gewa	0	*0*	3110	*.77*	54145	*13.48*	**57255**	***14.26***
Goran	0	*0*	526	*.13*	8781	*2.19*	**9307**	***2.32***
Passur- Kankra	220	*.05*	0	*0*	1110	*.28*	**1330**	***0.33***
Passur-Kankra-Baen	860	*.21*	0	*0*	177	*.04*	**1037**	***0.26***
Baen	74	*.02*	575	*.14*	231	*.06*	**880**	***0.22***
Keora	392	*.10*	2653	*.66*	206	*.05*	**3251**	***0.81***
Gewa Metal	0	*0*	0	*0*	10	*.00*	**10**	***.00***
No Forest	1643	*.41*	3461	*.86*	1014	*.25*	**6118**	***1.52***
T. land of M. Forest	**149144**	***37.13***	**145863**	***36.32***	**106624**	***26.55***	**401631**	***100.00***

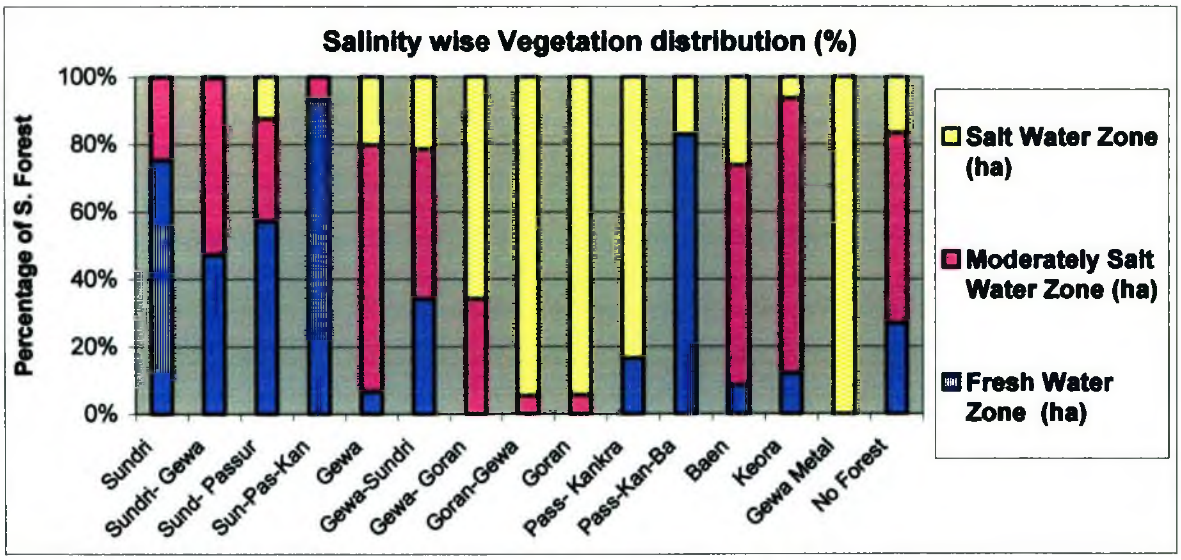
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

Graph-1.7 Sundarbans Forest type Area of total Land



Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

Graph-1.8 Sundarbans Forest type & Salinity distribution (% of Vegetation)



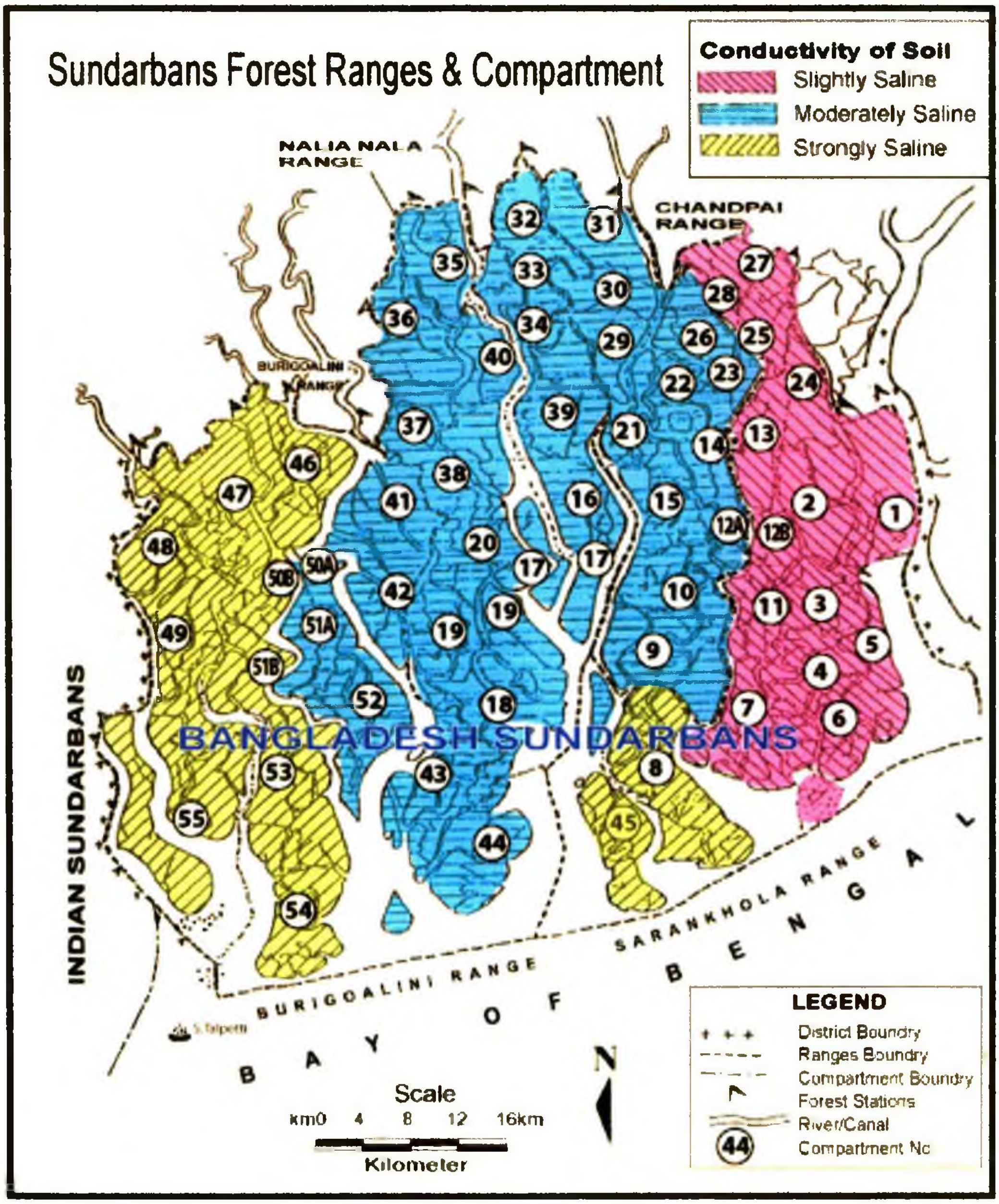
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

The understudy is formed of Singra on dry soils, Amur on moister soil and Goran especially in the more saline area. Species common on new islands, banks of rivers, on streams and in the swampy areas are Keora (*Sonneratia apetala), &* Golpatta (*Nypa frutieans*).

1.5.2 Moderately Saltwater Forests Vegetation

Moderately saltwater area lies to the west of the line (described under fresh water zone) and east of Malancha rivers. This type occurs near the sea and around the semi-moribund rivers. The dominant species is Gewa (*Excoecaria*), mixed with Sundri (*Horitiera*), growing over fairly dense crop of ceriops. The dominance of Sundri

Fig- 1.04 : Sundarbans showing Forest Ranges, Compartment and different salinity zones



***Source :** Modified and edited after, Hassan, 1983*

(Heriteria) decreases towards the west and the south. *Xylocarpus* is more frequent in this zone. It is found in association with Kankra (*Bruguiera gymnoriza*) and Baen (*Avicennia officinaloa*) particularly where the ground level is generally low. On new islands, Banks of streams and in swamp areas near the freshwater forest, species like *Sonneratia* (Keora, Ora), *Avicennia* (Baen), *Nypa* (Golpatta), *Carapa spp, Bruguiera, Lumitzera* (Kirpa), *Aegiceras* (Kalisha, khalshi) *Kandelia* (Gura, Gurae) are found.

1.5.3 Salt water forest vegetation

From west of Malancha rivers until the international border. The channels in this zone have a high mean salinity throughout the year. The soil is hard. The forest consists mainly of sparsely-spaced *Excoecaria* (Gewa) below 7m in height and a dense understudy of *Ceriops*, with dense patches of *phoenix Paludosa* (Hantal) on the drier soils. *Carapa* species and occasional *Bruguiera gymnorhiza* (Kankra) occurs sporadically throughout the area. Common species on the bank of stream and channels, on new islands and in the low lying areas are *Rhizophore conjugata* (Garjan), *Kandelia Rheedii* (Gura, Gurae, Gural) and *Avicennia alba* (Sadda Baen). *Sonneratia apetala* (Keora) is found occasionally and when found is low and spreading in habit.

1.6 Importance of the Study

Different studies have so far been made mainly on the different botanical or other plant-ecology related aspects of this mangrove forest. However, very little studies have been conducted on the geographical aspect especially on the spatial configurations of floral species of *Sundarbans* With Reference to its Geomorphological and Hydrological variations. In view of the unique biological characteristics of mangrove, it is the immense interest to assess the extent to which, these ecosystem can be used as indicators of coastal change or rise in the sea level. These diversities will include changes in the physiographic or variations in the hydrological conditions of different areas in the forests, along with the result and variations in salinity, changes in soil properties and some other important correlates of the combined out come of the physio-hydrological effects of the mangrove ecosystem of *Sundarbans* on the spatial distribution of the different floral species in the forest. Each species of mangrove occurs in different ecological conditions that approach its limits of tolerance with regard to salinity of the water and soil as well as the inundation regime.

1.7 Aims and objective of the study

The Present study aims to investigate the spatial variations of the floral species of *Sundarbans* Mangrove forest of Bangladesh with spatial reference to its Geomorphological and Hydrological peculiarities.

The specific objectives of this proposed study are:

- To conduct in depth investigation in the spatial variation in the occurrence of different major Mangrove species of plants in species of plants in *Sundarbans*.
- To examine and delimit the different Geomorphological units in *Sundarbans* forest.
- To identify the different Hydrological regimes and their related spatial regions in *Sundarbans*.
- To find out and asses the influence of the Hydrological and morphological variations of the distribution of different major Vegetation species of the *Sundarbans*.
- To examine the effect of the increase of salinity on the degradation of the plants of the *Sundarbans*.

- To investigate into the effect of human interference into the plant ecosystems of *Sundarbans* and finally.
- To predict some future probable environmental changes in *Sundarbans* forest with reference to the changing Geomorphological and Hydrological scenarios.

Salinity intrusion is a major problem to the southwestern coastal region of Bangladesh.

The main objective of this study is to investigate diurnal, monthly and yearly variation of saline concentration and also correlate this with vertical tidal variation, discharge and rainfall pattern.

1.8 Methodology of Study

In order to achieves the aforesaid goals and objectives of this proposed study a through and in depth research with be conducted. Both the primary and secondary data sources will be utilized in this study. On the basis of some empirical field oriented sample surveys important and relevant primary data will be generated for analysis among which on elaborate floral species inventory for several morphological units of different parts of the *Sundarbans* forest will be prepared. Simultaneously the role of Geomorphological and Hydrological variables in the occurrence and distribution of the different floral species in different areas of the forest will be critically examined with the help of appropriate techniques of environmental and ecological tests.

The study is done on the basis of reviewing some related previous works *(Bibliography)* and also interpretation of some raw data as supplied by Bangladesh Water Development Board. The analysis are expressed both graphically and in tabular form. The temporal as well as spatial changes in the forest, landform units and drainage system in the study area will be identified and mapped with the help of topographical sheets, old and new maps, Arial photograph and satellite imageries. Other steps of investigation are-

1.8.1 Generation of the Primary data &Field Investigation

Primary data and field information will be generated through the field survey. Several in depth field trips will be made to collect different data i.e. sediments to logical, floral species inventory, salinity measurement, water flow measures, soil condition and other relevant date etc.

In order to achieve the objectives of the present work *Sundarbans* areas have been selected on the basis of Geomorphological and hydrological configuration. Each these study areas covers Floral/Vegetation areas. From the sample areas the following hydrological and Geomorphological parameters on floral species were chosen for analysis.

1.8.2 Secondary Data Base

For the purpose of studies on spatio-temporal changes of the landform and vegetation of the Sundarbans and adjoining areas, some satellite imageries of different years and topo-sheet maps have been used in this study.

It would be collected from the following sources. Forest Ministry, Forest Adidaptar, BRAC, Forest Department, SPARRSO, Geology Department, Soil Department, Environment Adidaptar etc. Arial Photograph, Satellite imageries, Topographical maps will be collected from SPARRSO. Survey of Bangladesh Forest inventory map, Different old and new map, other data sources will be collected from Forest Department, and other library sources.

1.8.3 Sampling Procedure

To collect primary data sampling technique will be applied in different ranges. Sample will be collected from at least 3 stations. At least two sample will be collected from each station.

1.8.4 Laboratory Tests

Some relevant Laboratory tests will be made for identification of variation in the sediments and water in different study areas of the *Sundarbans*.

1.8.5 Quantitative and Statistical tests

In order to assess the relationship between different variables in the *Sundarbans* under the present study statistical method like multivariate factor analyses, variance test or other appropriate tests will be performed.

The study was based on computation processing, analysis, interpretation of the available ground water level data and the river stage data of the year collected from the ground water and surface water hydrology of the BWDB.

The river stage elevation were correlated with the ground water elevation in the observation wells of the respective section lines against their distance from the river bank. These determined the flow direction of the ground water along the section lines for different months.

To determine the erosion and accretion of the river bank and shifting of the river course hydrographic charts supplied by BIWTA and satellite images from SPARRSO have been studied by superimposing on over the other.

1.9. Survey of Literature

A review of literature on the mangrove ecosystem were made with the main biotic elements which constituting the ecosystem that is mangrove flora and fauna their inter- relationships with their management implications.

Study of Relevant Literature

Blasco, F. ; Saenger, P. ; Janodet, E. 1996 has produced good thesis on an view of the unique biological characteristics of mangroves, it is the interest to assess the extent to which these ecosystems can be used as indicators of coastal change or rise in sea level. Each species of mangrove occurs in ecological conditions that approach its limit of tolerance with regard to salinity of the water and soil, as well as the inundation regime. If the duration of daily immersion were to be modified by tectonic, sedimentological or hydrological events, the species either readjusts to the now conditions to unsuitable conditions. Consequently, the use of remote sensing data for mangrove ecosystems offers excellent potential as a tool for monitoring coastal change.

- **Chaudhury, MU. 1990** has produced good topic on Digital processing of landset data was not satisfactory for forest cover mapping mixed mangrove *(Sundri and Gewa)* forests , although crop cover density could be monitored. Digital analysis of high resolution SPOT-1 data identified vegetation zonation in the mangrove forests and could also be used to monitor the ecological status of the mangroves. The SPOT-1 data showed a reduction in the area of Sundri and increasing dominance of Gewa.

- **Hossain, M. ; Ali, M. ; Akter, S. 1998** has produced good paper on a regeneration study was carried out in mangrove forest in the Chandpai range, using on sample plots *(10X10 m)* from each stratum based on inundation at various distances between 0 and 300 m. from the watercourses to the interior. In each of the 46 sample plots all trees, sampling and seedlings of the major tree species *(Sundri, Gewa, Kankra, Amur, Goran, Baen)* were recorded separately in september-November 1995. Sundri was dominant at all growth stage classes for different species much less frequent. Sundri was the highest, followed by Gewa, But Sundri regeneration increased with increasing distance from the canal bank while regeneration of Gewa decreased. Regeneration of the other species was low or absent.

- **Hussain, Z. (ed.) ; Acharya, G. 1994.** -The book gives a detailed description of the faunal and floral diversity and management of the *Sundarbans* mangroves found in the SW portion of Bangladesh- an area about 5,77,000 ha and an important resource base for the economy of this area. The ll-chapter by various authors provide an introduction to the area, and descriptions of the physical environment, vegetation, natural regeneration, fisheries, fauna, conservation of the faunal resources, policy, acts and regulations, history of forest management, management of forest resources, and environmental impact. An index is provided.

- **Katebi, MNA. ; Bari, A. ; Moudud, HJ (ed.) ; Rashid, HE. (ed.) ; Rahman, AA. 1988** has produced good paper on a account of mangrove afforestation projects in Bangladesh since 1956-66, 1973-74, 1979-80, giving details of how the projects developed, their silviculture, management, organization, funding ad problems and achievements. The total area planted in these 2 phases were 12340 and 77193 acres respectively. The total area planted in this project from 1980-81 to 1984-85 was 110172 acres. This project was extended for a further 5 years in 1985 and the total area planted from 1985-86 was 60300 acres.

- **Latif, MA. ; Rahman, MF. ; Das, S. ; Siddiqi, NA. 1992** has produced good paper on analysis are presented of data collected on six occasions from 1977 to 1990 from 12 permanent plots in mangrove forests throughout the *Sundarbans*. Diameter at breast height increment for the two most important species - Sundri and Gewa were estimated separately for all site qualities/height classes and salinity zones. Mean annual Diameter at breast height increments ranged for Sundri *(0.062cm to 0.151 cm)* and Gewa *(0.049cm to 0.189cm)*. There were only a small number of trees of Passur, Keora, Baen and Kankra. Mean Diameter at breast height increments for Passur *(0.206cm)*, Keora *(0.192cm)*, Baen *(0.219cm)* and Kankra *(0.178cm)* respectably. The increment rate was height at higher site qualities and in lower salinity zones. The annual rate of in growth for Sundri was 15 trees per hectare, while annual natural death and removals were 27 trees per hectare. The corresponding data for Gewa were 22 and 8.1, respectfully. These observations suggest that the proportion of Gewa is increasing and that of Sundri is decreasing. Keora is being eliminated naturally without natural regeneration in the plots.

- **Siddiqi, N. A. 1986, 1987** has produced nice paper on a site, which had become unsuitable for natural regeneration of mangroves was selected in the Bangladesh Sundarbans mangrove forest for trials of 5 mangrove and 6 mainland species. The site was slightly saline and only inundated during high tide in the rainy season. Average survival of the mangroves *(Sundri, Gewa, Baen, and Kankra)* after 3-months is 26.4-73.8% over all area, except for Keora, which did not survive. Of the mainland species, most of the seedlings is unfenced areas were destroyed by deer browsing, only babla and minjiri showing significant survival (respectively 23% and 17%). All species except babla survived significantly better in fenced areas: minjiri 58%; raintree 53%; babla 37%; korai 33% mahogany 23% and ipil ipil 18%. Height and diameter growth were best for minjiri, followed by raintree, babla and koroi. Al species grew better on higher ground because of their sensitivity to water-logging. Other animals causing damage were porcupines and monkeys.

- **Rob, M. A. 1991** did his Ph.D. on "The Fluvial Geomorphology of the Gangetic Delta". In his thesis he tried to portray some of the morphological and hydrological aspects of the deltaic rivers of the Southern Bengal region. At the same time he tried to reveal the nature and process of the land-building activities along in with changes in the coastal region of the Bengal coast. In his studies he has compared the old and new maps and satellite-imageries of the late 20th century. After the studies of Baghchi (1943) – Rob's studies on the Ganges delta can claim to be the original and in-depth study on the Fluvial Geomorphology of the deltaic land of Bengal.

- **Sengupta, A. ; Choudhuri, S. 1993** has produced good paper on Data are reported on the physical and chemical properties of the soils of 4 succession stages of mangrove sediments of the Sundarbans *(in West Bengal and Bangladesh):* !)formative mangrove swamp; !!) developed mangrove swamp; !!!) declining ridge mangrove; & !!!!) degraded mangrove and embankment protected agricultural land. The parameters studied *(P^H electrical conductivity and exchangeable anions and actions)* indicated that the soils are characteristically saline. There was a direct relation between soil salinity and stages of soil formation and saline water inundation, which was heights in stage ! and lowest in stage !!!!.

- **Tack-J. ; Polk ; Haper-D (ed) ; Brown-T 1999** has produced good paper on distribution of the mangrove forests is often linked with the presence of estuaries and creeks and the influence of the catchment area on the mangrove area through the runoff of the river is clear. However, there are mangrove areas where no rivers or estuaries are the immediate neighborhood. An explanations suggested for these exceptions, making use of a mathematical groundwater flow model. The model is able to explain the distribution of mangroves in three different areas *(Kenya, Bangladesh and Florida Everglades).* The model can also be used to predict mangrove destruction in response to change in groundwater flow.

- **Wescot, JL Jr. 1990** has produced good topic on Water has a dual role in the Sundarbans area of southwestern Bangladesh. Hydrological process are vital to the ecological function and cultural identity of the mangrove ecosystem. At the same time, large scale water development creates external forces that threaten the Sundarbans environment. Section two surveys water management issues and institutions at six geographical scales: the international basin; Indian and Bangladesh; Greater Bengal; Bangladesh; Southern Bangladesh; and Khulna district. The conclusion stresses the role that the political geography of water will play both within and outside the Sundarbans ecosystem.

1.10 Problems of the Study

The management of mangrove forests has been so intricate and problematic requiring a high degree of scientific knowledge and administrative proficiency, as the management of mangrove forests of the *Sundarbans*. The demand for the forest produces by the people residing in the vast hinter land and livelihood of the people residing around the *Sundarbans*, the increased demand on the forest produces being alarming, foresters are to remain in their toes to protect. The foresters have to carry out forestry operations and simultaneously look after the safety of the workers in the forests, they have to preserve and protect the most resourceful but fragile ecosystem and manage them with almost care and efficiency.

1.10.1 Related to the Sampling Procedure

The study area is vast and physically rough. But the length of time is not so long. So the define or perfect sampling is very difficult.

1.10.2 Related to the access to the data

All necessary and relevant data are not easily available. Sometimes stick official formalities and restrictions did not allow the author to get excess to the data need for this study. Besides these most of the data are no perfect So which data is connected must be verified before study.

1.10.3 Problems related to Survey

In accessible and dense forests of the Sundarbans and the ferocious wild life especially fair of the Royal Bengal Tiger discouraged the author to conduct necessary ground toroth Surveys in the study areas. The physical roughness of Sundarbans land (i.e. for root of Sundri, Goran, Gewa, Passur and other species) is another problem for sample collection.

1.10.4 Other problems

Before of short time and without any financial support large scale surveying is not possible. During the study period, I was not physically fit. I had been suffering typhoid and jaundice for long time.

Chapter –2

Geomorphology of the Sundarbans

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2.0 Geomorphology of the Sundarbans

Apparently *Sundarbans* comprises a vast deltaic plain with an extremely flat and even surface. As a matter of fact the forest is occurred on numerous smaller deltaic islands that are divided and separated by innumerable coastal creeks and estuaries. Geomorphologically the *Sundarbans* mangrove forests occupy the lower edge of the Ganges delta and develop on the comparatively newly formed coastal tide dominated surfaces. These forested lands exhibit the morphological attributes of coastal marshes. The lands are formed by the depositional process of accretion in the shallow marine continental shelf of the northern Bay of Bengal. Land is the resultants of the combined siltation process of the both marine and fluvial actions.

The *Sundarbans* is presumed to be formed by deposition of silt brought down by the rivers Brahmaputra and Ganges from the Himalayas along with their network of tributaries forming an watershed area of 10,90,000 sq. km. A number of theories exist about the origin of this landmass. Previously it was depression in the coast which was ultimately filled up by thick sediment of recent Pleistocene origin. It has been estimated that present day *Sundarbans* came into existence about 4000 years ago. The Bengal basin tilted east ward on 12th Century because of geotectonic movement. This affected the course of the main river flow in recent geological past resulting in the reduction of freshwater supply to western rivers. This has given rise to accretion at river mouth, increase in salinity followed by subsequent change in biotic community *(Rahman-1998)*.

Another dimension to the geological history of the *Sundarbans* by calling attention to the tectonic instabilities of the Himalayan region. He states that the western and southern portion of the Ganges delta are now in *'full organic phase'*. Morgan and Mc Intire *(1969)* have also stated that the area to the west of the Meghna estuary is undergoing subsidence whereas uplifting is occurring to the east of the estuary. These geological phenomena place the low salinity eastern *Sundarbans* in the area that is undergoing subsidence with uplifting occurrence in the more-saline western *Sundarbans* as well as to the extreme east of the *Sundarbans*, towards Chittagong. Subsidence in the central spillway is attribute to the massive loading of river-borne sediments in the alluvial delta fan and on the submersed coastal shelf. *(Deb-1956)*.

2.1 General Geomorphology of the *Sundarbans*: Unit & Features

The broad belt of the entire *Sundarbans* mangrove extends a large area along coast and characteristics the most spectacular environmental unit of the area. In transverse mangrove from the mainland to the sea the important geomorphic units of the *Sundarbans* are include:

a) Distributary channels with lag., sub-aerial and sub-aqueous levees, aerial flat.

b) Marginal marshy areas above mean tidal level.

c) Tidal sand bars and islands of their network of tidal channels.

d) Pro-delta clays and silts.

- The general topography is characterized by three broad geomorphic units:

    -Natural levees.
    -Flood basin.
    -Backswamps.

The coastal process are influenced by a combination of interaction factors, comprising parameters, micro and macro tidal cycles and long shore currents found in the coastal tracts of *Sundarbans*, which vary during the pre-monsoon, monsoon and post monsoon periods. They are also affected by tropical cyclones. Field experiments have shown that the coast line is changing in the reclaimed areas due to high rates of cliff erosion. A variety of habitats are found in the *Sundarbans* including beaches, estuaries, mangrove swamps, tidal flats and tidal creeks, coastal dunes and back dunes areas. The mangrove vegetation of the inter tidal environment assists in the creation of new landmass and the inter tidal vegetation has an important role in swamp morphology. The active of mangrove fauna in the inter tidal mudflats, mangrove substrate and beaches, develop micro-morphological features which are very significant for trapping sediments and mangrove seeds. The morphology and evolution of the eolian dunes are controlled by an abundance of xerophytic vegetation's. Creepers and grassy vegetation play and an important role in stabilizing sand dunes *(Bhattacharya and Chowdhury-1985).*

2.2 Geomorphic Agents, Accretional Process Erosion and deposition in the *Sundarbans*

Salt affected soils *Sundarbans* occur in the coastal districts of Bagerhat, Khulna, Satkhira and Barguna. Most of the areas cover smooth floodplain landscapes of coastal lands interlaced by estuaries, tidal rivers and creeks, clusters of large and small estuarine and offshore islands and extensive mud flats and shallows. Topographically all these areas are low lying and have elevations mostly less than 3m above mean sea level. The Ganges tidal floodplain constitude about 49% of the total coastal areas including water bodies and urban areas. The area under *Sundarbans* comprises of clusters of islands separated from one another by wide, deep estuaries, interconnected tidal rivers and numerous creeks. Landscape is underlain by silty and clayey tidal deposits derived from the *Ganges* river system *(Karim- 1982).*

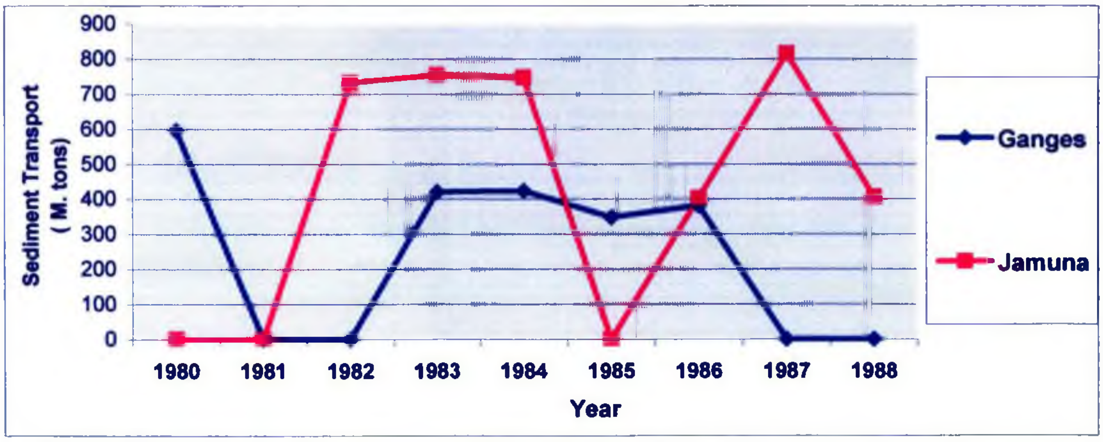
Sundarban mangrove like mangrove of any other areas accelerates new accretions in front. Advantage of this scientific truth is take not only for accelerating new accretions in the shore areas but also for stabilizing the new accretions by regenerating mangrove species on the new accretions. In Bangladesh advantage of these special characteristics of mangrove species have been taken in establishing the coastal afforestation.

Table-2.1 Summary of Sediment Transport in Millions tons in the *Ganges* and *Jamuna*

Year	***1980***	***1981***	***1982***	***1983***	***1984***	***1985***	***1986***	***1987***	***1988***
Ganges	596	-	-	420	423	348	381	-	-
Jamuna	-	-	733	754	747	-	403	815	407

Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. – Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

Graph- 2.1 Sediment Transport in the Ganges and Jamuna rivers in different year



Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. – Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

From available maps it is apparent that over the last two hundred years there has been minimal accretion and perhaps shore retreats on the mangrove coasts of the *Sundarbans*, but extensive accretion did take place on the mangrove-free coast of Patuakhali, Barisal and Noakhali *(Imam-1984)*. This results from the fact that accretion is primarily a function of sediment supply by rivers. Sediment load and discharges are low in the western delta but high in the eastern side in Bangladesh.

Despite their complexity and infinite variability the landmass of these alluvial deposit has been distinguished into the following types-

a) **Mud flats**- Mud flats are formed as the bars at the mouth of the rivers or as low lying accreting mud flats along the convex side of the meandering rivers and generally sloping towards the river channels. Mud flats thus are generally sloping towards the river channel. These landforms are subjected to direct wave action, flow and turbulence of the water current of the river. These new accretions provide differential habitats depending on their inclination of the slopes towards the channel or river courses. The common variants of the mud flats are:

- *Channel deposits*- They are found in the convex sides of braided or meandering streams courses and grows by individual increments outward into the meander curve. They occur as channel bars, point bars depending upon their position and origin.

- *Inclined slope*- Soft muddy inclined surface sloping towards the stream.

b) **Back swamps or basins**- The back swamps are sheltered and receive calm water only through the creeks. In draining the rainwater and the tidal water a tidal drainage system of the landscape is being formed with tiny streamlets coalesce to from tributaries that progressively coalesce to from streams and rivers. The smallest 1st order streams that flow from the depressions are locally called "*chatra*" or "*shishkhal*", two 1st order streams coalesce to form a second order stream. Two second order streams combine to form a third order stream and so on. The back swamp areas are being flushed by tidal water and act as drainage during ebb tide and rain water. Gullies and smaller creeks are formed to drain those depressions. Due to working by tidal waters a complex network of channels and creeks are formed as the drainage system of the basin through these creeks loses its velocity gradually and diminishes ultimately in the vegetated areas. Since larger grain size sediments settle on the levee and so only the finer particles are carried to the low lying back swamps or basin. Sometimes when smaller creeks are plugged with on rush of sediment during flooding season or due to tidal surges pool of water may be formed inside the forest. Depending on the catchment size of the plugged creek size of the pool very. These water pool areas are locally known as '*bills*'.

c) **Ridges or Levees-** Every year, during flooding, the rivers overflow and suspended particles are deposited over the edge of the river bank and spread slowly over the swamps resulting a few meters of narrow strips of land more elevated than the swamp interior. These elevation parts are the ridges or levees and from 5-15 m narrow strips fringing the rivers. Physio-graphically levees are the most raised lands in the deltaic formation. Some the outer slope of the levees from a inclined slope with steep gradient towards the channel side.

d) **Tidal creeks-** In a tidal drainage system of the landscape tiny streamlets coalesce to form tributaries that progressively coalesce to form streams and rivers. The result is a dendrite system. These ramifying and meandering channels vary in size from a few centimeter to several meters in depth and a few hundred meters in width. The smallest streams coalesce to form a second order stream, two second order streams combine to form third order stream and so on.

2.3 Role of Fluvial Process Land Building Activities in the *Sundarbans*

The western part of the delta, from the river Bhagirathi across the Bangladesh border to the line of the *Gorai- Madhumoti* and *Rupsa- Passur* rivers, is the moribund region of the delta; in this area the characteristic land-building activities of a delta have ceased. Most, if not all, of the many rivers and channels are no longer tributaries of the River Ganges; for most of the year they have no flowing water and during rainy season they only drain the immediately adjacent countryside. The extent to which the remainder of the delta is actively building land is uncertain. There are frequent changes in the land forms. But land is also being eroded. One study has reported a comparison of early maps with more recent ones which indicates that land forms are changing, but that the total area of land within given boundaries is remaining roughly constant. It is likely that deep water and heavy tidal currents have placed limits on the extension of the delta by deposition.

There are three sources of water flowing into the *Sundarbans* of Bangladesh. They are first, the flow of the major rivers coming from India, primarily the River Ganges; second, rainfall draining from the surrounding countryside and finally there may be a contribution from water stored in the ground. Two distributaries withdraw water from the Ganges in Bangladesh, the *Gorai* and *Arial Khan* rivers. Decreased forest area may have reduced ground-water storage and percolation in the basins, and may have led to increased flooding and decreased dry season flows, but the extent to which sedimentation and flooding can be attributed primarily to recent changes in forest cover has been exaggerated.

Freshwater discharge through the *Sundarbans* mainly from the Ganges passing by the north in a southwest to the east direction. During the winter months, there are inadequate surface flow in the Ganges due to diversion of water from the Farakka through the *Bhagirathi-Hoogly* to the sea. The main rivers caring surface water viz. The *Gorai-madhumati-Baleswar-Haringhata* and the *Passur* have freshwater in their estuaries at the sea board during the rainy season. The rivers of the *Sundarbans* remains active for quite a distance inland by the action tides. Their headwater are narrow, thin and shallow *(Chowdhury- 1984).*

The Gorai flows north-south from the *Ganges/Padma,* but their flow change direction towards west in the southern part, hence it supplies freshwater to the rivers of the *Sundarbans.* The *Passur* and the *Sibsa* flow to the south carrying bulk of the freshwater from upland. With the fall of water levels and great reduction of discharge during the winter months, the supply of freshwater through the '*Sundarbans* Channels' has been reduced.

The *Sundarbans* forest ranges, freshwater charge is more, hence salinity is less, tidal influence is more and saline water from the sea directly penetrates in this belt. Tidal water now move deeper inland through the estuaries and the creeks. The tidal influence has there for increased further inland. The salinity in general increases westward from the freshwater zone at the sea board at the *Meghna* mouth *(Chow-1984).*

A SPARRSO (1987) study on coastal dynamics of Bangladesh for the period 1960-84 showed net erosion. The amount of *Sundarbans* land accretion area is 78.02 sq. km, erosion area is 375.65 sq. km, and net erosion area is 297.63 sq. km.

2.4 Coastal Geomorphology in the *Sundarbans*

The total length of Bangladesh coastline is about 650 km of which the Sundarbans cover about 125 km. Historically, Bangladesh experienced both erosion and accretion. However it has been demonstrated by bird that the deltaic growth and erosion are more or less in a equilibrium *(Bird-1985).* Understanding the present hydro-morphological setting of the Bangladesh coastline is very important if we like to predict the future development. Fluvial imputes of freshwater and sediment and marine inputs of tide and wave are different in different areas of the coast.

Bangladesh is drained by a large network of rivers centering one of the largest river systems in the world; the Ganges, the Brahmaputra and the Meghna (GBM). The GBM carries about 2.4 billion tons of sediments per year *(Holeman, 1968)* into the Bay of Bengal. These sediments interact with dynamic processes in the Bay leading to accretion in one place and erosion in the other.

The bottom topography of the Bay of Bengal is characterized by the Ninety East Ridge to the west of the Swatch of No Ground (a submarine canyon) and the Bay deep sea fan. To the east are the Mayanmar trench and the Nicobar Fan *(Islam, Huq & Ali-1999).*

According to Ali (1991) the salient and major features of coastal morphology of Bangladesh are:

- Low coastal bottom topography.
- Low coastal land topography.
- A large network of rivers, canals and streams.
- A huge discharge of river water heavily laden with sediments.
- High wind and tidal actions.
- Frequently occurring tropical cyclones and storm surges.
- A vast tract of mangrove forests influencing the flow dynamics.
- A large Continental shelf particularly near the Meghna estuary.

Table-2.2 Some important features of Agro-ecological Regions occurring in the Sundarbans Saline zone of Bangladesh.

Thana/ Upazila	AEZ Region	Agro Ecological Zone (AEZ) Sub Region				Main Soil Texture		Main General Soil Types						
	Ganges Tidal Floodplain	Saline,	Saline,Calcareous &	Saline,acid sulphate soils	Nonsaline,Calcareous & non-calcareous	Loamy	Clayey	Calcareous Alluvium	Calcareous Grey Floodplain soils	Calcareous Dark Grey Floodplain soils	NonCalcareous Grey Floodplain	NonCalcareous Dark Grey Floodplain soils	Acid Sulphate	Peat
Shamnagar	α	α	α	α		α	α	α	α	α	α	α	α	
Dacope	α			α			α	α	α	α	α		α	α
Koyra	α					α		α	α	α	α	α	α	α
Mongla Port	α	α			α	α	α	α	α	α	α		α	
Sarankhola	α	α				α			α		α			

Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. – Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

To the south of the *Sundarbans* region lies the submarine canyon Swatch of No Ground which largely controls the flow dynamics in the northern Bay of Bengal. This area is less erosion activity to the other coastal area.

The sea level rise is one of the driving mechanics of coastal erosion. With a rise in water level, the coastal morphological system will adjust itself to the height water level situations by creating a new coastal profile. This process, as described by *Velinga (1986),* is as follows:

a) By a rise in water level, the water line will shift land ward.

b) As a coastal profile becomes steeper, erosion will occur until a new dynamic equilibrium is reached at a higher level.

c) The natural filling rate of lagoons and tide basins will increase with an accelerated rise in the sea level *(Rakibul, Huq & Ali-1999).*

2.5 Off-shore Islands in the *Sundarbans*

Natural succession near the sea face on the newly formed islands and on the river banks inside the *Sundarbans*. On both the formations, the first colonizer varies according to the salinity of soil and water. The climax is attained by Sundri in all cases but by different routes as shown below *(Das-1977).*

Table-2.3 Different types of Forest on new landform area in the Sundarbans (Salinity wise)

Land Form	Water Salinity	Forest Types
On newly formed Island	*Sweet water*	Keora, ➔Gewa, ➔ Sundri+Kankra and others ➔Sundri.
	Brackish water	Keora, ➔ Gewa and other+Sundri, ➔Sundri.
	Saline water	Goran+Keora, ➔ Mixed Mangroves.
On River Banks	*Sweet water*	Grasses, ➔ Baen, ➔Gewa+Golpatta and mixed Vegetation, ➔ Sundri.
	Brackish water	Grasses+Keora,➔Gewa+Golpatta,➔Kankra, Gewa+Passur+Goran, Goran, ➔Sundri.
	Saline water	Gewa, ➔Gewa+Sundri, ➔Sundri+Gewa.

Source: *Integrated Management of Ganges flood plain and Sundarbans Ecosystem BRAC, July, 1998.*

In different parts of the deltaic lobes mangrove develop in different manner of growth of the saline-swamp vegetation. On the basis of the morphology of the delta mangrove forests can be categorized into the following types:

1. Fringe forest occurs along shoreline and tidal channels where there is a topographical slope and inundating tidal water flows in the same direction & subsequent exit.

2. Basin forest occurs in the subsided depression.

3. Riverine forest occurs in the floodplains of fresh water streams.

4. Over-wash forest occurs on island which are completely inundated by tidal water.

5. Dwarf forest occurs in the form of sparse, scattered community of shrubs like mangrove species in carbonate environment and in arid areas.

The entire delta is the formed by the estuarine sediments of the Ganges, Brahmaputra and Meghna rivers in Bangladesh and the Hoogly and its distributaries in India which combined in geologically recent times. The Geomorphological and other conditions which have been responsible for the structure of the delta and the vegetation which, is supports are:

- Topographic position.
- Drainage lines.
- Freshwater flushing.
- Sedimentation.
- Temperature.
- Humidity.
- Proximity to the sea.
- Salinity.
- Tidal periodicity.
- Tectonic.
- Land use in upland watersheds.
- Extreme stress including factors.

Photo- 2 : Narrow Sea-beach in the western Coast of Dublar- char in Sundarbans

Photo- 3 : Fishing in the Coastal water in the Sundarbans

The origin of most of the sediments is far. These are supplemented by tributaries of the rivers whose catchment mostly now lie to the south of the main Ganges channel, notably the *Kholpetua-Arpangasia*, the *Kobadak-Baleswar*, and the *Passur/Sibsa-Kunga*. The delta has four principal estuaries: the *Bangor, Kunga, Malancha* and *Raimangal.*

The combined sediment load of the rivers that flows through the *Sundarbans* has also created a large submarine fan which slopes almost uniformly southward for about 300 km. The enormous quantity of sediment carried into the sea by the river is distributed between the delta fan and coastal areas. Discharge to the delta fan takes place through submarine canyons at the head of the bay situated south of the *Raimangal-Malancha* estuary is the "*Swatch of No Ground*" where shallow water of 5-10 fathoms suddenly changes to depth of 20-300 fathoms. The sediments are distributed by currents, which run mainly from north to south. These sediments have accumulated in places to thickness of 15 km.

2.6 Morphometric Analysis of the *Sundarbans*

Geomorphic features like the natural levees along the banks of the streams of the region have given rise to saucer shaped depression in the inter-Riverine tracts causing drainage congestion in the *Sundarbans*. Checking up the channels of the region due to higher rate of siltation and formation of numerous mud-flats, sand-bars, shoals and off-shore is-lands are some of the typical morphogenetic situation of the *Sundarbans* mangroves.

The *Sundarbans* has developed on a terrigenous setting which can be categorized as the deltaic/ estuarine setting *(Thom, 1982)* where the dominant physical process is the high tidal range with strong by directional tidal currents and enormous discharge of freshwater and sediment from the upstream. During the process of development a large number of irregular formation or islands have been formed as a result of fluvial processes of the main distributaries and the tidal process. Each of these islands developed a complex drainage network of sinuous tidal creeks through which water alternately flows seaward and landward.

The configuration of each of islands or the alluvial formation appear like a saucer shaped basin surrounded by an elevated outer ridge enclosing the central low-lying areas towards which the land surface slopes in every direction from the exterior. During the formation process these landscape presents some recognizable Morphometric types common to each island and having distinct drainage pattern unique to the each island. These landforms are extremely heterogeneous. No two landforms are exactly alike and that every vista differ in some detail from the next in their Morphometric elements i.e. linear, aerial and relief properties.

2.6.1 Study of Slope of the Sundarbans

The deltaic *Sundarbans* in Bangladesh mainly comprises a vast very flat and extremely gently sloping alluvial plain. However, this tidal forest is divided into numerous blocks of alluvial tracts composed of mudflats and silty clays. The units are separated from each other by a maze of numerous estuarine, creeks and *channels* which have created a network of checker-board in the area. The inclination of the surface is very low and the gradient varies from around 0.4 to 1 cm in the different point from north to south.

The whole of the deltaic *Sundarbans* is formed with the deeply accumulated alluvium washed-out from the Himalayas to the shallow coastal shelf-region of the Bay of Bengal. The sedimentary deposits of the Pleistocene and recent geological ears overlie sedimentary deposits which, were laid down in the Miocene and Oligocene eras and were subsequently folded.

In a tide dominated delta like Gangetic, the strong bi-directional effects of tides prevent the formation of a prograding delta and instead lead to the formation of tidal and sub-tidal shoals and flats separated by numerous active tidal creeks and estuaries. Which are ultimately covered with the overgrowth of mangrove floral species of different types.

2.6.2 Network of Streams in Sundarbans

The *Sundarbans* comprise the deltaic distributaries of the Ganges and the estuarine creeks of the southwest Bangladesh. All the rivers and streams of the region experience regular influxes of the tidal effects. Among the major distributaries of the Ganges the *Sibsa*, the *Passur*, the *Kobadak*, the *Kholpetua*, the *Bhadra*, the *Baleswar*, the *Raimangal* are important. Among the rivers are-

2.6.2.1. The Sibsa: The river Sibsa originates from the area above Paikgacha with the district of Khulna. It passes through mostly low lying areas which is inundated during monsoon in high tides. From Nalianala unto the confluence with the Passur both banks are covered with deep *Sundarban* forest. The combined course *(Kunga rivers)* falls in Bay of Bengal below Hironpoint. Near Paikgacha, the river maintains a comparatively much narrow section and gets direct link with Arpangasia-Kobadak river system through Katakhali. It gets the flow of water through a good number of creeks such as Badurgacha, Garikhali, Daki and Nalion to form an intricate networks *(Israil-1994).*

2.6.2.2. The Passur: The Passur is the continuation of the Rupsha and is formed of the union Bhairab and the Atrai. At present, must of its water is from Gorai diverted through the Nabaganga. From near Baitaghata, the Rupsha changes its name to Kazibocha, which is given up near Chalna for the name Passur. Near the Mongla anchorage, forest outpost at Chandpai it receives the Mingamari cross-channel from the Bhola, both on the left bank. On the right bank the Manki *(Israil-1994).*

2.6.2.3. The Baleswar: Passur leaves the Baleswar northeast of Khulna and flows 177 km pest Chalna. In Madhumoti Rivers upper course it is called the Garai. In its lower course it is known as the Baleswar; and its 14-kilometres wide estuary mouth is called the Haringhata.

2.6.2.4.The Kobadak: The Kobadak first touches on Khulna near Chakla, a short distance from Trimohini in Jessore, it then forms for same distance the boundary between the Khulna and Satkhira districts and for the rests of its course is a large tidal stream. In its upper reaches there are numerous windings which render navigation tedious. It crosses the outer boat route at Chndkhali and passes the markets of Tala, Kapilmuni and Katipara *(Israil-1994)*. Five miles east of Asasuni the Kabadak is joined by the Marichhap Gang.

2.6.2.5. The Kholpetua: The Kholpetua is a river branching off from multiplicity of the streams but receives its waters principally from the Kobadak near Asasuni. It first keeps a westerly direction for a short distance being called the Marachar in this portion of its course and after receiving the waters of Betna turns to the south till it is joined by the Galghasia *(Israil-1994).*

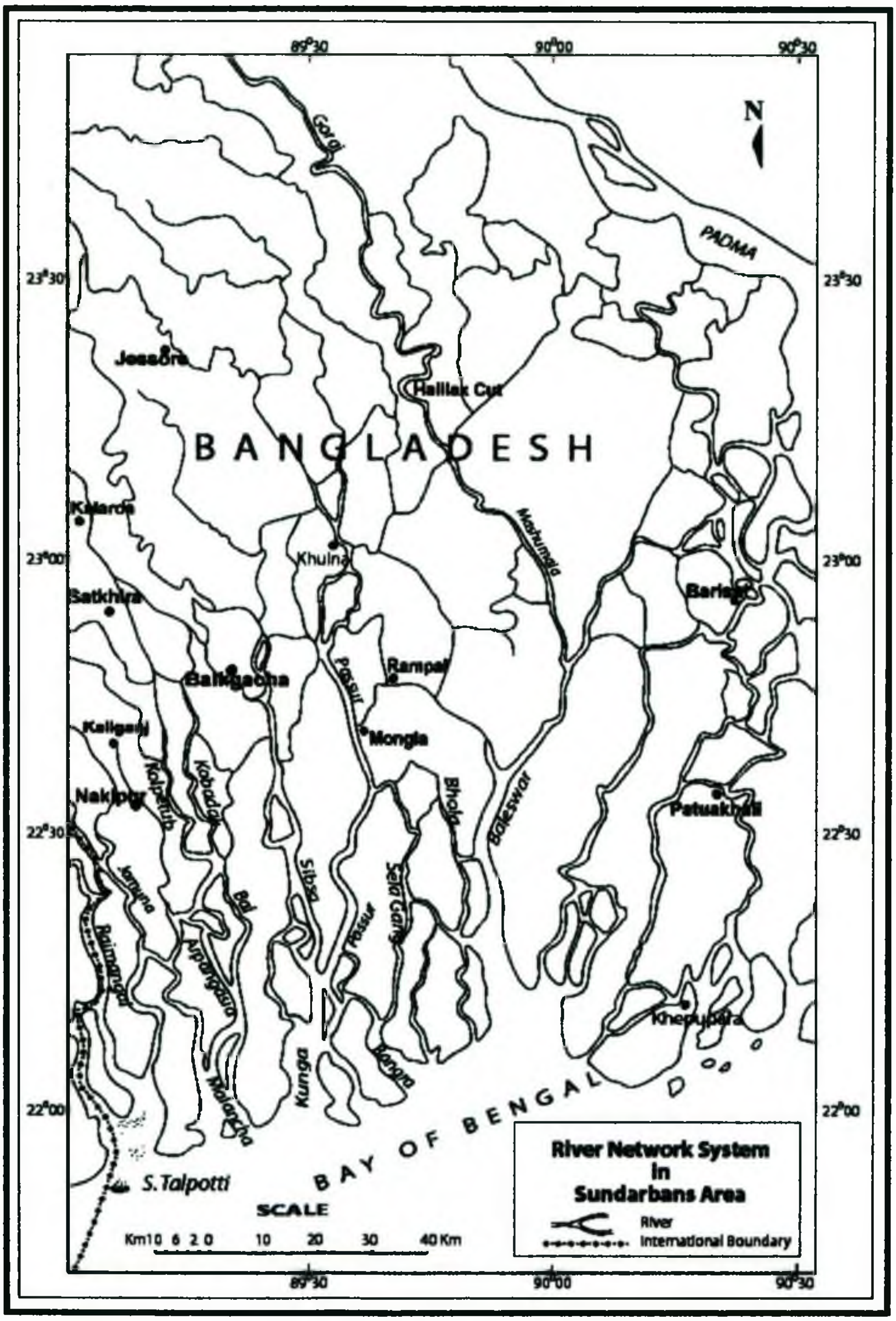
2.6.2.6. The Raimangal: The Raimangal is a famous river in the *Sundarbans* areas. Its origin at Hoogly river in India.

2.6.2.7. The Hariabhanga: The Hariabhanga is the river at the border of the *Sundarban.* The Hariabhanga river is a distributary in the Hoogly river. New Talpottri island is located in the southern portion of the Hariabhanga river.

2.6.2.8. The Bhadra: The Bhadra enters Khulna district at Baratia and continuous in a south-easterly direction to the *Sundarbans*. Below Kesabpur is widensout and in this portion of its forms a large tidal stream *(Israil-1994)*

2.6.2.9. The Bhola: The Bhola origin from Passur river at Gauranga. The Bhola enters in the border of the *Sundarbans* at Morelganj. At present its flow was closed. The Bhola is a river in the *Sundarbans*. Its water is saline.

Fig- 2.1 : Rivers & Stream Network System in *Sundarbans*



*Source: **Modified after** Hassan & Acharya, 1994*

2.6.2.10 The Haringhata: Tributary of Madhumati river, flowing through southwestern Bangladesh. In its upper course it is called the Garai, in its lowest course it is known Baleswar and its 14 km wide estuary mouth is called the Haringhata.

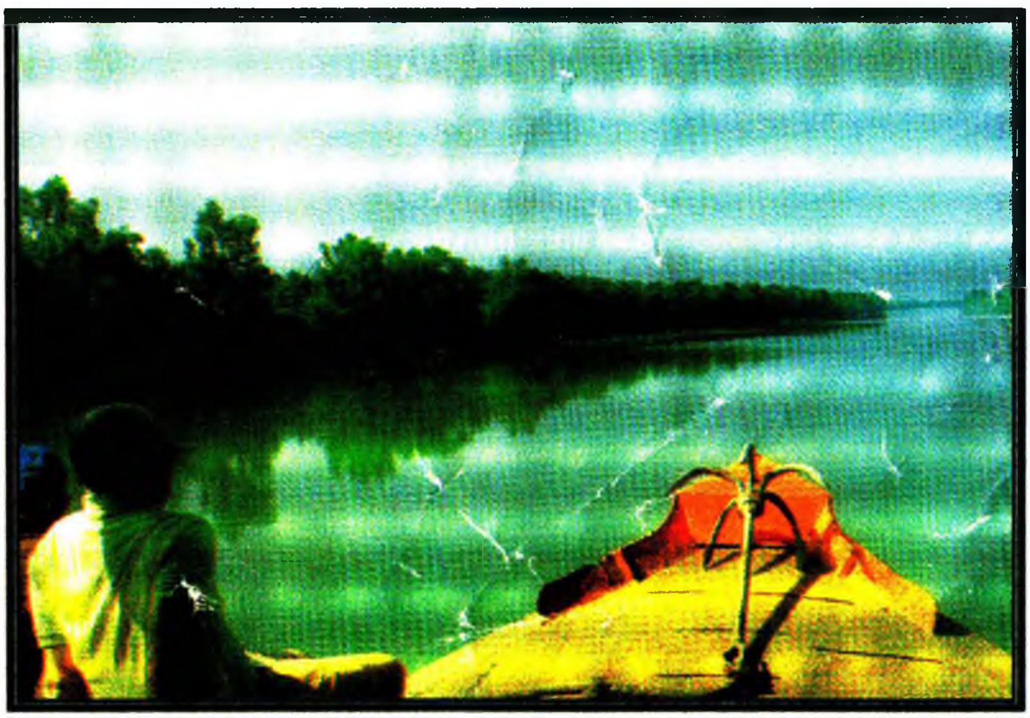
2.6.2.11 The Kalindi: The Kalindi river forms the international boundary between India and Bangladesh, and takes the name Raimangal towards the south as it flows through the Sundarbans.

2.6.2.12 The Jamuna: The Jumuna originating from Kishenganj in India, bifucates at Bangsipur where it is called Madargang and flows through the north of Sundarbans.

2.6.2.13 The Arpangasia: Arpangasia receives water through the Kholpetua and the Kobadak while the Baleswar river is connected with the Sipsa system through jafa and to the Kobadak system through the Andarmanik Khal and Chalking.

2.6.2.14 The Kunga: The Passur and the Sipsa combine to form the Mardat river which then flows into Kunga river. The Kunga flows further down and receives the Hansharaj and the Kaga near Hironpoint.

Photograph- 4 : Entry to the Sundarbans



2.7 Geomorphological Changes and Evolution of land Formation in Sundarbans

The *Sundarbans* has been experiencing constant change and evaluation. The vast forest clad areas of the mangrove regions of the delta have been encoarched upon by the deltaic people for agriculture and settlement purposes. About two-third of the *Sundarbans* of West Bengal (India) and half of Bangladesh have already been cleared up and reclaimed and the northern limits of the forest is gradually being pushed down towards south. As a result of this continuous encorachment into the virgin forest by man the areas of the mangroves of the *Sundarbans* has gradually swindled. For example, only about two hundred years back, during the survey of Rennel in 1764, 70 almost one-fifth areas of the Ganges deltaic areas was marshy and occupied by depressions and about one-third of the deltaic areas was covered with mangrove forest. But at present almost all the depressions and marshes of the delta have been reclaimed and only about one-tenth of the different tracts of today is covered by the Sundarbans, mangrove forests of the delta.

Table-2.4 Showing the Areas of *Sundarbans* Reserve Forest

Area type	Area (Km^2)
Total area if extended into Bay of Bengal to national marine border (12 nautical miles)	**7620**
Additional marine area (inc. in total above)	1603
Total area inside Sundarbans Reserve Forest boundary	**6017**
Total Waterbodies	1874
Total Land area	**4143**
Exposed Sandbars	42
No Forest	32
Area covered by Forest	**4069**
Existing wildlife sanctuaries	301

***Source**-A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

a) **Changes in River System:** Rennel's map of the East Bengal surveyed between 1867 and 1876 shows the rivers as pointed out by *Martin (1984)*, The Ganges used to flow a course more or less along the present day Arial Khan and had an outlet to the sea independent of the lower Meghna. *(Williams-1919)* noted that in the 80 years period prior to 1918, beginning when the Padma changed to its present course, that a complete change had taken place in the western *Sundarbans*. It was no longer an active delta but instead had silted in which resulted in a condition in the more inland areas that he termed "water logged". This change in the condition of the western *Sundarbans* was attributed both to the course change. River System, main channel of a river together with all-tributary rivers and streams that flow into it. River systems can change significantly over geological time. They gradually lower the land surface through erosion as sediment from hillsides is transported toward the mouth of the river system. River systems can enlarge themselves through the process of headword erosion, in which the gullies erode farther back into the hillsides at the heads of tributaries.

b) **Changes in Land and Islands:** The coastline of this part of the tidal delta is higher broken and the offshore-shelf area dotted with numerous shoals and newly formed islands. The Ganges delta almost all the tracts of the forested land faces are virtually divided into many smaller inland by the inter-connecting network of cress and estuarine channels. Which, become considerably deep and wide during high tide period and the subsequent recression of the tide water leaves a huge quantity of deposits comprising silt and clay over these tracts of the *Sundarbans* (Appendix – 2).

c) **Changes in the Coastline:** The West coast are part of the Ganges-Brahmaputra delta systems. The natural shapes of the Sundarbans coastline is controlled by the forces of erosion and accreting involving tides and waves. where tidal forces dominate, complex pattern of tidal creeks result as on the west coast (*Sundarbans*). It is the forces of rivers and the sediments that they carry dominate over tides or waves, the char and estuaries of the eastern part of the Sundarbans. The coastline along the *Sundarbans* always changes due to continuous erosion and deposition. (Appendix – 2) The Sundarbans is an ancient mangrove forest. It is not known accurately when the forest appeared first but is understood that it is about 2000 years old. There have been varied degrees of human encroachments to the forest from time to time.

d) **Changes in Wetlands:** Wetlands typically occur in low-lying areas that receive fresh water at the edges of lakes, ponds, streams, and rivers, or salt water from tides in coastal areas protected from waves. In wetlands, the surface of the water, called the water table, is usually at, above, or just below the land surface for enough time to restrict the growth of plants to those that are adapted to wet conditions and promote the development of soils characteristic of a wet environment.

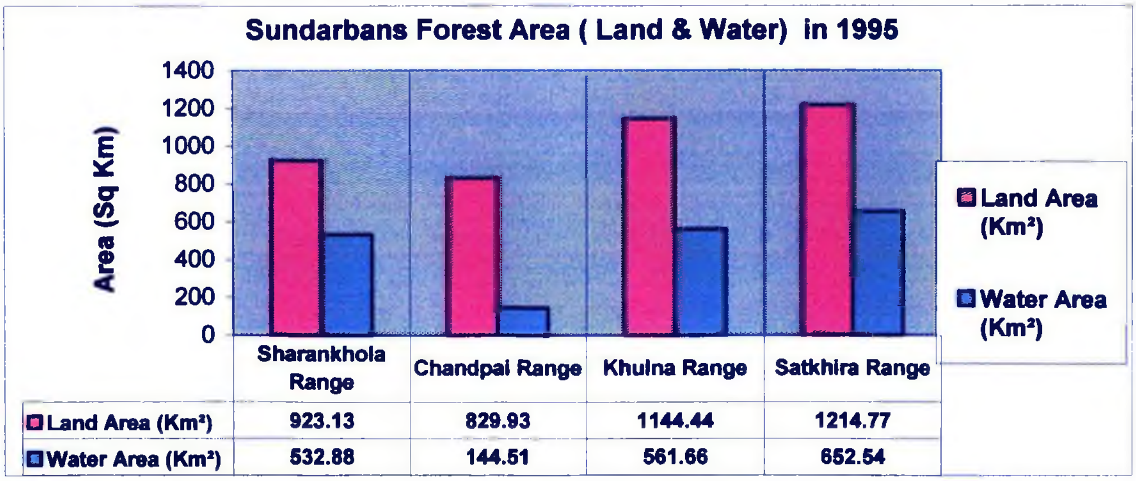
e) **Changes in the Coastal Salinity:** Changes in the surface water salinity pattern due to 30 cm of sea level, the present dry season salinity front is expected to move 30 km to 50 km north affected most Khulna (Satkhira, Bagerhat), Jessore, Barisal, Patuakhali and Noakhali (greater) and part of Faridpur and Comilla district. With one meter rise of sea level, it may be expected that cyclonic surges will penetrate further north into the country.

Table-2.5 Area of the Sundarbans Reserved Forests in 1985 & 1995 and Area of Ranges in 1926 ***(in Km^2)***

Year/ Ranges	Land Area (Km^2)	Water Area (Km^2)	Total Area (Km^2)
Total Area in 1926	4361.23	---	---
Total Area in 1985	4142.59	1874.13	6016.72
Total Area in 1995	4112.27	1891.59	6003.86

Source: SRF area, distribution and status of forest types from 1985 to 1995- M. Runnel and Istiaq uddin ahmad, 1997.

Graph-2.2 Sundarbans Lands & Water area distribution in different Ranges in 1995



Source: SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin ahmad, 1997.

f) Changes in the surface water flow: The changes in surface water flows outlined above would have had some effect on the level of ground-water in adjacent areas of Bangladesh. It is, however difficult to establish the size of this effect. The hydraulic cycle of surface and ground-water are independent. In 1976 the ground-water level in the highly affected area went down by 3 to 8 feet. Three possible cause of lower ground-water levels were-

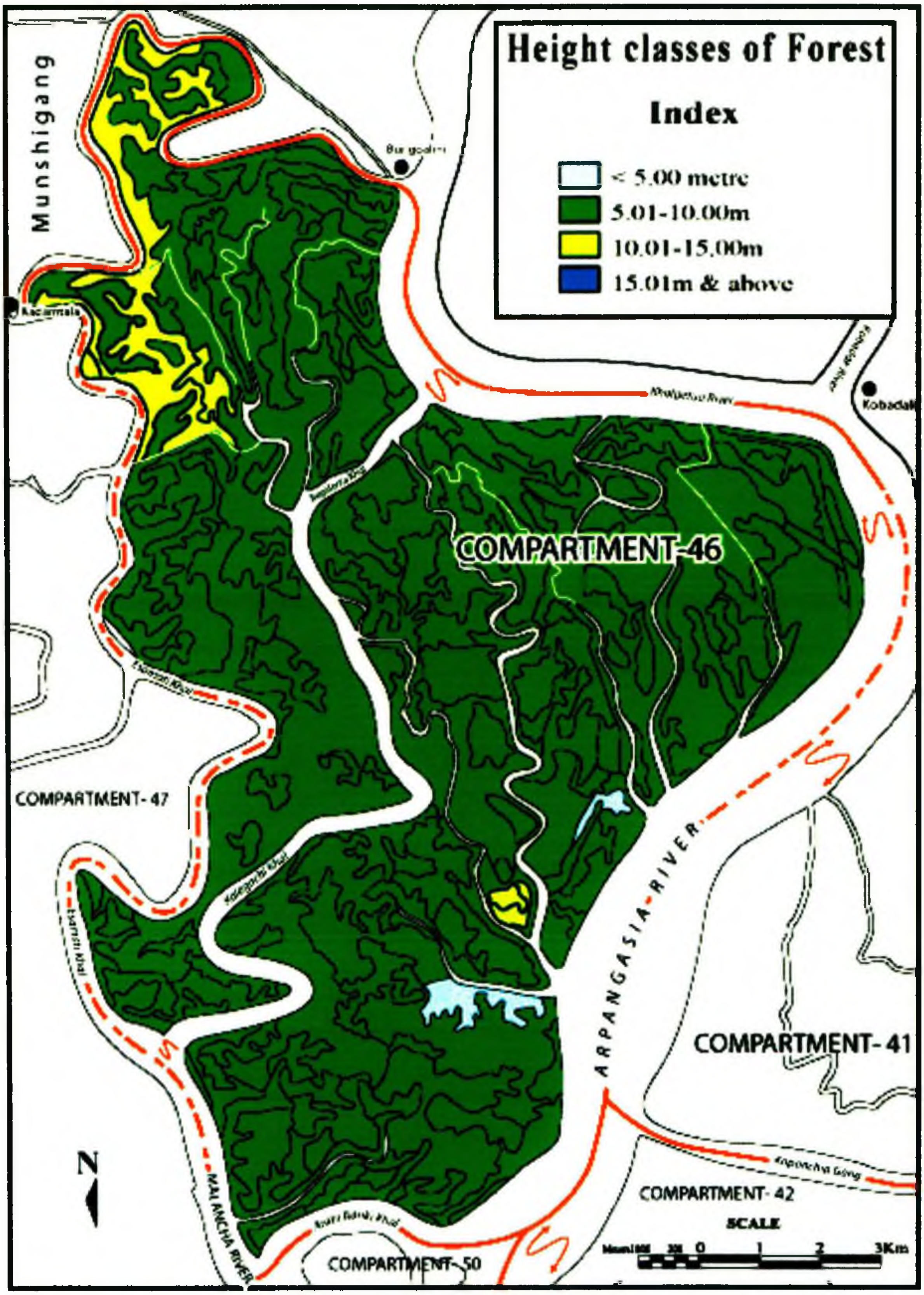
- Increased ground-water pumping for irrigation;
- Meteorological conditions, reduced rainfall combined with increased with pumping to meet the shortfall; and
- Upstream diversion reducing the recharge from the rivers.

The causes of the changes were, however, difficult to establish accurately, and the blame could not be laid wholly or even primarily on the Farakka diversions.

The popular concept of a coast is that of a stable and fixed zone, but coastal zones actually fluctuate and vary in width with differences in location and time. The difference between high and low tides, for example, may be a few inches or several miles, depending upon the location, the topography, and the lunar and, to a lesser extent, the solar influences on the water. Minor coastal changes are usually caused by the action of waves and currents, but major changes and major coastal features are frequently the result of movements of the earth's crust.

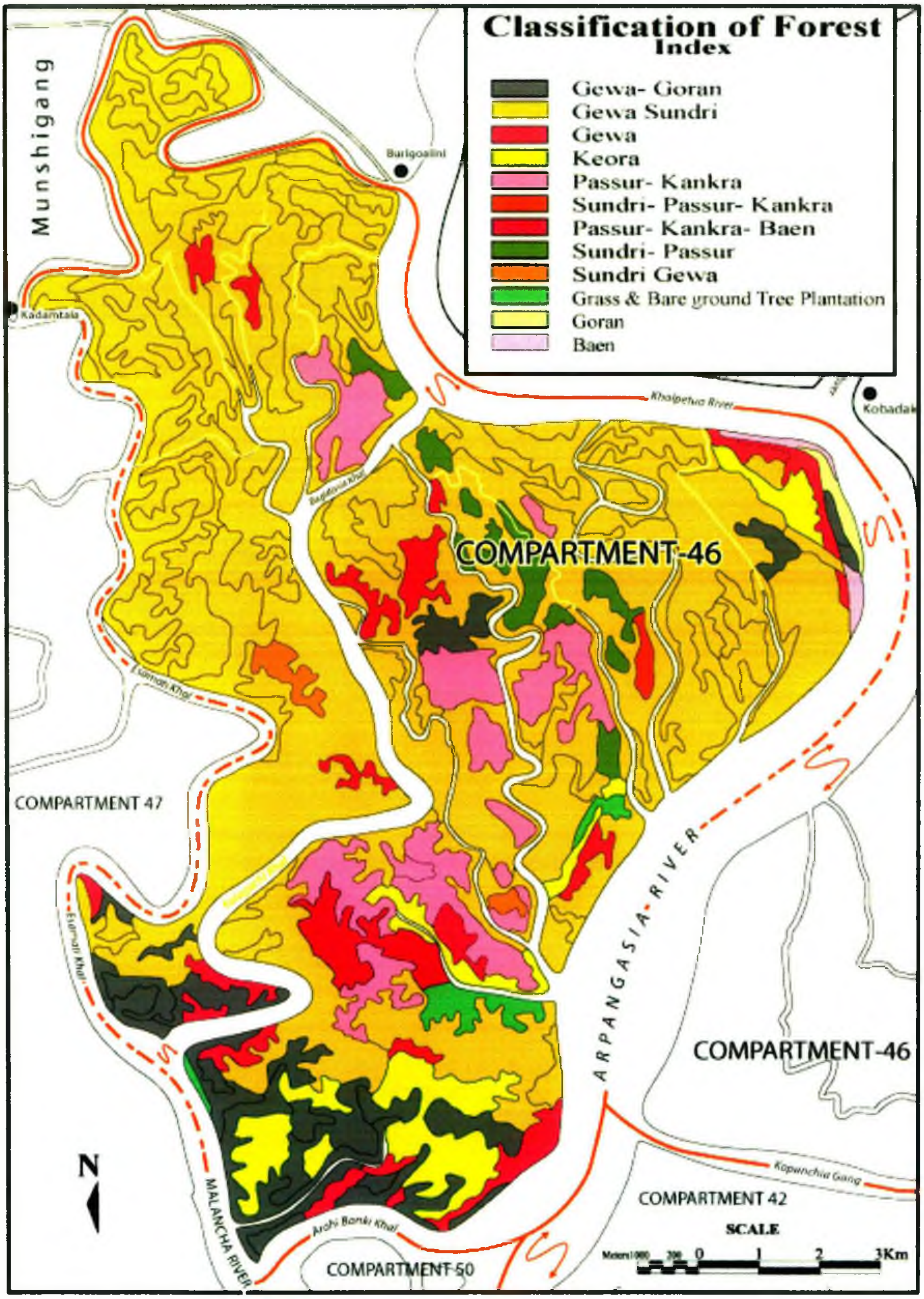
Minor changes in the coast are usually caused by the action of waves and currents cutting back or eating away at the coast. Because soft material is more easily broken up than hard material, small bays may be formed in sediments or soft rock, while the harder, more resistant rocks remain as headlands, points, and peninsulas. In other cases, waves or currents may deposit so much material that they build up bars, peninsulas, spits, or barrier beaches.

Fig-2.2 : Height Classes of Forest Type in Burigoalini Range Area at *Sundarbans* (Study Area-1)



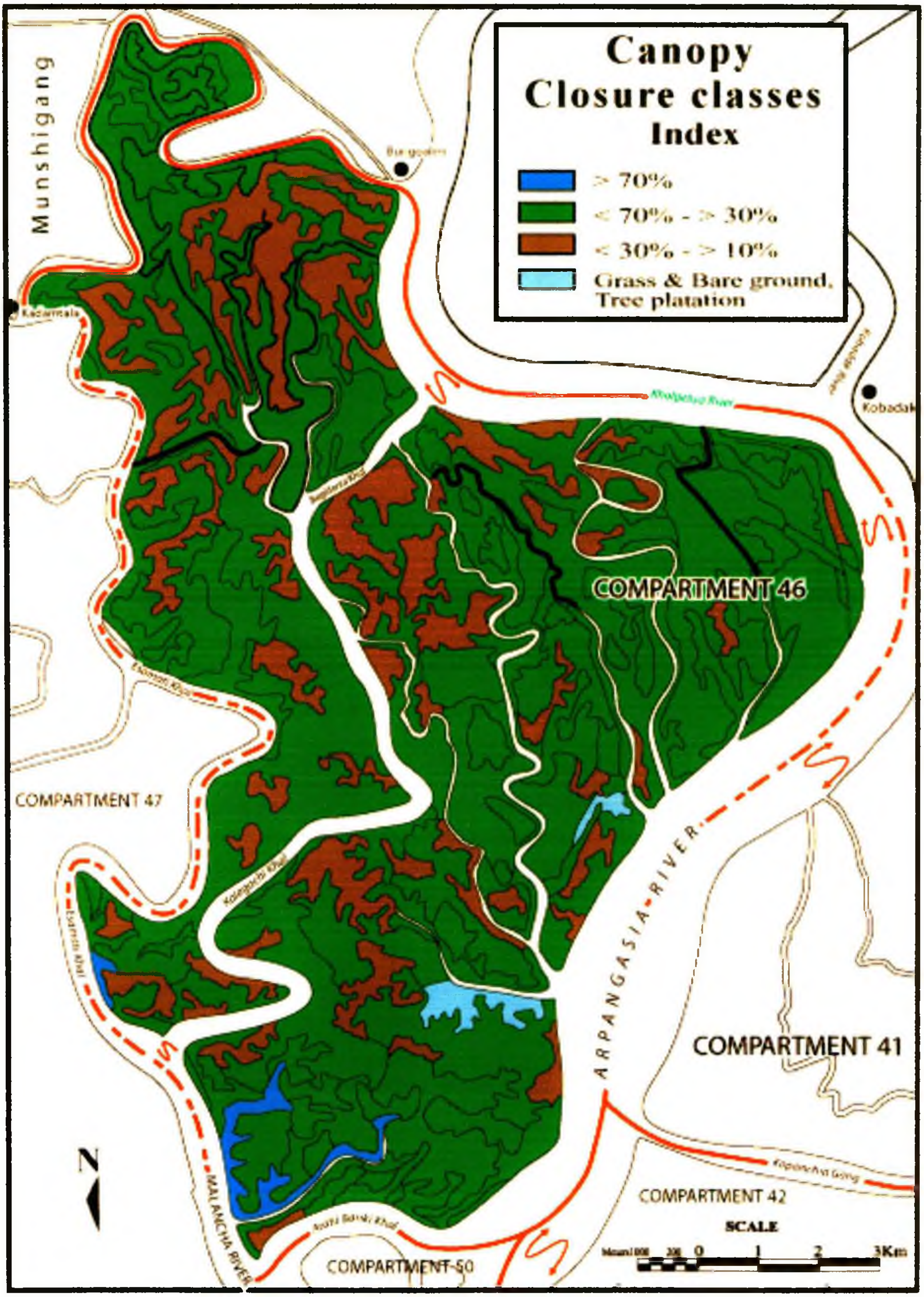
Source: Modified and edited after *the Land Resource Development Center, 1985. The Survey of Bangladesh*

Fig-2.3 : Classification of Forest Type in Burigoalini Range Area at *Sundarbans* (Study Area- 1)



***Source: Modified and edited after** the Land Resource Development Center, 1985. The Survey of Bangladesh*

Fig-2.4 Canopy Closure Classes in Burigoalini Range Area at *Sundarbans* (Study Area-1)



***Source: Modified and edited after** the Land Resource Development Center, 1985. The Survey of Bangladesh*

Comments-

Fig-2.2 ***(Study Area-1, Compartment -46 Satkhira Range Area)*** shows height classes of forest in Saline water zone of the Sundarbans.. About 0.03% covered by 15.01m & above height trees. Species of this area are mainly nil and some other species Sundri. About 3.80% covered by 10.01m –15.00m height trees. i.e. mainly Gewa, Sundri. About 95.36% covered by 5.01m –10.00m height trees. i.e. mainly Gewa, Sundri, and other species Passur, Kankra, Goran, Baen, Keora etc. On the other hand , below 4.99m height trees area is nil. But no forest area & grassland cover 0.81%. Though this is Saline water zone, most of forest should be covered by about 5.01m-10.00m height trees. but only about 95% area covered by 5.01-10.00m height trees. The reason are – increasing salinity, cutting of the trees, diseases in different trees, tidal variation, cyclone storms, siltation varieties, settlement on Sundarbans surrounding area, shrimp culture system, increasing catching fish and hunny collections of Sundarbans area, people awareness etc.

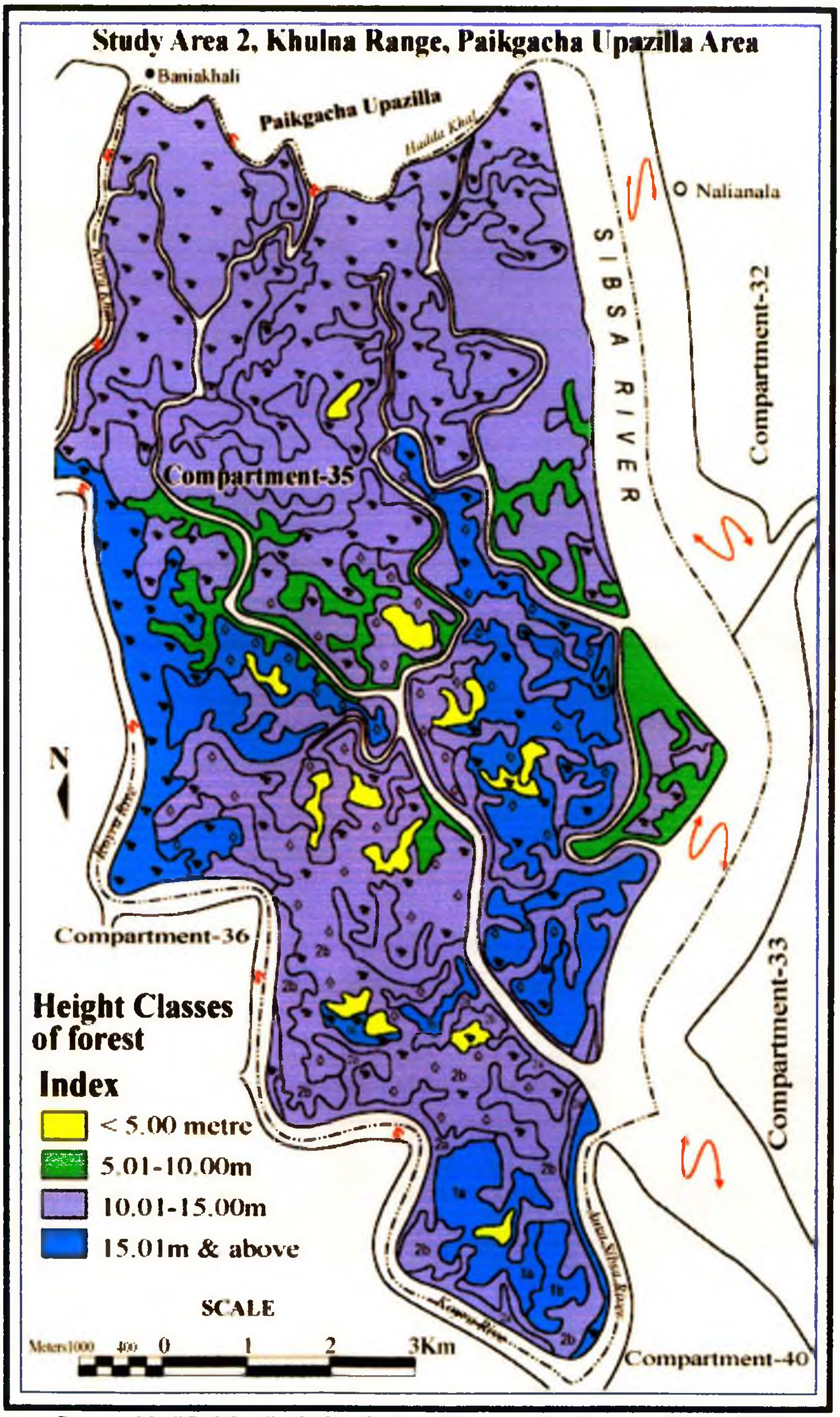
Comments-

Fig-2.3 ***(Study Area-1, Compartment -46 Satkhira Range Area)*** shows classification of forest in Saline water zone of the Sundarbans. Species of this area are mainly Gewa and other species Sundri, Goran, Kankra, Passur, Baen, Keora etc. About 68.20% covered Gewa- Sundri species, 8.10% Gewa-Goran species, 6.92% Passur- Kankra species, 5.33% Gewa species, 5.28% Goran-Gewa species, On the other hand, about 2.18% covered by Sundri-Passur-Kankra, 1.42% Passur-Kankra-Baen, 0.58% Sundri-Gewa & 0.81% of no forest area.

Comments-

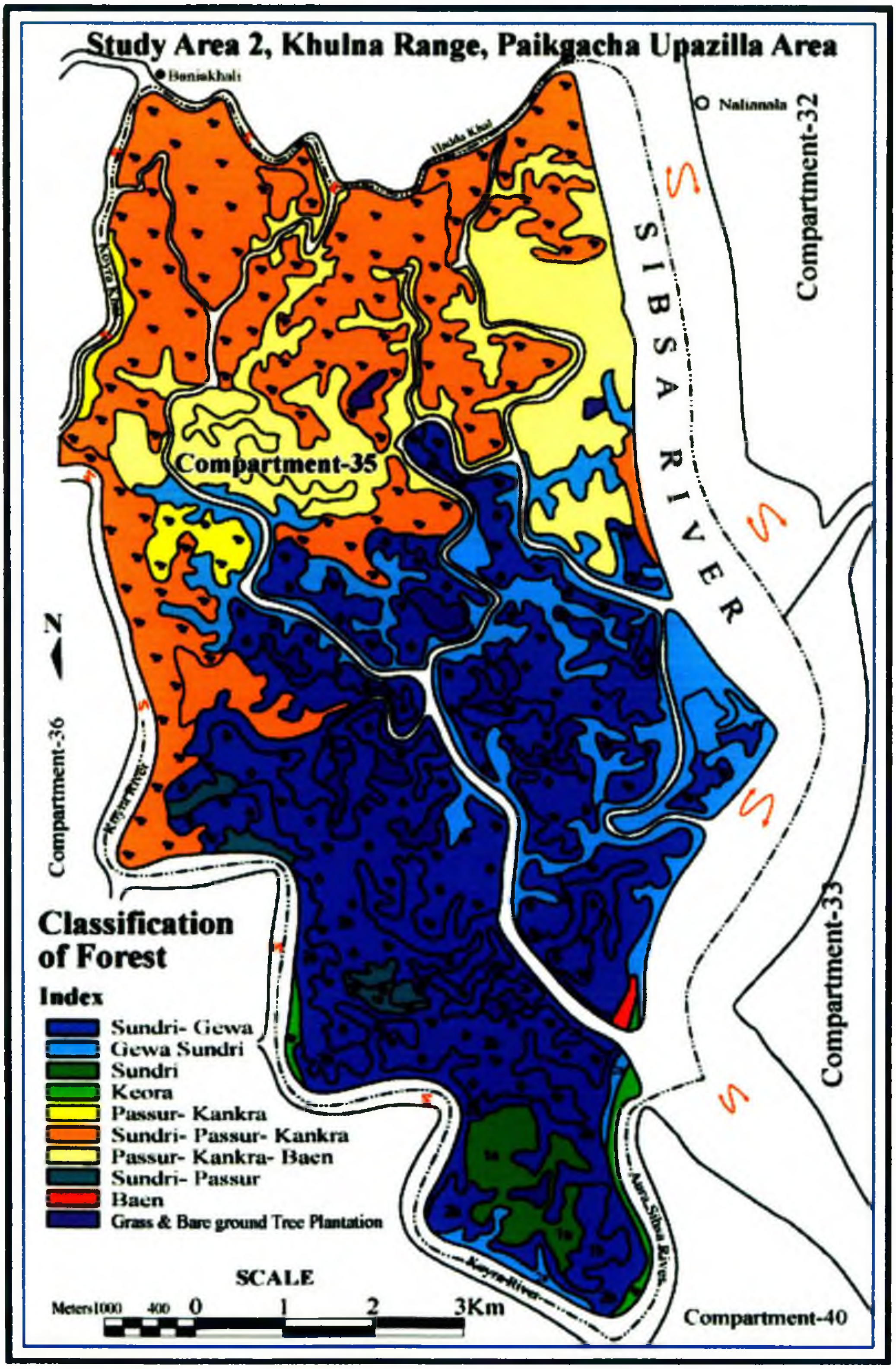
Fig-2.4 ***(Study Area-1, Compartment -46 Satkhira Range Area)*** shows canopy closure classes in Saline water zone of the Sundarbans.. About 2% covered by >70% canopy closure classes, about 80% covered by <70%-30% canopy closure classes and about 15% covered by <30%->10% canopy closure classes in this study area. but only about 2%-3% area covered by grass & bare ground, tree plantation in this study area. Species of this area are medium density and maximum species are medium. Species of this area are mainly Gewa, Sundri, and other species Passur, Kankra, Goran, Baen, Keora etc .

Fig-2.5 : Height Classes of Forest Type in Khulna Range Area at *Sundarbans* (Study Area-2)



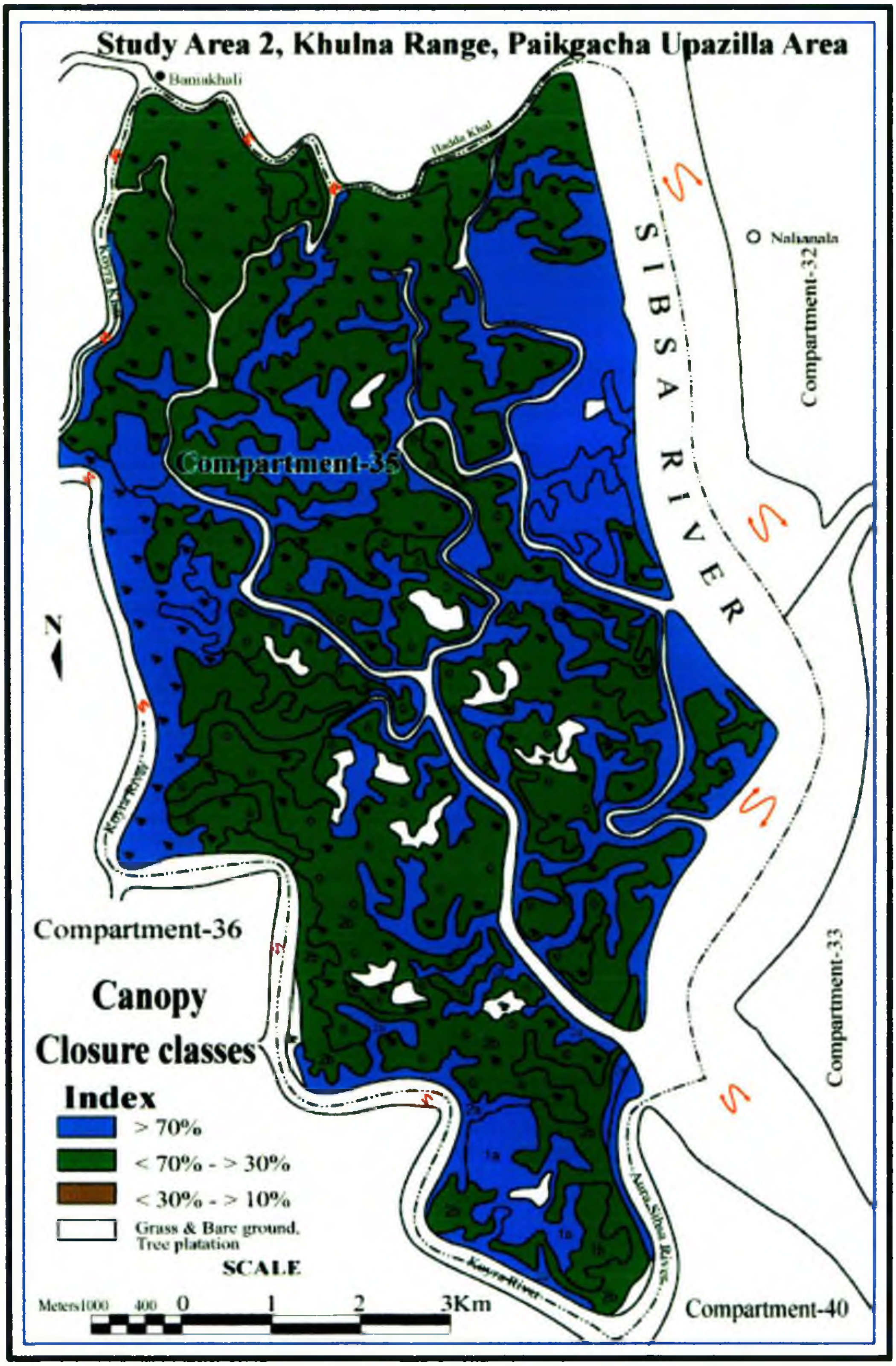
***Source: Modified & edited after** the Land Resource Development Center, 1985.*
The Survey of Bangladesh

Fig-2.6 : Classification of Forest Type in Khulna Range Area at *Sundarbans* (Study Area- 2)



Source: Modified and edited after the Land Resource Development Center, 1985. The Survey of Bangladesh

Fig-2.7 : Canopy Closure Classes in Khulna Range Area at *Sundarbans* (Study Area- 2)



Source: Modified and edited after The Land Resource Development Center, 1985. The Survey of Bangladesh

Comments-

Fig-2.5 ***(Study Area-2, Compartment -35 Khulna Koyra Area)*** shows height classes of forest in freshwater zone of the Sundarbans.. About 21% covered by 15.01m & above height trees. Species of this area are mainly Sundri and other species Gewa, Passur, Kankra etc. About 54.25% covered by 10.01m –15.00m height trees. i.e. mainly Sundri, Gewa, Passur and other species Kankra. About 21.25% covered by 5.01m – 10.00m height trees. i.e. mainly Passur, Kankra, Gewa and other species Sundri, Baen, Keora. On the other hand , below 4.99m height trees area is nil. But no forest area & grassland cover 3.5%.Though this is freshwater zone, most of forest should be covered by about 10.0m & above height but only 72% area covered by 10.0m & above height trees. The reason are – increasing salinity, cutting of the trees, top dying of Sundri, diseases in different trees, tidal variation, siltation varieties etc.

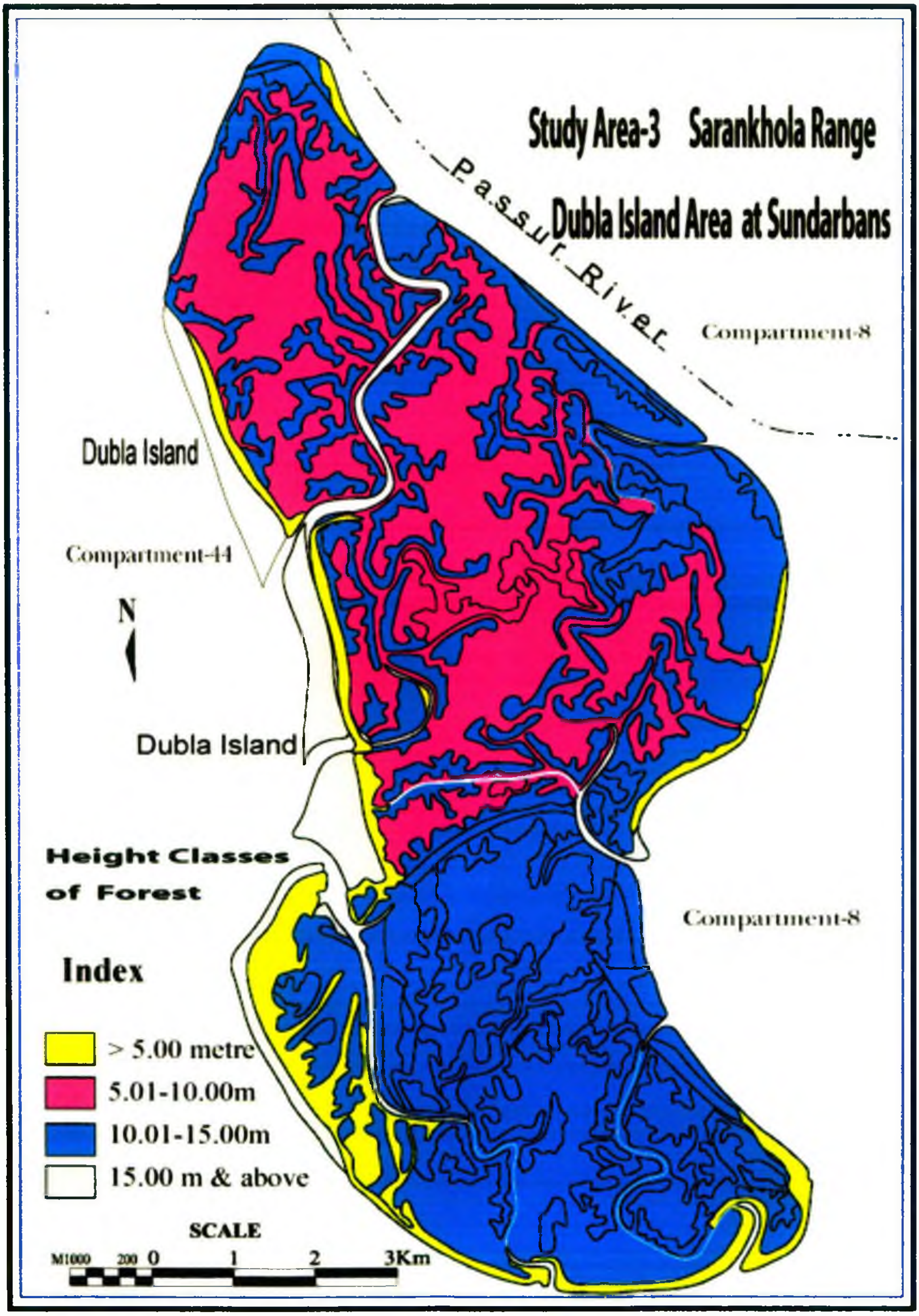
Comments-

Fig-2.6 ***(Study Area-2, Compartment -35 Khulna Koyra Area)*** shows classification of forest in freshwater zone of the Sundarbans. Species of this area are mainly Sundri, and other species Gewa, Passur Kankra, Baen, Keora etc. About 32.30% covered Sundri Gewa species, 28.44% Sundri-Passur-Kankra species, 12.61% Passur-Kankra-Baen species, 10.06% Gewa-Sundri, 7.61% Sundri. On the other hand, about 3.24% covered by Passur-Kankra, 1.68% Sundri- Passur, 0.64% Keora & 3.43% no forest.

Comments-

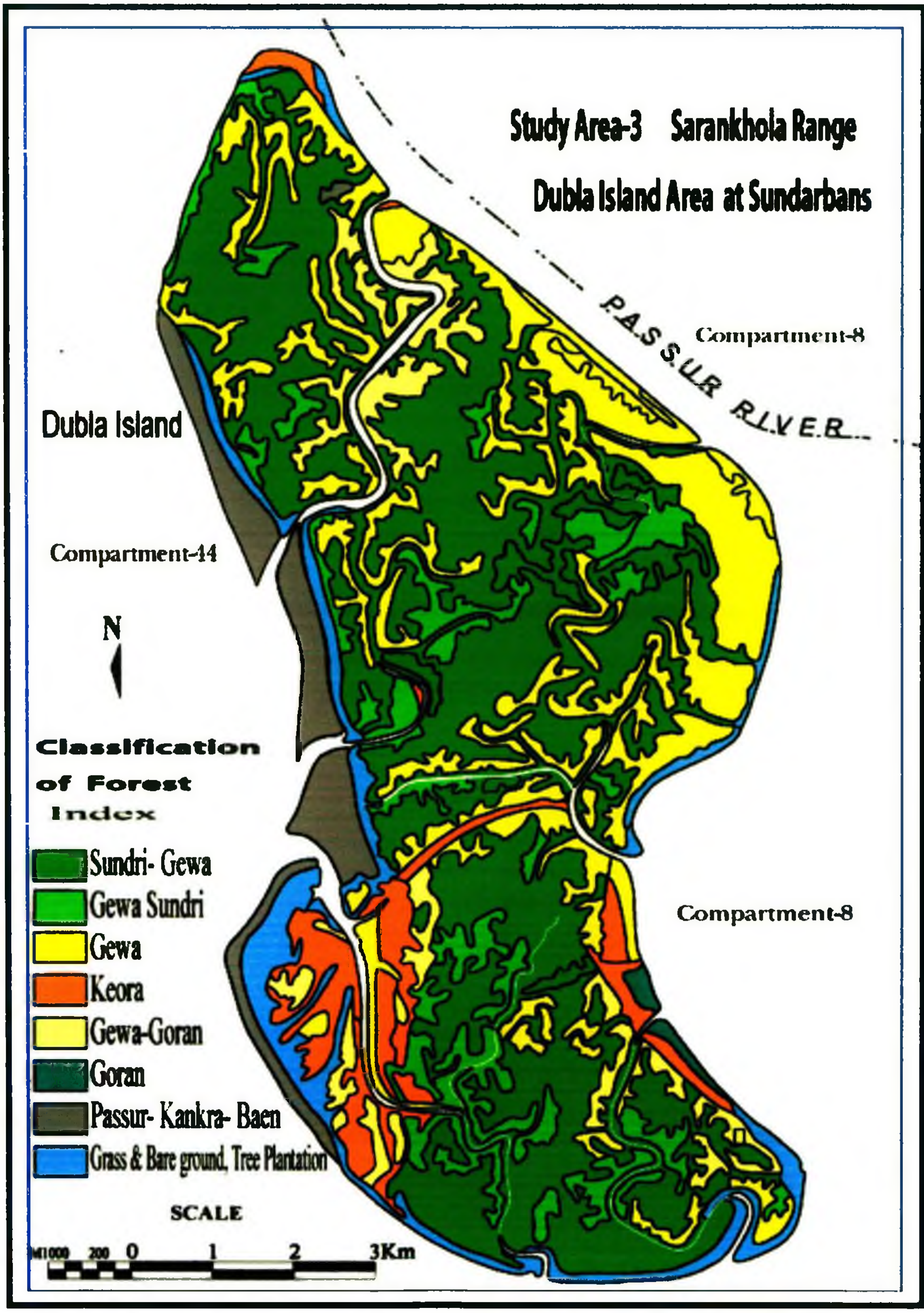
Fig-2.7 ***(Study Area-2, Compartment -35 Khulna Koyra Area)*** shows canopy closure classes in freshwater zone of the Sundarbans.. About 46% covered by >70% canopy closure classes and about 50% covered by <70%-30% canopy closure classes in this study area. but only about 3%-4% area covered by grass & bare ground, tree plantation in this study area. Species of this area are very high density and maximum species are tall. Species of this area are mainly Sundri Gewa, Passur, Kankra etc. and other species Kankra, Baen, Keora, Dhundul etc.

Fig-2.8 : Height Classes of Forest Type in Sarankhola Range Area at *Sundarbans*
(Study Area-3)



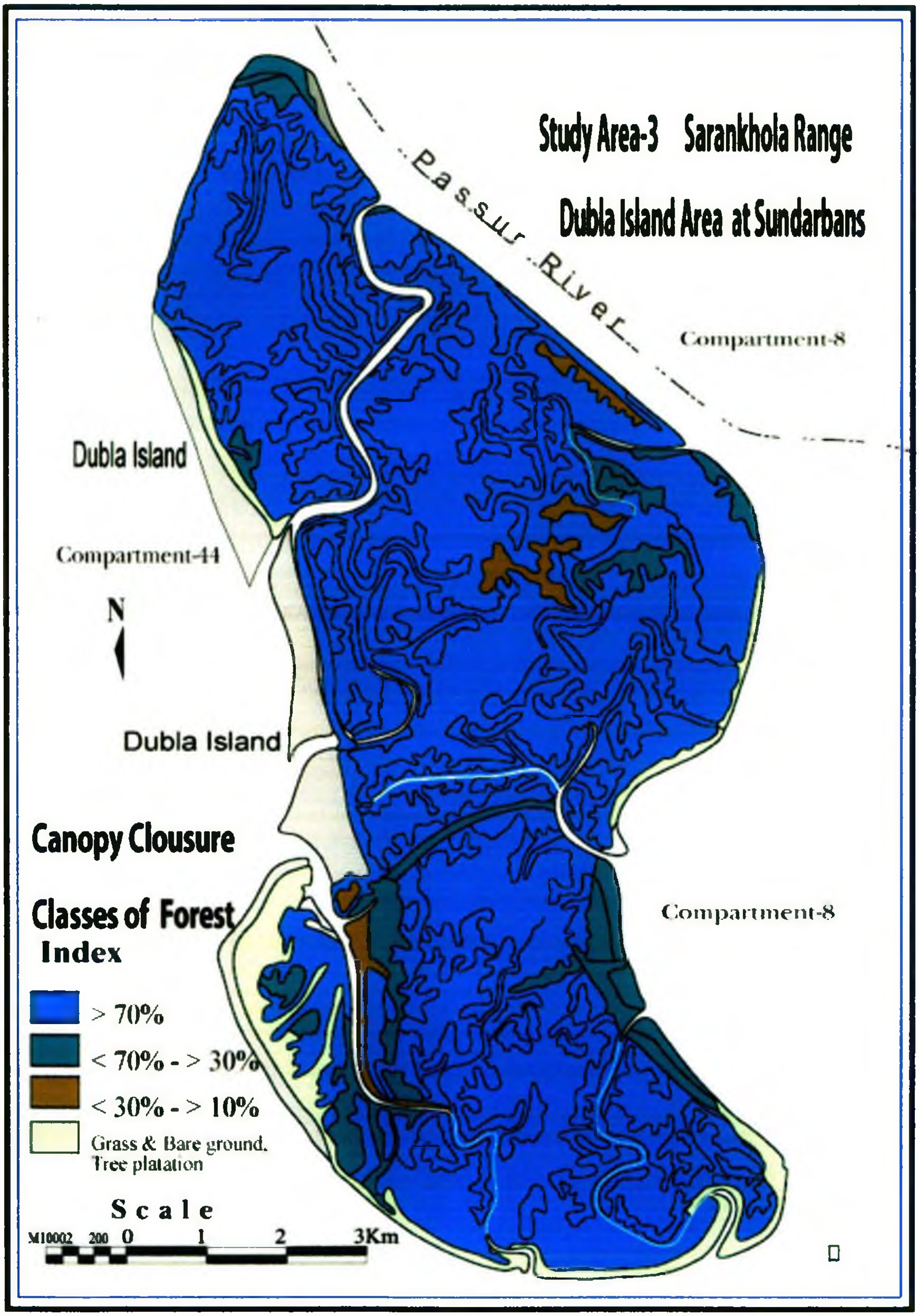
***Source: Modified and edited after** the Land Resource Development Center, 1985.*
The Survey of Bangladesh

Fig-2.9 : Classification of Forest Type in Sarankhola Range Area at *Sundarbans* (Study Area- 3)



***Source: Modified and edited after** the Land Resource Development Center, 1985.*
The Survey of Bangladesh

Fig-2.10 : Canopy Closure Classes in Sarankhola Range Area at *Sundarbans* (Study Area-3)



***Source: Modified and edited after** the Land Resource Development Center, 1985. The Survey of Bangladesh*

Comments-

Fig-2.8 ***(Study Area-3, Compartment -45 Sarankhola Range Area)*** shows height classes of forest in Moderately salinewater zone of the Sundarbans.. About 0.97% covered by 15.01m & above height trees. Species of this area are mainly Sundri. About 39.57% covered by 10.01m –15.00m height trees. i.e. mainly Gewa, Sundri. About 51.90% covered by 5.01m –10.00m height trees. i.e. mainly Sundri, Gewa, Goran, Keora etc. On the other hand , below 4.99m height trees area is 0.46% trees are mainly Gewa. But no forest area & grassland cover %. Though this is Moderately salinewater zone, most of forest should be covered by about 5.01m-15.00m height but only 52% area covered by 5.01-10.00m height trees. The reason are –top dying of Sundri, salinity increasing, tidal variation & tidal cyclone and hazard, siltation deposition, structure of mud flat etc.

Comments-

Fig-2.9 ***(Study Area-3, Compartment -45 Sarankhola Range Area)*** shows classification of forest in Moderately salinewater zone of the Sundarbans. Species of this area are mainly Sundri, Gewa, and other species Goran, Keora etc. About 39.58% covered Sundri Gewa species, 27.11% Gewa species, 9.83% Gewa-Sundri species, 9.28% Gewa-Goran species, 5.97% Keora Species. On the other hand, about 1.00% covered by Sundri, 0.14% Goran & 7.10% no forest area in the Mangrove Sundarbans..

Comments-

Fig-2.10 ***(Study Area-3, Compartment -45 Sarankhola Range Area)*** shows canopy closure classes in Moderately salinewater zone of the Sundarbans.. About 75% covered by >70% canopy closure classes, about 10% covered by <70%-30% canopy closure classes about 4%-5% covered by <30%->10% canopy closure classes in this study area. but only about 9%-10% area covered by grass & bare ground, tree plantation in this study area. Species of this area are high density and maximum species are high. Species of this area are mainly Gewa, Sundri, Goran, Keora etc.

2.8 Morphological Activities of the *Sundarbans*

Tectonically the delta of the Ganges falls in the Geo-tectonic division 'Bengal fore deep' lying to the south of the *Sundarbans* of the Indian platform. This is an unstable region and is undergoing much tectonic changes. The *Sundarbans* occupies the southern portion of the moribund part of the Ganges delta and is typically subjected to morphologically changes at the seaboard under river discharge and tidal influx conditions and interactions *(Chowdhury-1984)*.

- In the Pleistocene period the area which is now occupied by the *Sundarbans*. The main channel of the Ganges had proceeded much further to the east while letting off distributaries- the Isammati, Jalangi-Matabhanga, Gorai-Madhumati, Arialkhan one after the other. The rivers carried and deposited silt and sediment and gradually built up the delta. These channels again were the sources of supply of fresh water in the delta and by their uneven distribution determined the vegetation types in the south- mesophytes.

- Geologically, this area is deposited the loose silt and sediment only. The materials are generally carried by rivers. Silt coming with tides, is also added. Bars are formed at the river mouth or out into the sea. Land is formed by compaction of the materials.

- Lands thus formed in the delta and the *Sundarbans* have thickness more than 20,000 ft in places. There are contra over sides regarding the thickness but it is undoubtedly very thick.

- The daily tides, bars and shoals have been forming at the river mouth and the sea shore. These bars and shoals had been gradually integrated in the delta. The formation of the bars and shoals depends on the river channels and mouths, discharges and tidal actions. The main factor determining the formation of a bar is the river discharge and sediment load.

- When shoals rise up the water level, the new accretions have channels all round, thus blocks of lands are formed. The channels here are also formed by the formation of the blocks. The rivers are the arms of the sea and remain active by the action of effective tides.

- Morphologically, the Sundarbans is the most interesting area in the region. Blocks of land occur in between the rivers and the creeks and when the creeks are closed by sedimentation, bigger blocks are formed. These blocks when submerged during floods or tides, receive silt and sediments compaction takes place and a part or the whole block gets submerged.

- The land in the *Sundarbans* are formation of two level surface higher land and lower swamps. The swamps also in course of time rise up by sedimentation. The levees at the river banks if any are higher and gradually slope inland to form the low swamps.

- The delta region has high lands in the north which is moribund, gradually slope down southward to the sea. Again the western part of the delta is well built and rised up which gradually slope down eastward through the mature delta area. The southern part of the delta is more or less of the same nature and structure.

- The estuaries are wide and action of daily tides is strong. Since this area is the meeting place of the saline-water and fresh-water at the sea board, saline water occupies the bottom layers. Sedimentation takes place but again is swept down by ebb-tide which settle in the sea. The transportation power of the long shore sediment flow by waves and currents exceeds the volume of sediment discharged by the river, bar is destroyed.

- The *Sundarbans* block subsidence occurs, when existing vegetation die out and new vegetation comes up. By re-sedimentation when these block rises up again former vegetation gradually comes up. All these changes occur through changes through changes in the morphological features and changes in the habitat.

- Morphological changes in the *Sundarbans* area are occurring primarily rivers changes in the discharge of freshwater and influx of saline water through them. The freshwater discharge decreases, naturally the saline water intrusion shall be more and goes deeper inland.

- The river had although been changing their courses and by depositing their characteristic silt and sediment built up this area which is now occupied by the *Sundarbans*.

2.9 Inshore and Offshore Islands and Accretion

The mangrove ecosystem is affected by human activity both in side and outside the ecosystem. Deforestation upstream increases deposit of sand, silt and clay downstream; changes in the pattern and volume of freshwater runoff can be attributed to irrigation projects. Land formation is complicated and variable since it is dependent upon the vagaries of sediments which, are initially introduced through the Ganges system in the Bay of Bengal where they are probably finely sorted and brought back by again by tidal currents inside the SRF *(Grepin-1995)*.

This results, in irregular rates of sedimentation and in some places may be responsible for rapid changes in the floristic composition of the mangrove forest where variations in soil elevation plays an essential part. An important consideration in short and long-term management is the propensity not only for continuous accretion and erosion along the Riverine but the also the emergence of new land or chars.

Land is formed by huge beds of shifting silt and sand sometimes more than a kilometer long and travelling at rates up to 600 meters per day *(Custers-1992)*. These are carried downstream and deposited by rivers in places where water velocity drops on meeting relatively slow moving tidal water in the delta. New accretions, opportunities for afforestation, wildlife management and coastal zone development are all matters requiring monitoring and co-ordinates management planning.

As in other deltaic mangroves, the vegetation of the SRF is a mosaic of species reflecting differences in soil elevation, drainage and salinity. Continuous introduction of nutrients during sedimentation is essential to maintain primary production and rates of growth since the greater part of all biomass is exported to the sea by tides.

The usual pattern of sedimentation is as follows:

- Emergence of a flat bed of sediment often in the form gently inclined mudflats.
- Deposit of coarse particles on edges of the bed.
- Creation of raised areas or levees along the shore of the sediment patch.
- These leaves enlarge with deposition of coarse particles, isolating central area depressions which, fill with fine particles of silt and clay. Rain water and tidal flows carve the soft sediments in an arborescent pattern of small dichotomized channels reproducing the same zonation and land form to create basins and Backswamps:

  Raised area : Sandy, hard, well drained soil.

  Lower area : Silt, clay, soft, waterlogged soil.

The natural shape of coastlines is controlled by the forces of erosion and accretion involving tides, rivers and waves. Where tidal forces dominate, complex patterns of tidal creeks results, and the sediment that they carry are more important than tides and waves, the chars and estuaries of the coast *(Sundarbans).* How the relative strength of these factors may shift in the future due to climate change and sea level rise is therefore a critical issue.

Concluding Remarks:

From the above discussion it is evident that a substantial morphological information has been going on in the Sundarbans Mangrove Forests in Bangladesh. Both the marine and the fluvial actions are working behind these changes. Huge land building activities are taking alliance along the southern coastal off-shore areas of the Sundarbans. In the northern areas choking-up of the channels or decay in the courses of the river are occurring through the normal deltaic process of land formations. In places both erosion and deposition are also occurring south Talpottri, Dublar char, putney Island and Haringhata, Raimangal, Malancha, Kunga, Bhanla, Passur, Harinbhanga river coast area etc.

Chapter -3

Hydrology and Surface Drainage

Chapter -3

Hydrology and Surface Drainage

3.0 Hydrology and Surface Drainage

The quantity of fresh water discharge into mangroves depends on the size of the watershed, the climate, river flow characteristics and diversion of water for other land uses. The extensive flooding usually occur during the monsoon months and the peak flows coincide with high spring tides *(Mujibur-1995).*

The *Sundarbans* is criss-crossed by a network of interconnecting channels and creeks. The main rivers are Passur, Sibsa, Kobadak, Baleswar, Jamuna, and Raimangal. Baleswar and Passur are linked with the Ganges through the Gorai-Madhumati and Arial khan. The Sibsa and Kobadak are not connected with the main flow of the Ganges during the lean season. The Baleswar, washing the eastern fringe of the *Sundarbans*.

A large part of the *Sundarbans* 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 tidally flooded through out the year. However, Whole of the Sundarbans become submerged during high monsoon tides. Depth and duration of the tidal inundation depend on factors like the: Distance from the sea, distance from the main rivers, local relief, general elevation of the area, load content of the inundating water, etc. these factors also influence the ecological conditions of a site within the *Sundarbans (Hassan-1990).*

3.1 General Hydrology of the *Sundarbans*

Deltas are formed where major rivers meet the sea. Typical delta features are the deposition of river sediments and subsequent extension of the delta into the sea. The rapid changes in the configuration of the river channels and the shifting of those channels, the flatness & low elevation of the level lands and the effects of cyclone & storm surges from the sea.

*The *Sundarbans* mangroves forests area are Hydrologically in different system-

- ***River systems-*** The Sundarbans forest is intersected by an elaborate network of rivers, channels and creeks. The bigger waterways are called *'Nadi'* or *'Gang'*. While relatively smaller channels are called Khals. Rivers such as the Passur, Sipsa and Raimangal are depth and wide. From east to west these comprise Bangra estuary, Kunga estuary, Malancha estuary, Raimangal estuary etc.

- ***Subsystem-*** The changing pattern of the hydrological regime broadly divides the *Sundarbans* into three subsystem:

  a) Western Subsystem- The area represents the western part of Aura Sipsa and east of Raimangal and is connected with the upper moribund part of Kobadak-Betna river system.

  b) *Central Subsystem-* This area is located east of Aura Sipsa and west of Passur river.

  c) Eastern Subsystem- This area east of Passur river and west of the Baleswar river represents this Subsystem.

- ***Surface water flow-*** The Surface water flow in the rivers of the *Sundarbans* mainly comes from the Ganges-Padma through Gorai-Madhumati and from the lower Meghna through the Swarupkati-Kocha river. The other sources of surface water flow in the rivers is the runoff from the local catchment area.

- ***Ground water flow***- The occurrence depth and salinity of the ground water and soil water system in tidal swamps and adjoining hinterland are important hydraulic factor that can affect mangroves.

- ***Sedimentation***- A huge amount of sediment is carries from the upper catchment area from India-Nepal and deposited in Bangladesh. Very little is known about the rate and pattern of sedimentation in the *Sundarbans*.

- ***Tides***- Tide is an important regular of mangrove productivity through its control on transport of oxygen to the root system, physical exchange of the soil water solution, tidal flushing by interacting with the surface water, vertical motion of the ground water table.

Hydrology of the *Sundarbans* is regulated mainly the high local rainfall during the monsoons (1600 mm from May to October) and by tidal inundation. It may remembered that a small part of the Ganges flow, released at Farakka during the lean season, flow to the sea through the Padma-Meghna channels. Only a small part of its flows through the Gorai- Modhumoti channels to the Baleswar and Passur rivers *(Hassan, 1990)*. Salinity in the *Sundarbans* is primarily by seasonal river discharge.

3.2 River Types of the *Sundarbans*

The *Sundarbans* forest is intersected by complex network of rivers, canals and creeks. These Waterways are of varying width and length and occupies an area of 1829 sq. km. The bigger waterways are called *"Nadi"* or *"Gang"* while relatively smaller channels are called *"Khals"*. The extended part of a Nadi when joins another Nadi, it is known as Gang. Generally the rivers flow north to south and interconnected with a large number of side channels and known in the Sundarbans as the *"Bharaini"*.

Table-3.1 Main River according to length

Name of the River	Area (Km²)	Area covered (Km²)
Garai-Madhumati-Baleswar	371	Kushtia(58), Jessore(146), Khulna(167)
Kobadak	259	Jessore(79), Khulna(180)
Bhadra	193	Jessore(58), Khulna(135)
Betna Kholpetua	191	Jessore(103), Khulna(88)
Bhairab	159	Jessore(130), Khulna(29)
Rupsha-Passur	141	Khulna(141)

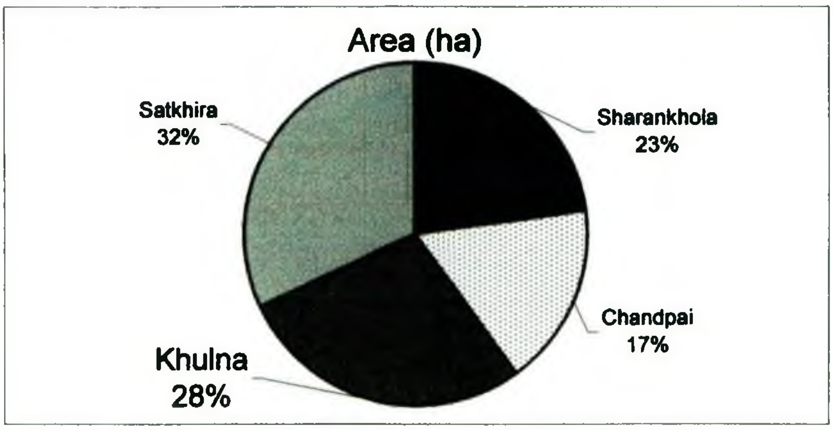
Source: *Bangladesh Water Development Board, BBS.1998.*

Table-3.2 Range-Wise distribution of Headquarter, Compartment, Area (ha), Percentage and Rivers.

Forest Range	Headquarter	Forest Range & Revenue station	Compartment	Area (ha)	Area (% of T.Land)	Rivers
Sarankhola	Sarankhola	Sarankhola R., Supta, Bogi	1,2,3,4,5,6,7, 8, 12B, 24, 45,	130998	22.69%	Kunga R., Passur R., Bhanlra R., Supti R., Haringhata R.
Chandpai	Chandpai	Chandpai R., Dhansagar, Jewdhara, Dhangamari (Mongla port).	9, 10, 12A, 13, 14, 15, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31,	100021	17.32%	Passur R., Sela R.
Khulna	Nalianala	Nalianala R., Kassiabad, Baniakhali, Kalabagi, Sutakhali	16, 17, 18, 19, 20, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44.	161345	27.95%	Baleswar R., Mardat R., Sipsa R., Passur R.
Satkhira	Burigoalini	Kadamtala, Koikhali, Burigoalini R., Kobadak.	41, 42, 46, 47, 48, 49, 50A, 50B, 51B, 51B, 52, 53, 54, 55,	184992	32.04%	Raimangal & Harinbhanga R.(Indian border), Malancha R., Jamuna R, Malancha R, Barapaga R, Arpangasia R, Baleswar R., Kunga R.

Source: *Hassan & Acharya, 1994.*

Graph-3.1 Area of total Sundarbans forest Ranges in percentage



Source: *Hassan & Acharya, 1994.*

There are rivers and canals spread across this forest like a net with their innumerable branches. Thirty percent (1,75,685 hectares) of the *Sundarbans* are rivers. Four hundred and fifty big and small rivers are spread like a net on the area. Almost all the rivers flowing through this forest have originated from the Ganges or the Padma.

- -To the eastern parts of the *Sundarbans* are the Haringhata and the Baleswar rivers.
- -In the middle of the eastern portion is the Passur rivers, forming the boundary between Khulna and Bagerhat districts.
- -To the southwestern parts on the eastern border of the Satkhira district are the Kapotaksha and Arpangasia rivers.
- -The biggest rivers on the western border of the *Sundarbans* are the Raimangal and the Harinbhanga.

Photograph-5 : Vegetation System inside the River at Sundarbans

Among the other rivers are the *Hansharaj, Sumati, Bhola, Malancha, Chhaprakhali, Singra, Jamuna, Kalindi, Golkhali, Kukumar, Chalki, Chunar, Koyra, Sutakhali, Firingi, Bhomrakhali, Lataberi, Atharabeki, Bhetuipara, Baluijhaki, Dudhmukhu, Andermanik, Sapkhali, Matura, Khasitana, Matabhanga, Barasheola, Neelkamal, Dobeki, Bhadra, Chunkuri, Jhapa, Katka, Rangabari, Dhanpati, Rajakhali, Jatghata, Kanchikata, Burigoalini, Taltali, Kadamtala, Dangmari*, etc.

3.3 Drainage Pattern of the *Sundarbans*

The southwestern coastal part of Bangladesh is almost flat and wide where the average elevation does not exceed 1.5 meters contour line with very gentle sloping towards the southeast. In this region there exist a very complex river system. Which bifurcates and again join each other forming a network and there rivers are under the influence of the Ganges-Padma flows. The Kobadak, Gorai-Madhumoti and Arialkhan are the three spill channels of the Padma contributing freshwater to this coastal region. The river Baleswar-Haringhata, Rupsha-Passur and the river between them receive limited freshwater from the Ganges through the Gorai-Madhumati, Nabaganga and Kaliganga. The rivers west of the Rupsha-Passur such as the Sibsa, Kholpetua-Arpangasia, Kobadak have very little freshwater supply from upstream and during monsoon there rivers get flushed by local runoff only from rainfall. The rivers east of Baleswar-Haringhata and west of Tetulia receive freshwater from the Arial Khan and thus become less saline than those of western rivers.

The *Sundarbans* receives large volumes of fresh water from inland rivers following from inland rivers following from the north and of saline water from the twice, daily tidal incursions from the sea. The westernmost river system comprises the Raimangal and Jamuna, which flow into the Raimangal-Harinbhanga estuary, through which runs the international boundary. Further east, the Malancha and Arpangasia join to form the Malancha estuary.

The Sibsa and Passur dominate the central section of the Sundarbans and join to form the wide and deep Kunga estuary. This provides access for ocean-going vessels, via a deepwater channel in the Passur rivers, to the port of Mongla.

To the east again is the Sela Gang. This is distributary of the Passur and Bhola rivers but comes an important waterway in its own right before it debauches into the Bay of Bengal the Bangra river estuary. At the eastern edge of the *Sundarbans* the Bola and Baleswar rivers combine to flow into the Baleswar estuary.

The Sibsa rivers and all other rivers to the west of it receive freshwater only from localized catchment lying between the Ganges and the northern edge of the forest.

The Passur has a connection with the Ganges via a distributary called the Gorai or Madhumati. This river supplies the Baleswar with freshwater and, through a man made channel called the Halifax cut, it also supplies the Passur.

3.4 River System of Ganges Delta in the *Sundarbans*

The *Sundarbans* occupy the Ganges delta. Soils is the delta are unripened, slightly calcareous, tidally flooded, Grey, massive, alkaline, clayey mud with low (<2%) organic matter content *(Hassan, 1982; 1985; Anon., 1967)*. The carbonates initially present in the sediment are lost rapidly due to lateral decalcification *(Ponnamperuma-1965)*. The Sundarbans soils are very poorly drained and fine textured. In classifying these soils hydraquents are separated from haplaquents based on their physical properties (N-value). Sand content has no place in calculating the N-value. The Sundarbans soils are rich in clay and silt content. Under such conditions the low sand content of these probably has little influence as to be a potential source of mineral nutrients *(Hassan-1990)*.

The *Sundarbans* comprises extensive, flat, coastal and deltaic land, which is crossed by large tidal rivers as well as numerous small channels and creeks, all discharging into the Bay of Bengal. Rivers in the *Sundarbans* are meeting places of all salt water and fresh water, of fresh water and salt water. Thus it is a region of transition between the fresh water of the rivers originating from the Ganges and the saline water of the Bay of Bengal. Rivers here are characterized by the existence of tidal motions transmitted from the sea and by salinity variations caused by the gradual mixing of fresh water and seawater. The dynamics of the system are controlled by three major factors:

-the river discharge at the head.

-the tidal input at the mouth.

-the topography of the area. *(Wahid-1995)*

There are a number of large estuarine rivers in the great Ganges delta, which flow from north to south. The importance of these estuarine rivers is Sibsa, Passur, Kobadak, Kholpetua, Bhadra, etc.

3.5 Other Hydrology of the *Sundarbans*

3.5.1 Existing course

Mangroves provide the coastal tropical formation found along the border of the sea reaching as far up the river banks to the point where the water is still saline growing in swampy soils and covered by the sea during the high tides *(Blasco-1975)*. Even more unpredictable, rivers of Bangladesh may changes their courses in case of sea level rise. In a dynamic deltaic plain, such as Ganges estuary, small changes in water levels, river discharges and sediment transport may be generate complete shifts of river courses. This natural events will have major impacts on the socio-economic conditions of the nearby areas and Bangladesh as a whole.

3.5.2 Changing in course or Shifting of Bankline

Changing to river channel form would affect the height and duration of the tide. This is important because freshwater from the polder can only be drained by gravity if the water level within the polder is higher than the level of the river. However, predicting the change in channel form, is difficult due to the interaction of factors which affect channel form, including rainfall patterns, the Sundarbans and mean sea level (which may affect tidal height and strength).

In addition, modification in channel form includes the location of areas of erosion and deposition along channel banks. At present, embankment erosion is not a major problem in the polders in the west. However, if both tidal and fluvial flow strengths increase in future, an increase in bank erosion could be expected.

Shoreline erosion is expected to increase due to effects of sea level rise. Most of the rivers of Bangladesh are meandering and braided. These characteristics are favorable for river bank erosion. The phenomenon is common in major and minor flushing, tidal and non-tidal rivers. It is expected that, in case of sea level rise, the meandering and braiding process will be enhanced. Mangroves are evergreen forests between the land and sea occupying tracts along sheltered coasts, estuaries and deltas where they are en-hanged by tides, salinity and rainfall. Mangroves from unique environment and floral faunal assembled.

3.5.3 Changes in Discharge, Volume, Flow, Velocity

The main sources of freshwater which affects the Sundarbans is derived from the Ganges through its distributary the Gorai, a branch of which, the Baleswar, forms the eastern boundary of the forest reserve. During the rainy season the near-shore coastal water is fresh for some kilometers around the mouth of the Baleswar rivers and this river is responsible for most of the freshwater influence in the eastern part of the Sundarbans. Freshwater is also discharged through the Passur river passing

Khulna and to some extent through other distributaries. The former spill rivers of the Ganges in the western part are now abandoned and are semi-moribund. The discharge of the Ganges varies considerably. The average annual discharge of the Ganges, measured at Hardinge Bridge about 50 km inside Bangladesh, for the period 1965-1975 was 10,374 m^3 /sec. The maximum measured discharge was 73,155m^3 /sec *(UN-1982)*.

3.5.4 Marshes and Swamps

Tidal forests are found on somewhat higher elevations than mangroves. Such forests are influenced by the tidal movements and may be flooded by fresh or slightly blackish water twice a day. Tidal amplitude various from place to place. Where the amplitude is high, the area subject to periodic tidal flushing is large and usually gives rise to a wide range of ecological sites. The natural vegetation in tidal forests is more diverse than that of mangroves, although still not as diverse as that of dense inland forests. Flood plains are areas seasonally flooded by fresh water, as a result of rainwater rather than tidal movements. Forests are the natural vegetation covers of river floodplains, except where a permanent high water table prevents tree growth.

Table-3.3 Evidence of subsidence in the *Sundarbans* Recent Deltaic Plain or River Basin.

Location of data	Type information	Evidence	Subsistence in-dictated (in feet)
Near Kobadak forest Station	Shallow hand auger boring	Wood *(Sundri)*	12-14
Talpatti Khal	Shallow hand auger boring	Peat layer	14
Near mouth of the Raimangal R.	Shallow hand auger boring	Intermittent organic down to 20 feet	20
Dhaki Khal boring	Shallow hand auger boring	Peat layer, Wood *(Sundri)*	13-16, 21-22, 18
Dhaki Khal 34 mile from boring	Tank excavation	Wood *(Sundri)*	18
Dhaki Khal 200 yards from boring	Tank excavation	Human artifact *(Milling or grinding stone)*	13
Dubla Island	Shallow hand auger boring	Intermittent organic down to 20 feet	20
Shekretak Ruins near Sibsa river	Shallow hand auger boring	Peat Wood Organic	6 16, 20-23, 23-34.5
At Khulna, about 12 mile N. Sundarbans	Tank excavation	Large Sundri trees in place & layer of vegetable mould	18

Source: *Morgan & McIntire, Quaternary Geology, Bengal Basin-March, 1959.*

3.5.5 Estuarine

Salt-marsh estuaries are also part of the coastal plain. Although they have a well-defined drainage network, they are not usually fed by rivers and thus they contain predominantly salt water. Due mostly to oscillations in river flow, the three main estuarine zones—saltwater, brackish, and freshwater—can shift seasonally and vary greatly from one area to another.

Numerous small rivers and Chara rivers are flowing in the north-south portion of the *Sundarbans*. The mixtures of freshwater and saline water in those rivers are flowing in the network system. There are five estuaries from west to east which are-

1. Harindanga Estuarine.
2. Malancha Estuarine.
3. Kum Ganga Estuarine (its origin from Sibsa and Passur).
4. Bangra Estuarine (its origin from Silaganga).
5. Dhaleswar Estuarine (its last boundary of the eastern portion of the *Sundarbans*).

3.6 River Basin of the *Sundarbans*

The forest is flat and elevation is hardly three meters above mean sea level. The entire area is intersected by a complex network of streams and rivers varying considerably in width and depth. At a comparatively recent period, all these rivers were connected with the Ganges. Baleswar, Passur, Sipsah, Arpangasia, Malancha, Jamuna, Raimangal have direct or indirect connection and they receive overflow of the Ganges during rains. They also receive a considerable amount of local drainage throughout their long and meandering courses during the monsoon *(Das-1985)*.

3.7 Drainage System Waterbodies and Catchment Area

The spatial feature of coastal mangrove ecosystems is their dependence upon the dynamics of three sources of water: Precipitation, upstream catchment and the sea. The middle catchment is formed by the floodplains of the three big rivers, the

Brahmaputra, Ganges and Meghna and the proximate catchment, which has the most bearing upon water relations is the southwest region's Ganges- Gorai drainage lying to the east of the Hoogly and west of Meghna. Together these sedimentary plains are known as the Bengal Basin.

The *Sundarbans* Reserve Forest drainage system has three subsystems to the east, center and west, which formed estuaries of the Bangra, Kunga Malancha and Raimangal. The whole area is dissected by large tidal rivers, notably the Baleswar, Passur Kobadak-Sibsa, Arpangasia and Raimangal together with innumerable small channels and creeks. The main south-west catchment together with the sub-catchment are referred to as SW-1 to SW-27.

Water is the main force which shapes the coastal landscape and although the forest and the dissected low lying land surface dissipate much of the energy of the tides and rivers flows, water remains the powerful architect of the environment.

The rivers in the Sundarbans are classified in three different series:

a) **Raimangal-Sibsa Series:** The Raimangal is a broad deep river which carries cross boundary flow from India and discharges into the Bay of Bengal. The main flow which, enters from the river into the *Sundarbans* is through Jamuna to Khaikhali. The river Jamuna is also a broad deep channel with well marked shoals. It issues a large part of its flow into Malancha rivers through Firingi Khal. The tides ebb and flow through this khal which is in reality a large river. The Malancha is connected with the Arpangasia rivers through Araibeki rivers. The linkage between Arpangasia and Sibsa is the chalki-Sonakhal-Taidup river. Through this river, the flow movement is towards Sibsa and ebb direction towards Arpangasia. This linkage appears to be morphologically stable. The Arpangasia upstream joins with the Kobadak which brings in a significant runoff from the upstream catchment basins. The Kobadak and Sibsa have the same tidal phase.

b) **Passur-Sibsa series:** The Passur-Sibsa system is much cross-connected. The tidal flood water flowing up the Passur and Sibsa penetrates into numerous small rivers and Khals. Strong tidal dominance of water induces net tidal circulation with a strong spring-neap variation between the two major rivers. The Sibsa is connected with the Passur through Bishanbari khal and the Mara Bhadra-Manki system with in the Sundarbans Reserve Forests. Freshwater discharge to the river system is provided by local rainfall and tributary flowing from the Ganges into the Gorai-Madhumati river. The main freshwater source in the system is the inflow from the Gorai through the Halifax Cut. During the monsoon about 80% of the Gorai flow passes through the Halifax Cut near Bardia to the Passur-Sibsa system. In the wet season this amounts to 3200-4800 whereas the inflow from January to May is negligible.

c) **Passur-Baleswar series:** The major rivers in the series in between Passur and Baleswar are Bare Siala Gang, Mirgamari-Silla Gang and Bhola-Supti systems. There is no major exchange of flow between these two rivers except minor flow through the Mingamari-Sela Gang-Pathuria rivers. During flooding in the Passur rivers, water in the Bara-Siala river discharges into the Passur with a tidal meeting point in Passur khal. The Mingamari receives water from the Passur during ebb tide condition in the later. This water flow into the Sela-Gang which diverts some of its flow into the Passur through the Arial khal and some to the Baleswar through the Patakhata and Badamtala rivers *(Wahid-1995).*

3.8 Tides in the *Sundarbans* : Nature and effects

The tide in the sea results from the gravitational pull of the moon, the sun and the planets and from meteorological disturbances. The tides in the Bay of Bengal are pre-dominantly semi-diurnal, that the tidal period is 12 hours 25 minutes. The energy which creates the tidal flow, i.e., attrition of the sun and the moon in the deep sea is very limited and manifested party as potential energy rise in tidal level and partly as kinetic energy, viz., velocity of flow. The former causes the tidal flow up the river and the later determines its power for transporting silt. It is generally observed that the duration of ebb tide in a tidal river is longer than that of the flood tide. The capacity of water of transport silt depends on it velocity. Therefore the ebb tide generally fails to transport back fully the silt that has been carried up this tidal rivers by the flood tide *(Wahid-1995)*.

The overall picture in the dry season is that the system is flood dominate with peak discharges, and hence sediment transport, greater during flood than ebb. In the wet region the situation is less pronounced or reversed. Annually the dry season effects appear to exceed the wet season effect making the system a net importer of sediment but this important topic requires further verification with the aid of the sediment transport model. The inland tidal condition is also subject to changes caused by major invention in the river system *(Wahid-1995)*.

The tidal range is 4m. There is relatively large seasonal variation in the level of spring tides. The maximum reached in the monsoon period is nearly 1 m higher than the winter period. The highest astronomical spring tide at Sundarikota inside the Sundarbans in 1984 will be 4.21 m on 28.8.84. In February the highest tide here was 3.40 m *(BIWTA-1983)*. This seasonal variation is an important ecological factor.

Table-3.4 Inflow to some river system in the upstream catchment area

Description	catchment No	Area (Km^2)
Inflow to Nabaganga-Atrai-Rupsa	SW- 2,3,7,8,9,10,14,15,	5790
Inflow to Gorai-Madhumati	SW- 11	445
Local inflow to Sibsa	SW- 20,21,26,23 (50%)	1997
Local inflow to Passur	SW- 24 (25%)	334

Source: *Integrated Resource Development of the SRF of Bangladesh- S.M. Wahid, June, 1995*

The tidal current in the large rivers usually varies from 3 km/h near the sea-face to 6 km/h in the northern part of the forest, but during spring tides currents may exceed 10 km/h. The tidal current in the large rivers continue to run, on its own momentum, for about an hour after the tidal bore has passed, and this momentum tends to deepen the low tides and increase the high tides. The tidal variation is therefore higher inside the forest than at the sea-face *(Choudhury-1968)*.

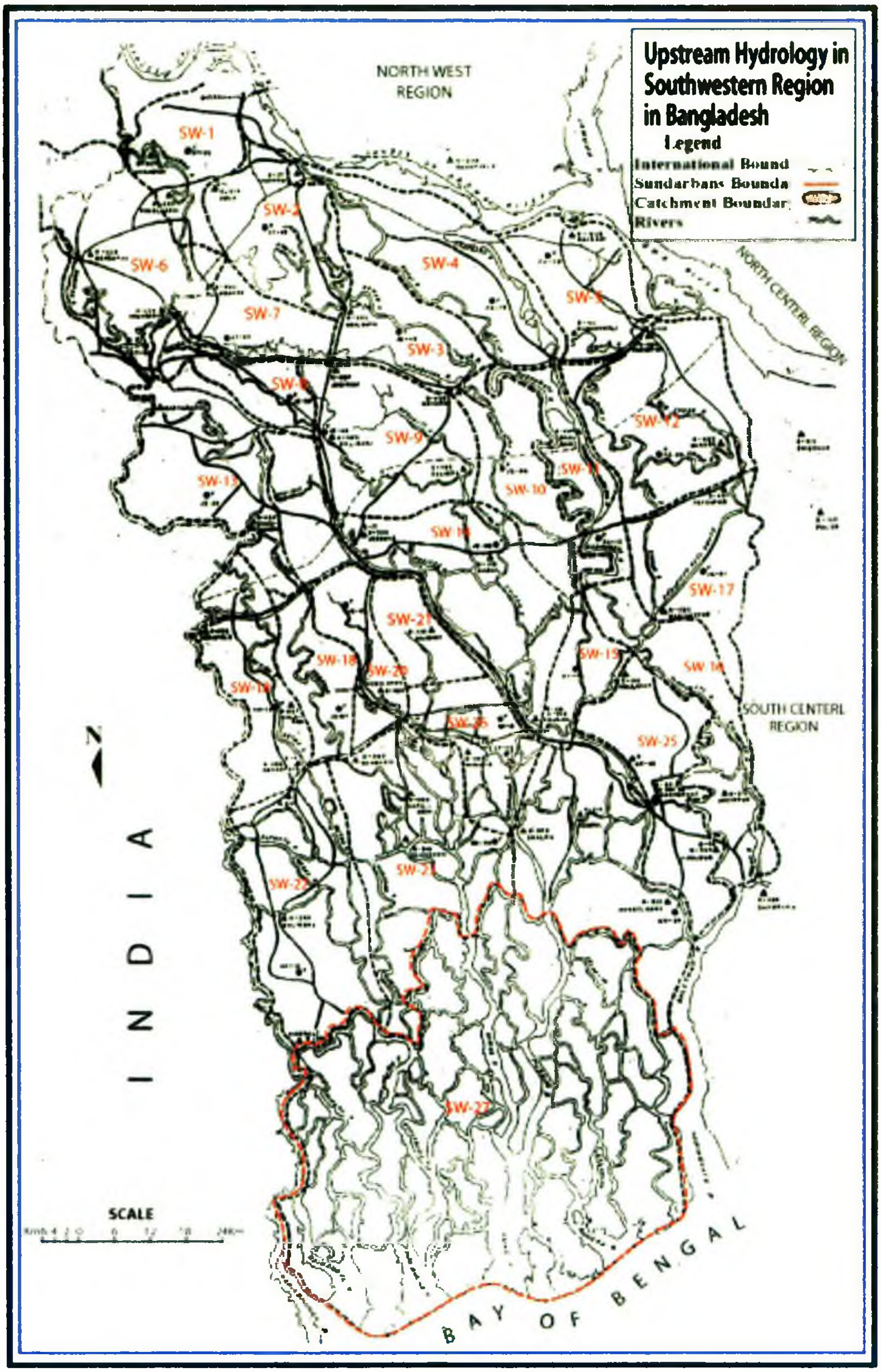
3.9 upstream Hydrology and South west Regional Model

About a century ago, the upstream rivers, Kumar, Nabaganga, Chitra, Bhairab and Kobadak were active distributaries of the Ganges, sediment laden water flowed into the sea in a south easterly direction. Under normal conditions sediment that reached the sea would be returned at high tide and be deposited over tidal spill areas.

The upstream catchment area today covers greater Kushtia, Khulna, Jessore and Faridpur districts. The area is bounded in the north by the Ganges river, on the south by the bay of Bengal, on the west by Indian border and on the east by the Baleswar river. To study the present situation in these catchment and their effect on the hydrological regime of the *Sundarbans* Rainfall-runoff modeling was carried out along with detailed hydraulic modeling of the area. For modeling purposes the area is divided into 27 catchment. The catchment are delineated taking into consideration the actual drainage pattern of the catchment. The catchment boundary was demarcated by drawing drainage basin divides lines with the help of available 1:50,000 scale satellite image maps. It should be noted that delineation of *Sundarbans* catchment (SW-27) as shown as drawing – 4was done for rainfall runoff modeling only and does not show the boundary of SRF *(Wahid-1995)*.

Geomorphologically, the catchment of the region fall into two zones. The Ganges river flood plain in the north and the Ganges tidal flood plain in the south. Upstream catchment SW-1 to SW-21 fall in the Ganges river flood plain and the remaining downstream catchment in the Ganges tidal flood plain. The dominant features in the upstream part are meandering rivers curved ridges, saucer shaped basins and abandoned channels. Generally, sandy or silty sediment are found in the ridges and finer materials in the basins. In the tidal flood plain the landscape is of very flat topography, narrow levees formed of very fine sand and an intensive network of channels.

Fig- 3.01 : Upstream hydrology and South-Western regional model (Inclu. *Sundarbans*)



Source: Modified and edited after *Integrated Resource Development of the SRF of Bangladesh- S.M.Wahid, June,1995.*

The entire upstream catchment area is more or less affected by tides generated in the Bay of Bengal. Only the northern part of the region is covering catchment SW-1 to SW-8 and SW-13 are free from tidal effect. The river system in the upstream catchment owes its origin largely to the Ganges river. The whole river system is connected to the Bay of Bengal through estuarine formation of the Sundarbans. In the upper part where the tidal influence is, more or less none, two major river systems can be identified. These are Gorai-Madhumati and Matabhanga, both distributaries of the Ganges. The Matabhanga river is the only active channel in the northwest part of the region and is hydraulically disconnected from the rest of the river system of the region. Downstream of the Matabhanga basin originate Bhairab, Chitra and Nabaganga rivers, which in the part were connected to the Matabhanga river.

Bhairab, Chitra and Nabaganga combine with the Madhumati, the downstream reach of Gorai, through a network of channels, to form a big river system. The combined flow of this river system is mainly drained through Passur and Baleswar in the south in the SRF. In the mid western part, near the Indian border, the Betna which originates from India and Kobadak, downstream reach of the old Bhairab, make up the only river system in the area. In the central part of the region, Hairier and Mukteswari rivers rise from large local depression or water bodies to form a complex network of tidal channels. The channels inter link with each other, often forming loops, along which the polders were constructed. The rivers enrobe to the Bay of Bengal from the estuarine environment of the Sundarbans forest *(Wahid-1995)*.

3.10 Extreme Floods and Cyclones

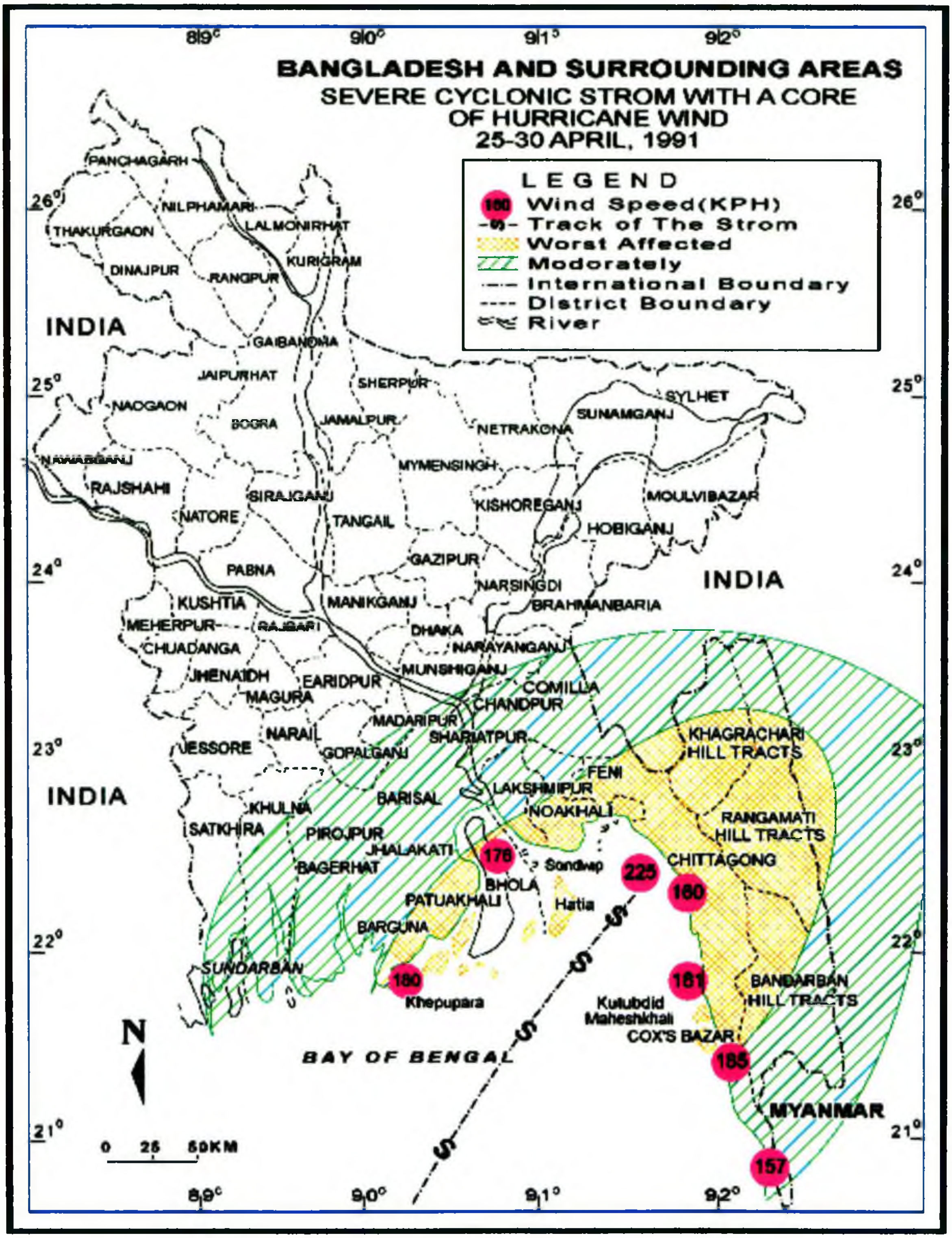
Cyclones in Bangladesh are quite frequent. Cyclones of a highly destructive nature, accompanied by tidal surges upwards of 10 ft, strike Bangladesh at an estimated frequency of once every five years. The main period in which cyclonic storms occur is during April and May. Cyclones should occur during the period September to December as well. The tidal waves sweep parts of the Sundarbans twice a day. Tide level also change depending on another meteorological factors, barometric pressure, wind velocity etc. The speed of tidal bore various from 50 km/hr at the Sea side to 25 km/hr in the interior. Tidal currents vary from 35 km/hr at the sea face to 7 km/hr in the upper reaches. Tidal wave moves from the south to the

Table-3.5 Chronology of Major Cyclonic Storms and Tidal surges in the Sundarbans

Year of Occurrence	Month and Date of occurence						Affected Area	Nature of the Phenomena	Max wind speed (Km/hr)	Storm surge height (m)
	May	Aug	Sep	Oct	Nov	Dec				
1895				α			Sundarbans	Cyclones accompanied by Storm Wave		
1901					α		Western Sundarbans	Cyclonic and Storm Waves		
1917	α						Sundarbans	Cyclonic and Storm Waves		
1942				α			Sundarbans	Severe Cyclonic Storm		
1960	α 25-29						Sundarbans Coast	Cyclonic Storm		
1967				α 11			Khulna & Sund Coast	Cyclonic Storm		2.0-8.5
1969				α 11			Khulna Coast	Cyclonic Storm		2.5-7.0
1970				α 23			Khulna	Severe Cyclonic Storm with storm surge		
1971					α 28-30		Sundarbans Coast	Low lying areas of Khulna town	60-70	0.67
1973						α 6-9	Sundarbans Coast	Severe Cyclonic Storm low lying coastal areas	122	1.5-7.5
1974		α 13-15					Khulna Coast	Severe Cyclonic Storm 50 mph	97	1.5-6.5
1975	α 9-12						Khulna	Severe Cyclonic Storm 60-70 mph		
1977	α 9-12						Khulna & Off-shore Islands	Cyclonic Storm 70 mph	122	
1978			α 30-	α 3			Khulna & Sundar Coastal	Cyclonic Storm 46 mph		
1981						α10	Khulna near Sundarban	Severe Cyclonic Storm(H)	120	0.8
1988					α 29		Khulna Coast near river Raimangal	Severe Cyclonic Storm	162	1.5-3.0
1995					α 7-10		Weakened & cross Sun Coast	Severe Cyclonic Storm(H)	-	-
1996				α 26-29			Sundarban Coast	Cyclonic Storm	75	-
1998					α 19-22		Sundar Coastal near Raimangal R.	Cyclonic Storm	90	4.0-6.0

Source: *1990 & 2000 Statistical year book of Bangladesh and Multipurpose cyclone shelter program, Main Report, Part-1, Vol-1. 1998.*

Fig- 3.02 : Devastation of the 1991 – Cyclone storm (*including Sundarbans*) in Bangladesh



Source: Modified and edited after Integrated Resource Development of the SRF of Bangladesh - S.M.Wahid, June,1995 north. Tidal waves are deformed in the *Sundarbans* due to channel character and uplands river discharge. The primary effects of the Sundarbans are the destruction of the sea front vegetation, some breakage of trees in the interior and a reworking, through massive erosion/accretion, of the shoreline. These areas, however, recover through the process of secondary succession and are seldom left barrier for any extended period of time. The *Sundarbans* forest is recognized in Bangladesh as a natural buffer which protects the inland areas in the southwestern part of the country from the full destructive force of the cyclones *(Snedaker-1984)*.

During the last 125 years more than 42 cyclones have crossed the coastal belt of Bangladesh of which eleven tracked through the *Sundarbans*. The cyclone winds rotate anti clock wise, producing the height wind and surge conditions on their right side. Records show that cyclone occurrences to be increasing this century now. This increase could be attributed to climate change or improved detection. The frequency of severe cyclones has been the same for pre-monsoon (April-June) and post monsoon (September-December) period.

3.11 Salinity Instructions : Past and present

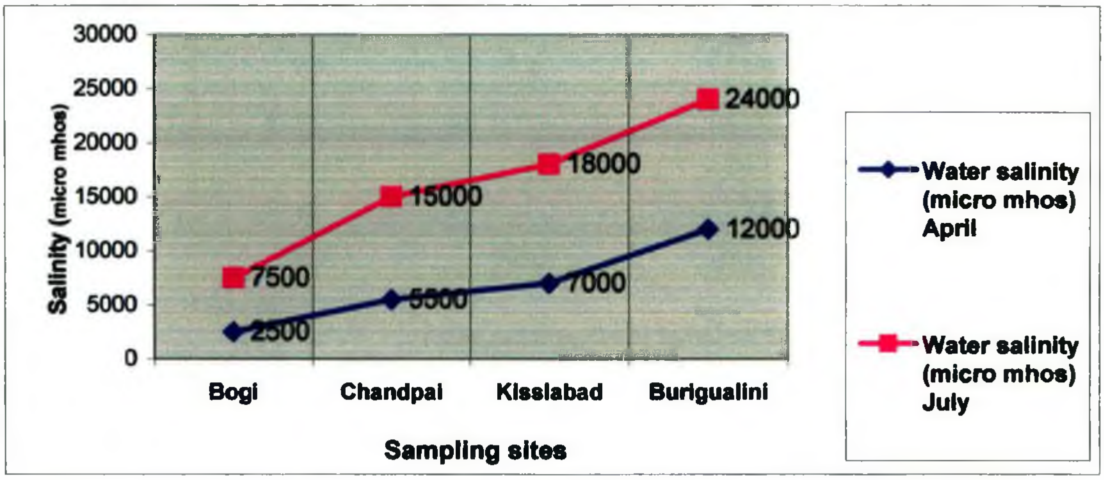
Salinity increases from north to south and from east to west, and is highest during the dry season month of February, March and April. In the *Sundarbans* forest during this period, it appears that the only free water available for transportation is the blackish surface water in the rivers and Khals. Which, is transported into the forests by tidal action. There is no evidence to suggest that there is sufficient groundwater (Fresh or blackish) to ameliorate the freshwater deficit. In the dry season, water levels in the rivers are at their lowest and the blackish water becomes increasingly more saline due to reduced flows of freshwater from upstream. Salinity of river at Bagi, Chandpai, Kassiabad and Burigoalini are presented in table-3.6.

Table-3.6 Mean salinity of river water adjacent to the sampling sites in April and July during 1976-86

Sampling sites	Adjacent rivers	Water salinity *(micro mhos)*	
		April	*July*
Bogi	Baleswar	2500	7500
Chandpai	Passur	5500	15000
Kassiabad	Koyra	7000	18000
Burigoalini	Kholpetua	12000	24000

Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri-Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong, 1990.*

Graph- 3.2 Mean Water Salinity in April & July (1976-86) to Four Sampling sites



Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri-Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong, 1990.*

The result showed that variation in salinity between 1000 and 49000 micro mhos does neither drastically affect regeneration nor the survival of Sundri seedlings during the observation of one year.

Salinity in the SRF is highly dependent on the salinity's at the coast and the volumes of freshwater flows discharging from upstream. Salinity's on the coast and in the forest channels vary over a number of different time scales *(SWMC, 1995)* as follows:

- ***Semi diurnal variations***: Tides in the Bay of Bengal are semi diurnal. The arrival of high water at the coast generally coincides with the peak in daily salinity and the daily range of salinity concentrations at the river entrances varies with the season.

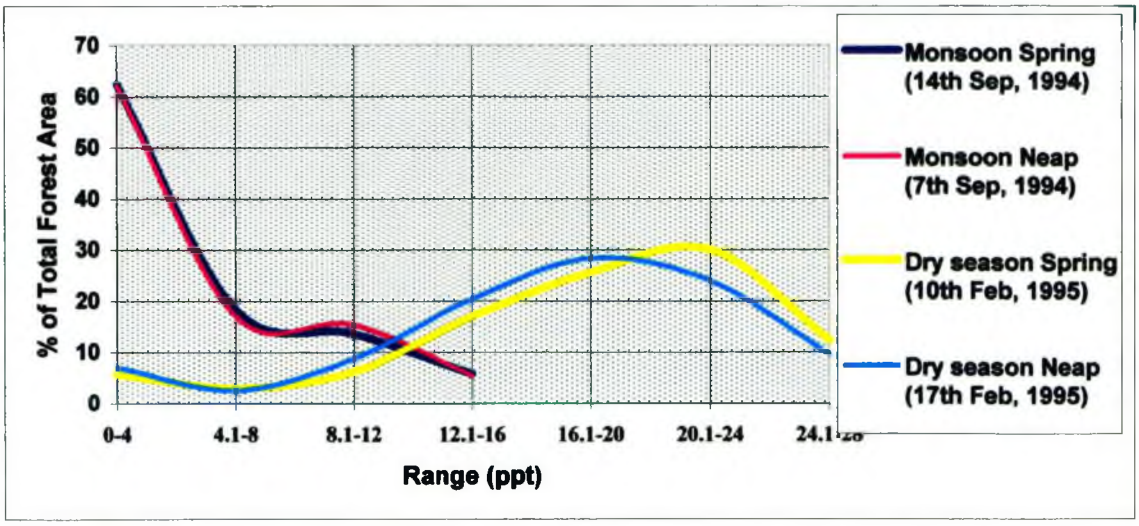
Table-3.7 Spatial Salinity Distribution in the *Sundarbans (% of total Forest Area)*

Range *(ppt)*	Monsoon		Dry season	
	Spring *(14th Sep, 1994)*	Neap *(7th Sep, 1994)*	Spring *(10th Feb, 1995)*	Neap *(17th Feb, 1995)*
0-4	62.4	62.1	5.7	7.0
4-8	18.3	17.1	3.0	2.5
8-12	13.6	15.4	6.2	8.7
12-16	5.7	5.4	17.0	20.3
16-20	--	--	25.6	28.3
20-24	--	--	30.1	23.9
24-28	--	--	12.4	9.5
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: Wahid-1995

Changes in salinity between Monsoon and Dry season.

Graph- 3.3 Spatial Salinity Distribution in different time Range (ppt) wise



Source: Wahid-1995

- ***Spring neap tides the variations:*** Tidal amplitudes during spring tides are around 2.5 to 3 times higher than during neap tides. The higher water levels occurring at the coastal boundaries cause greater volumes of saline water to enter the forest than during neap tides.

- ***Seasonal variations***: Average salinity concentrations at the coast are there fore higher in the dry season than in the monsoon measurements at Hiron point and Khaikhali between August 1994 and February 1995 indicate that salinity increases almost linearly from the beginning of October. This rise will generally continue until the start of the monsoon.

- ***Salinity distributions-*** Existing conditions: The spatial distributions of salinity's in the Sundarbans as simulated by the model have been presented as a series of salinity concentration maps, overlain on a topographic map of the Sundarbans Reserve Forest. The maximum or minimum simulated salinity concentration reached during 13 hours simulations periods on the dates.

- Local effects can however after this general pattern for example for the Malancha river entrance in September salinity generally increases during the mouth due to the declining volume of freshwater discharging into the Bay of Bengal as the monsoon comes to an end.

3.12 Probable Changes in Water Regime in the *Sundarbans*

The special circumstances of salinity, unconsolidated soils and exceptionally high year round water tables make potable water supplies difficult to organize and difficult to maintain at acceptable standards in the Sundarbans Reserve Forests. Strategies for provision of dependable potable water for all Forest Division (FD) stations could be as follows:

- Rainwater storage tanks have to be improved and their use extended because of their cheap construction. The tanks will be excavating the earth on relatively high natural ground and by providing sufficiently strong embankments or linings to store the water. As the distribution of rainfall throughout the year is uneven, the rainfall storage tank will be comparatively large in size. The surface area will have to be sufficiently large for rainwater collection. In addition to improving the present 14 ponds a further 9 new storage tanks should be dug at:

    1. Adachai Coupe Office.
    2. Sutakhali Forest Station.
    3. Andarmanik Patrol Post.
    4. Kalabagi Forest Station.
    5. Patakhata Patrol Post.
    6. Sakbaria Patrol Post.
    7. Bazbaza Patrol Camp.
    8. Kochikhali Wildlife Sanctuary.
    9. Koyra Patrol Post.

- Slow Sand Filters (SSF) should be installed at 20 new locations; these include all 9 new storage tank locations as well as 11 old pond sites where filters are not present. SSF is the best option for the following regions:

    - Skilled supervision is not required.
    - Capital cost and cost of operation is low.
    - Depreciation is low.

- SSF are package type filter units developed to treat usually low saline pond water for domestic consumption. In this system, water from ponds is collected by hand pump and discharged into a reservoir underlain by a sand bed; filtered water is collected through a tap.

- Charcoal can be used as a superior filter medium instead of sand. Easy and abundant availability of filter material, Sand and charcoal, makes it an attractive option for the Sundarbans Reserve Forests. Charcoal filtration leads to a high degree of improvement to the physical, chemical and bacteriological quantity of water *(Wahid-1995).*

3.13 Sea Level Rise

Predicted sea level rise (SLR) already directed due to global warming coupled with land subsidence will change water depths, tidal flows, salinity and sedimentation patterns throughout the area.

During last 100 years the climate has gradually become warmer. Average 1.5 m rise in sea level will inundate about one sixth of the country. The greenhouse effect may bring about great impacts on the socioeconomic aspects of the coastal area of Bangladesh. Rise in temperature is seawater may be intolerant to some species. Sundarbans may migrate northward, thus destroying the productive agricultural land in the north of it.

Past record show that global mean temperature has increased 0.3°-0.6° C over the last one hundred years, with the five warmest years being in the 1980s. Over the same period global sea level has increased by 10 to 20cm. Though predictive mathematical climate models give varying results on long-term global mean temperatures which ranges between 1°-5° C according to the joint statement of US scientist of the Nation Academy of Sciences, the Nation Academy of Engineers and the institute of Medicine *(CARDMA, 1989).* It is most likely that there is a move towards higher temperatures, which will cause the polar ice masses to melt and sea level to rise *(Wahid-1995).*

The reason that the *Sundarbans* are most susceptible to sea level rise is that not only that the coastal development processes in the estuary very complex. But also on the fact that entire forest is barely above the existing sea level and will be inundated by sea water causing permanent loss of this precious ecosystem. Studies conducted by FAP-4 detected a trend of sea level increase between 0.75 mm/ year to 1.4 mm/year in the *Sundarbans*. A simplified simulation of the SLR with assumed sea level increase of 35 cm was carried on for preliminary impact analysis. The impact of the assumed sea level rise (SLR) on flooding were assessed by simulating the increased flooding during the peak flood time of August–September. In case of the *Sundarbans* which is tide affected, the increased flooding due to high tide under the SLR scenario were assessed during the dry season, i.e. the month of April. Results indicated that the dry season the rivers between Arpangasia and Baleswar will experience a 35 cm increase in water level during a high tide whole the river to the south of Arpangasia will experience a increase of about 30 cm due to a SLR of 35 cm *(Wahid-1995)*. SLR the salinity front will move only marginally. SLR especially:

- Change in current and water characteristics such as temperature and density.
- Loss of breeding and nursery grounds for fish and shrimps.
- Saline precipitates on the forest floor due to increased evaporation.

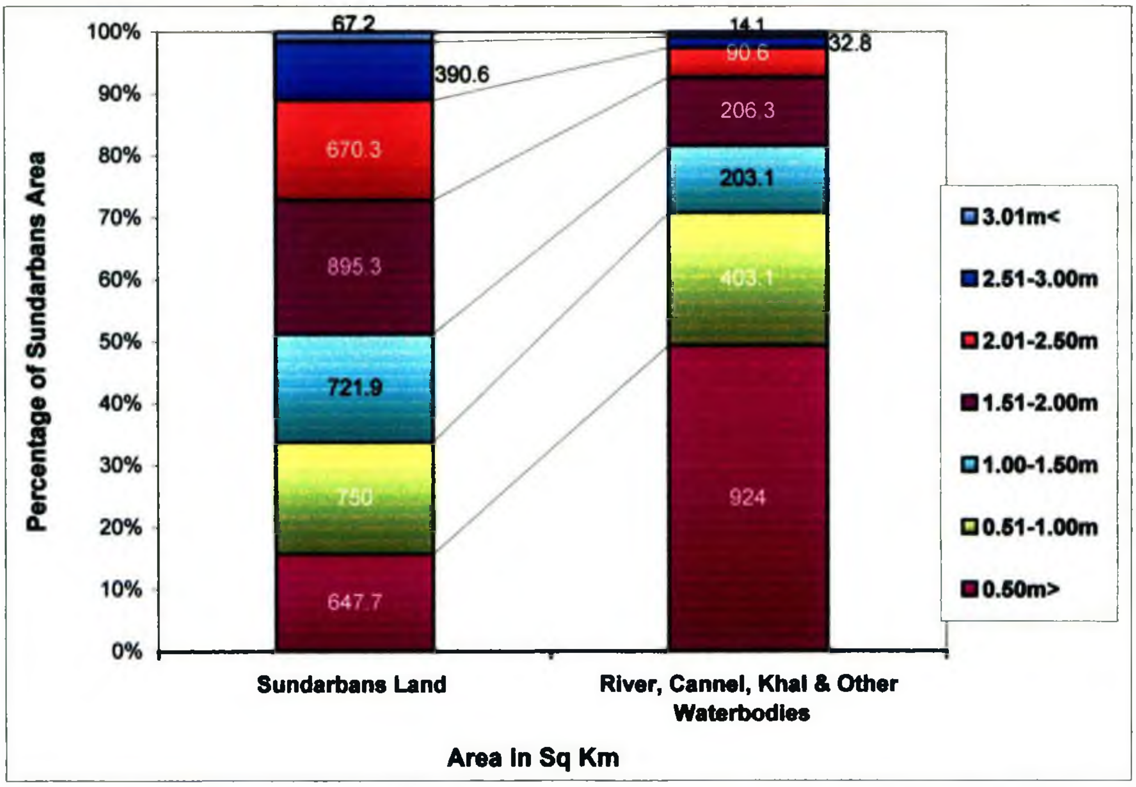
The velocity of flowing water in an important factor since the kinetic energy varies as the square of the velocity. If the velocity is doubled the cutting power is increased 4 times, the quantity of material of a given size that can carried is increased 32 times and the volume size of particles that can carried is increased 64 times. Slope is an important factor since velocity varies as the square root of the slope. Water will flow down a 40 percent slope with the velocity of that on a 10 percent slope. Vegetation acts to reduce erosion by slowing down the velocity of water flowing over the soil surface. Since erosion is caused by overland flow, the effect of vegetation is reducing and retarding overland flow also operate to reduce erosion (*Israil, 1994*).

Table- 3.8 Height Variation from mean Sea level Rise (*meter*) by Sundarbans land, Waterbodies & Total Sundarbans Area in Sq. Km.

Height Mean Sea Level in Meter	Sundarbans Land Area		River, Cannel, Khal & Other Waterbodies area at Sundarbans		Total Area at Sundarban	
	Area (Km²)	%	Area(Km²)	%	Area(Km²)	%
0.50m>	647.70	*15.63*	924.00	*49.31*	1571.70	*26.12*
0.51-1.00m	750.00	*18.10*	403.10	*21.51*	1153.10	*19.16*
1.00-1.50m	721.90	*17.42*	203.10	*10.84*	925.00	*15.37*
1.51-2.00m	895.30	*21.61*	206.30	*11.01*	1101.60	*18.31*
2.01-2.50m	670.30	*16.18*	90.60	*4.83*	760.90	*12.65*
2.51-3.00m	390.60	*9.43*	32.80	*1.75*	423.40	*7.04*
3.01m<	67.20	*1.62*	14.10	*0.75*	81.30	*1.35*
Total Area	**4143.00**	***100.00***	**1874.00**	***100.00***	**6017.00**	***100.00***

Source: *Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.4 Height Variation by Sundarbans land & Waterbodies Area in Sq. Km/Percentage.



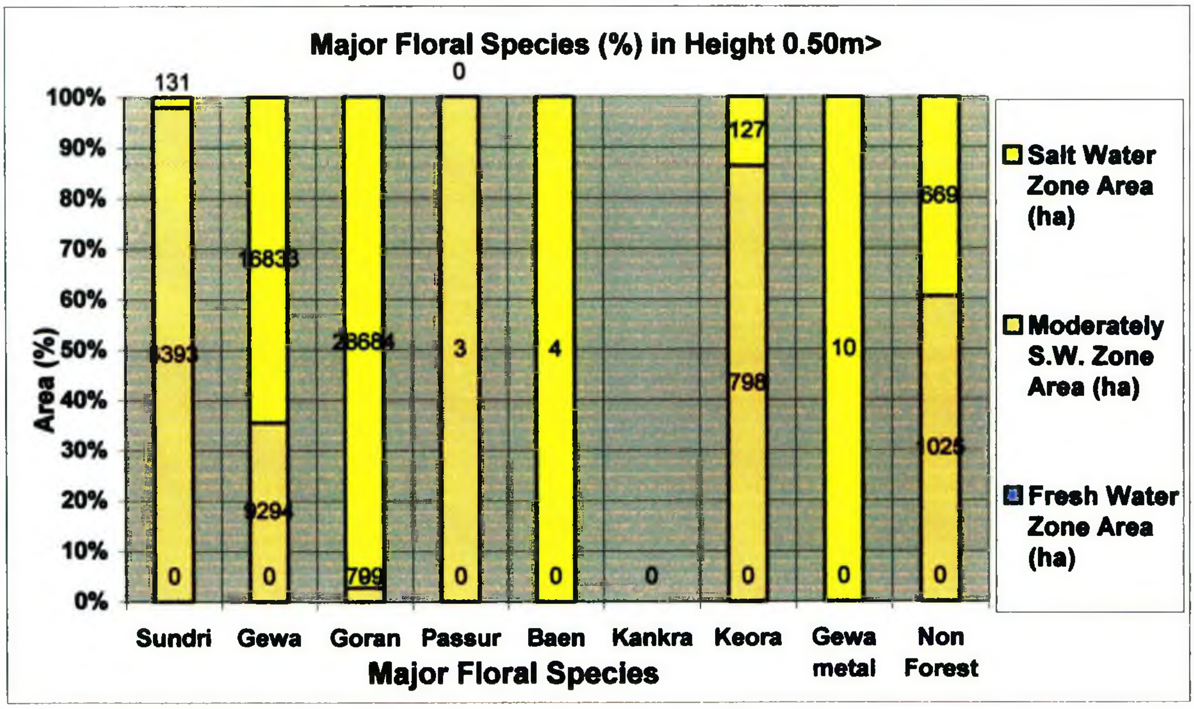
Source: *Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.9 Sundarban Major Floral Species by different Saline Zone & Total Area (*Hectors & Percentage*) in Height 0.50m> From Mean Sea Level

Major Species	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	–	–	6393	*9.87*	131	*0.20*	6524	*10.07*
Gewa	–	–	9294	*13.35*	16833	*25.99*	26127	*40.34*
Goran	–	–	799	*1.23*	28684	*44.28*	29483	*45.51*
Passur	–	–	3	*0.01*	–	–	3	*0.01*
Baen	–	–	–	–	4	*0.01*	4	*0.01*
Keora	–	–	798	*1.23*	127	*0.20*	925	*1.43*
Gewa metal	–	–	–	–	10	*0.02*	10	*0.02*
Non Forest	–	–	1025	*1.58*	669	*1.03*	1694	*2.61*
Total	–	–	**18312**	***28.27***	**46458**	***71.73***	**64770**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.5 Major Floral Species by different Saline Zone & Area (*Percentage*) in Height 0.50m>



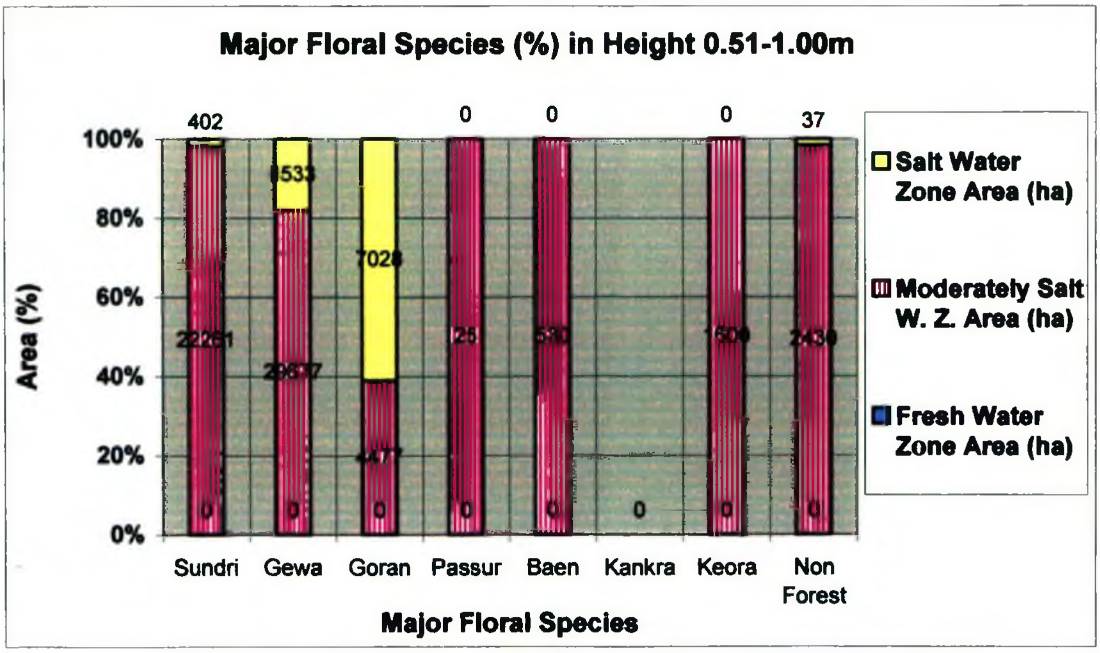
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.10 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* in Height 0.51-1.00m From Mean Sea Level

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	--	--	22261	*29.68*	402	*0.54*	22663	*30.22*
Gewa	--	--	29677	*39.57*	6533	*8.71*	36210	*48.28*
Goran	--	--	4477	*5.97*	7028	*9.37*	11505	*15.34*
Passur	--	--	25	*0.03*	--	--	25	*0.03*
Baen	--	--	530	*0.71*	--	--	530	*0.71*
Keora	--	--	1600	*2.13*	--	--	1600	*2.13*
Non Forest	--	--	2430	*3.24*	37	*0.05*	2467	*3.29*
Total	--	--	**61000**	***81.33***	**14000**	***18.67***	**75000**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.6 Major Floral Species by different Saline Zone & Area (*Percentage*) in Height 0.5-1.00m



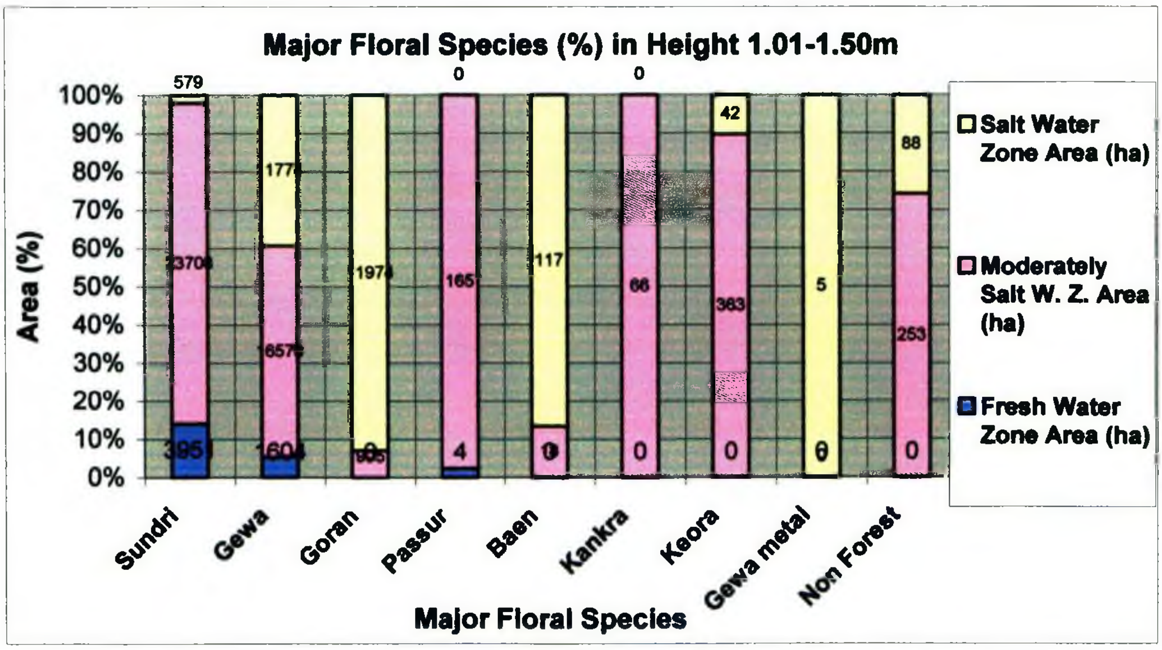
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.11 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* in Height 1.00-1.50m From Mean Sea Level

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	3951	*5.47*	23708	*32.84*	579	*0.80*	28234	*39.11*
Gewa	1604	*2.22*	16578	*22.97*	11774	*16.31*	29956	*41.50*
Goran	--	--	905	*1.25*	11974	*16.59*	12879	*17.84*
Passur	04	*0.01*	165	*0.22*	--	--	169	*0.23*
Baen	--	--	18	*0.03*	117	*0.16*	135	*0.19*
Kankra	--	--	66	*0.09*	--	--	66	*0.09*
Keora	--	--	363	*0.50*	42	*0.06*	405	*0.56*
Gewa metal	--	--	--	--	5	*0.01*	5	*0.01*
Non Forest	--	--	253	*0.35*	88	*0.12*	341	*0.47*
Total	**5559**	***7.70***	**42052**	***58.25***	**24579**	***34.05***	**72190**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.7 Major Floral Species by different Saline Zone & Area (*Percentage)* in Height 1.01-1.50m



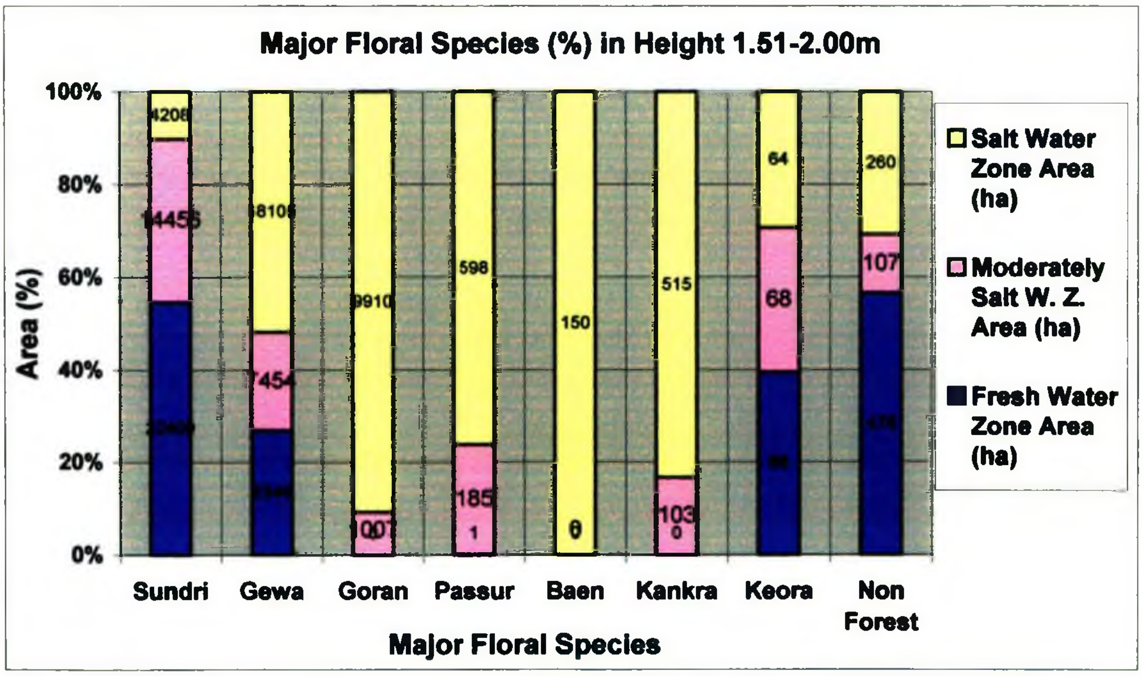
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.12 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* in Height 1.51-2.00m From Mean Sea Level

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	22409	*25.03*	14456	*16.15*	4208	*4.70*	41073	*45.88*
Gewa	9346	*10.44*	7454	*8.33*	18105	*20.22*	34905	*38.99*
Goran	–	–	1007	*1.12*	9910	*11.69*	10917	*12.19*
Passur	1	–	185	*0.21*	598	*0.67*	784	*0.88*
Baen	–	–	–	–	150	*0.17*	150	*0.17*
Kankra	–	–	103	*0.12*	515	*0.57*	618	*0.69*
Keora	86	*0.01*	68	*0.07*	64	*0.07*	218	*0.24*
Non Forest	478	*0.53*	107	*0.12*	260	*0.29*	845	*0.94*
Total	**32320**	***36.10***	**23380**	***26.11***	**33830**	***37.79***	**89530**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.8 Major Floral Species by different Saline Zone & Area (*Percentage*) in Height 1.51-2.00m



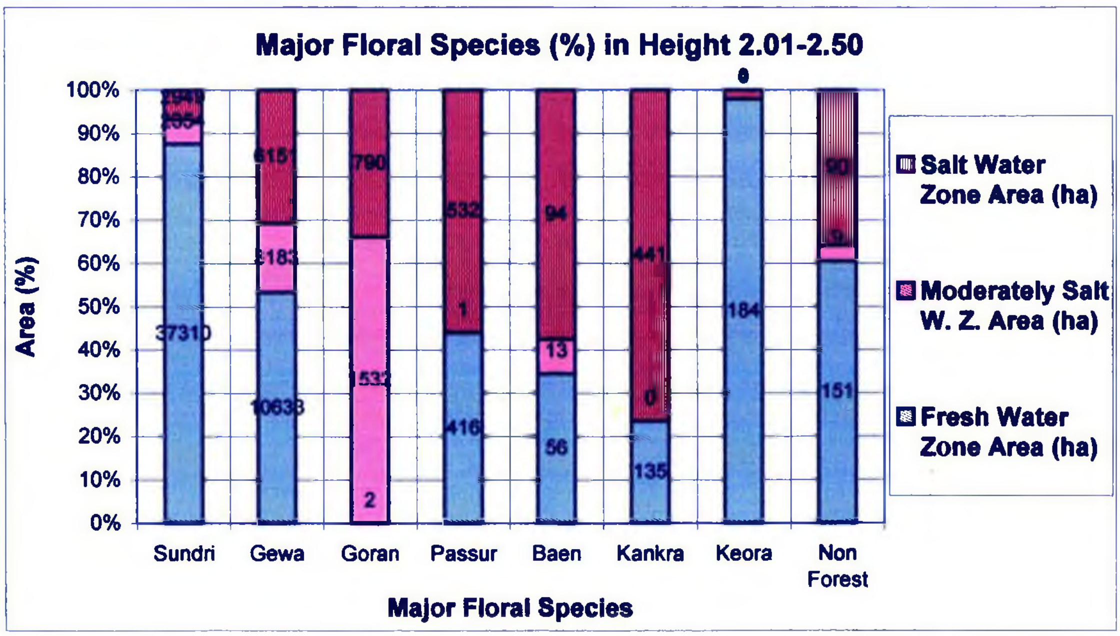
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.13 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* in Height 2.01-2.50m From Mean Sea Level

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	37310	*55.66*	2354	*3.51*	2949	*4.40*	42613	*63.57*
Gewa	10633	*15.86*	3183	*4.75*	6151	*9.18*	19967	*29.79*
Goran	2	--	1532	*2.29*	790	*1.18*	2324	*3.47*
Passur	416	*0.62*	1	--	532	*0.79*	949	*1.41*
Baen	56	*0.08*	13	*0.02*	94	*0.14*	163	*0.24*
Kankra	135	*0.20*	--	--	441	*0.66*	576	*0.86*
Keora	184	*0.27*	--	--	4	*0.01*	188	*0.28*
Non Forest	151	*0.23*	9	*0.01*	90	*0.13*	250	*0.37*
Total	**48887**	***72.93***	**7092**	***10.58***	**11051**	***16.49***	**67030**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.9 Major Floral Species by different Saline Zone & Area (*Percentage*) in Height 2.01-2.50m



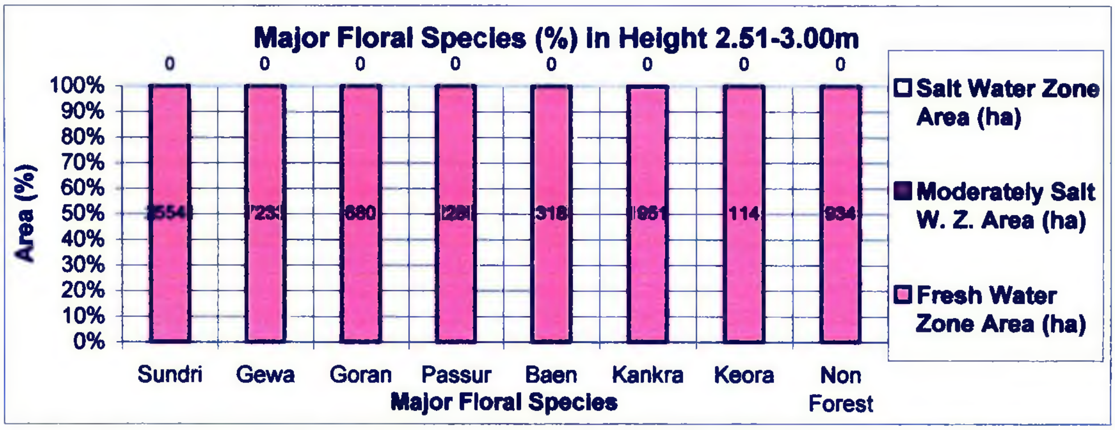
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.14 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* **in Height 2.51-3.00m From Mean Sea Level**

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	25541	65.39	--	--	--	--	25541	65.39
Gewa	7233	18.52	--	--	--	--	7233	18.52
Goran	680	1.74	--	--	--	--	680	1.74
Passur	2289	5.86	--	--	--	--	2289	5.86
Baen	318	0.82	--	--	--	--	318	0.82
Kankra	1951	4.99	--	--	--	--	1951	4.99
Keora	114	0.23	--	--	--	--	114	0.23
Non Forest	934	2.39	--	--	--	--	934	2.39
Total	**39060**	**100.00**	--	--	--	--	**39060**	**100.00**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.10 Major Floral Species by different Saline Zone & Area (*Percentage*) **in Height 2.51-3.00m**



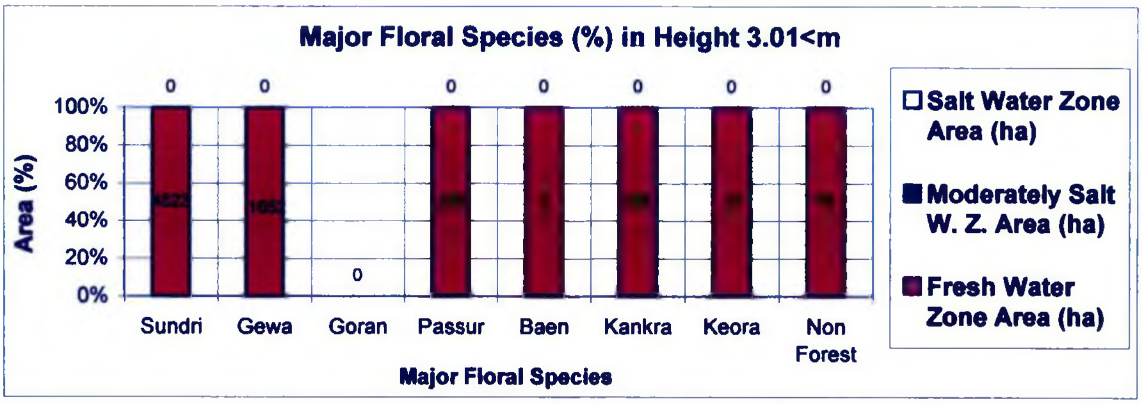
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 3.15 Sundarban Major Floral Species by different Saline Zone & Total Area *(Hectors & Percentage)* **in Height 3.01m< From Mean Sea Level**

Major Species	Fresh Water Zone		Moderately Salt W. Z.		Salt Water Zone		Total Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	4523	67.31	--	--	--	--	4523	67.31
Gewa	1652	24.58	--	--	--	--	1652	24.58
Goran	--	--	--	--	--	--	--	--
Passur	226	3.36	--	--	--	--	226	3.36
Baen	8	0.12	--	--	--	--	8	0.12
Kankra	226	3.36	--	--	--	--	226	3.36
Keora	10	0.15	--	--	--	--	10	0.15
Non Forest	75	1.12	--	--	--	--	75	1.12
Total	**6720**	**100.00**	--	--	--	--	**6720**	**100.00**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 3.11 Major Floral Species by different Saline Zone & Area (*Percentage*) in Height 3.01<m



Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

3.14 Water Pollution

Water Pollution has been endemic in the southwest region and become widespread in recent years with possible impacts upon the *Sundarbans* Reserve Forest, which have not yet been measured. All kinds of wastes either in solid or liquid form are dumped into rivers and ultimately find their way into the Bay of Bengal through the Sundarbans which can produce a change in the physical characteristics of the ecosystem *(Wahid-1995).*

Pollution originates from specific places such as a particular industrial source or has diffuse origins such as ocean currents or agricultural runoff. Within the southwest region, industries are concentrated along the roads between Kushtia-Jessore-Khulna and along the rivers. Several match factories, the Khulna shipyard and fish processing units in the Rupsa industrial area discharge their effluent into the Rupsa rivers. Khulna Newsprint Mill, Goalpara Power Station, some jute, hardboard and steel mills in the khalispur industrial belt also discharge their untreated wastes into the Bhairab river.

Oil pollution may be affecting the Sundarbans Reserve Forest *(Grepin-1995).* Bilge water and crude oil slicks derived from ocean going freighters, mechanized boats, fishing trawlers and passenger launches travel along the Passur rivers. ESCAP estimated in 1988 that accidental oil spillage, oil slicks, ballast and bilge water discharge would increase four-fold by the year 2000 under present operating rules.

Another important issue is the extent to which pollution from the Hoogly rivers in India reaches the *Sundarbans* ecosystem. Ground water contamination especially in the Border zone is unknown and should be studied as a matter of high priority together with problems relating agricultural pollution for the following regions:

- The accumulation of nutrients from fertilizers especially nitrogen and phosphorus, which contribute to the eutrophication of rivers.
- The toxic effect in the food chain of certain pesticides and herbicides, which are known to concentrate in organisms and in the other environment.

Present rates of agrochemical use in the greater district of Khulna demonstrates the problem while the area of land under cultivation between 1983 to 1989 remained almost constant at about 438000 ha, during the same period fertilizer use increased from 44.95 kg/ha to 146.52 kg/ha.

Coastal and marine fisheries are affected through the food webs leading to a depletion in the fish stocks. Quantitative deterioration also reduces the nutritional value of fish. The thin layer of oil on the water surface hampers light penetration and air-sea gas interaction, affecting the multiplication of plankton food organisms. Although there has not been any systematic study assessing the impacts of pollution on mangrove forest and fisheries, it is likely that the ecosystem may become a sump for pollutants not only because they follow into shallow areas rapidly that they are exported by natural tide action. Monitoring industrial pollution and its effect upon the *Sundarbans* Reserve Forest should be considered in more detail in future integrated research programs.

Chapter –4

Floral Species of the *Sundarbans* Mangrove Forests

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4.0 Floral Species of the *Sundarbans* Mangrove Forest

The natural vegetation of the *Sundarbans* is composed of halophytic tree species commonly termed as mangrove. The floristic composition of this forest is poor in number of species which are adapted to varied degree of salinity. The major predominant tree species are Sundri and Gewa followed by a major proportion of Passur, Keora, Baen, Kankra, Dhundul, Golpatta and a few other species with undergrowth consisting of Goran and others.

Mangroves are salt tolerant ecosystem in the tropical and subtropical inter tidal region of the world. The trees are evergreen and their height may be exceed 30 m. The forests are generally flooded with brackish water during high tides. Mangrove flora is not diversified. Globally, mangrove ecosystems are thought to contain about 60 species of trees and scrubs and more than 20 additional species frequently associated with mangrove flora but not necessarily restricted to it *(Barth, 1982)*.

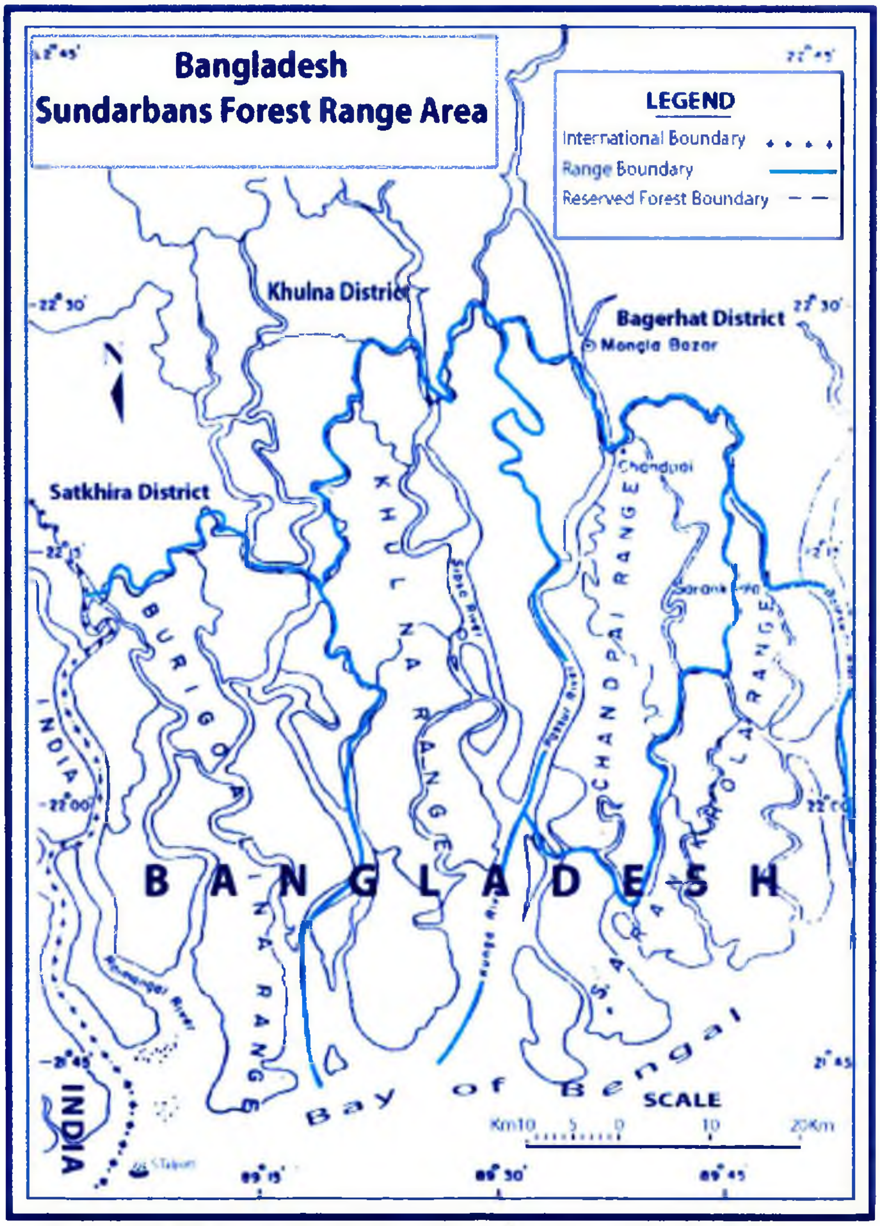
Mangroves in Bangladesh occur in the form of natural forests as well as plantation. The *Sundarbans*, the largest single-tract natural mangrove forest of the world. The *Sundarbans* is located at the southern extremity of the Ganges river delta bordering on the Bay of Bengal. The *Sundarbans* is a reserved forest and provisions of the forest act of 1927 are applicable to this area *(Appendix-2)*. The forest has been divided into four Administrative Range, Blocks and 55 compartments *(Fig- 4.5 & 4.6)*.

4.1 Different types Forest-Defines and Areas

Of the total area of the *Sundarbans*, some 3,80,340 hectares comprises classified forests and about 26,807 hectares unclassified forest. Of all the trees in this forest, 64 percent is Sundri and 36 percent is Gewa, Goran, Golpata, Keora, Dhundul and various other kinds of tree. Through there are innumerable trees in the Sundarbans, actual fruit-bearing trees rare. A full-scale survey of forest wealth was done in 1903. The survey found 334 species of trees. No full-scale survey has been conducted in recent times. However, surveys conducted by various voluntary organizations found no more than 100 species of trees. According to the survey by the *Sundarbans* study group there are 68 species of trees in the *Sundarbans* at present. The Sundri trees were the most numerous among the vegetation of the *Sundarbans*. They are seen everywhere in this forest. Other trees, especially mentionable, are *Keora, Passur, Gewa, Baen, Goran, Garjan, Golpatta, Dhundul, Kankra, Banchandan, Hijal, Bhatkathi, Amur, Hado, Shingra, Bhadal, Khalshi, Hingey,* etc.

Photograph – 6 : Typical Scenery of the Sundarbans Mangrove Forests and its Estuarine Creek

Fig- 4.01 : Location of four Ranges in Sundarbans Area



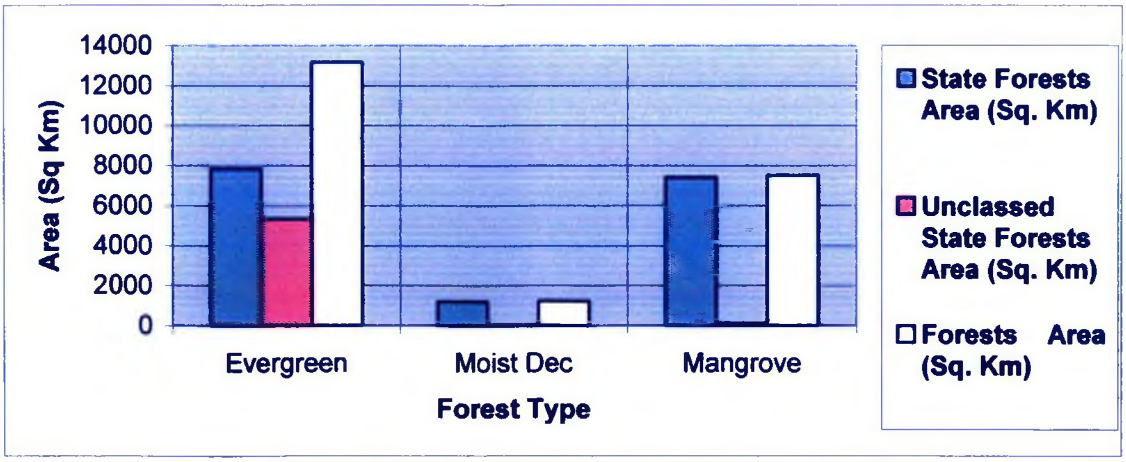
Source: Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report

Table-4.1 Area under different types of forests in Bangladesh- 1996-97

Forest Types	State Forests			Unclassed State Forests			Forests		
	Area (Sq.Km)	% of Forest	% of total Land	Area (Sq. Km)	% of Forest	% of total Land	Area (Sq.Km)	% of Forest	% of total Land
Evergreen	7820.45	35.69	5.30	5346.77	24.40	3.62	13167.22	60.09	8.92
Moist Deciduous	1209.14	5.52	.82	23.52	0.11	0.02	1232.66	5.63	0.84
Mangrove	7412.40	33.83	4.84	100.49	0.46	0.07	7512.89	34.28	5.09
Total	**16441.99**	**75.03**	**11.14**	**5470.78**	**24.97**	**3.71**	**21912.77**	**100.00**	**14.85**

Source: *Directorate of forest.*

Graph- 4.1 Different types of Forest Area in Bangladesh (1996-97)



Source: *Directorate of forest.*

The important trees are:

- **SUNDRI** ***(Heritiera fomes)***- The principal and climax species of *Sundarbans* forest. It is a gregarious evergreen tree with buttressed stem and Grey cracked bark. Sundri grows to a height of 15m to 25m (50-80 feet) according to a locality (The northern part of the *Sundarbans*). Average height throughout the forest is 10m to 15m. Sundri is dominant in the slightly saline and also the moderately saline zone and accounts for 73% of the growing stock *(Forestal-1960).* Growth of Sundri in the strongly saline zone is very slow. Sundri grows well in a well-drained soil inundated by tidal water of low degree of salinity *(Khan-1977).* The leaves are dark green. The flowers are unisexual and arranged in panicles. Sundri flowers in March- April and seed ripens in June-July *(Rahman-1982).* It falls into water, and being buoyant, it is carried by tidal water until stranded. The species seeds well and no periodicity has been observed *(Hasan and Howlader-1970).* The root system of Sundri is rather peculiar. The weight of Sundri wood is 65 lbs. Per cubic foot (1040 kg/m^3). The sapwood is pinkish-grey or buff. Heard wood is dark reddish brown. It is an extremely heavy, tough, strong, extremely hard, fine textured wood. Sundri species are used for bridge and house construction: boat, launch building; making body of buses, trucks; electric, telephone utility poles; anchor logs; flooring, paneling, scaffolding, piling, house posts, handles of tools, fuel wood for cooking and burning bricks etc.

Photograph – 7 : Sundri Trees *(Heritiera fomes)* Sundarbans

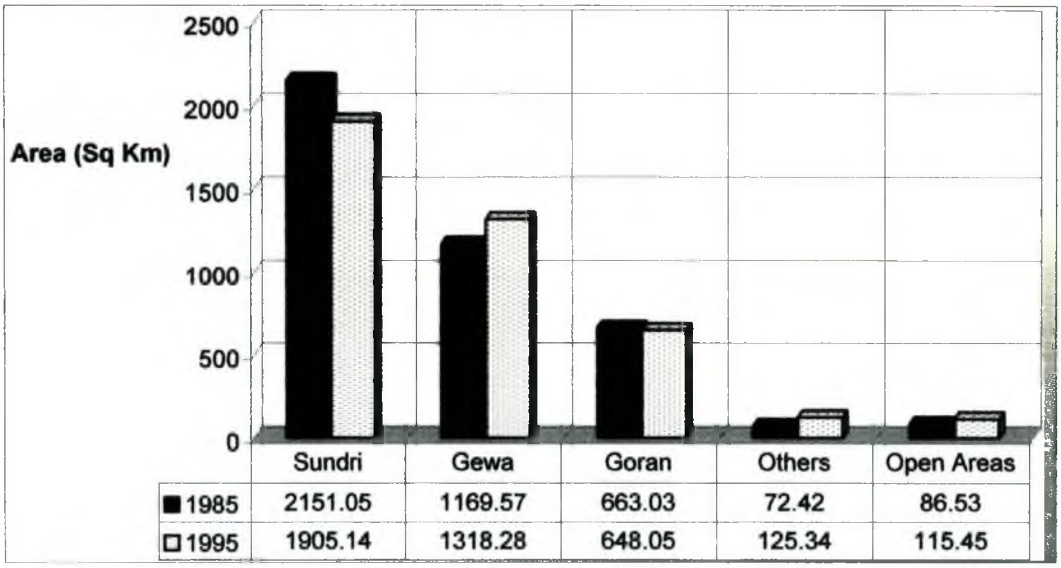
- GEWA *(Excoecaria agallocha)*- Gewa is a moderate size tree attaining a height of 10 m to 13 m. Bark is grey, smooth and covered with prominent lentils. It is fairly distributed in the moderately saline zone and is the second dominant species after Sundri in the Sundarbans and constitutes 16% of the growing stock *(forestal, 1960).* Mixed stands of Sundri & Gewa are the basic forest type throughout the forests and covers 45% of the area *(ODA-1985)*. Gewa species is used for raw materials (Newsprint, other papers, Matchsticks and boxes), firewood, cheap furniture and toys, cheap packing boxes, latex of kill fish (other countries) etc. It reaches a height of 60-70 feet (18.2m - 21.3m) in the northeastern part of *Sundarbans*. It is normally found from 30-35 feet (9.1m to 10.6m) in height depending on site quality and location. The fruit is green to dark brown, smooth, 3-lobed capsule, 0.75 cm- 1.3 cm or more in diameter. The primary root is moderately hard and thick, lateral roots are moderate in number and length. The growth rate oh Gewa is slow, particularly in saltwater areas.

Table-4.2 Summary by *Sundarbans* Mangrove dominating species in Area (Km²) & Area (%) Changes in 1985 and 1995

Dominating Species	Area (Km²)		*Area (%)*	
	1985	*1995*	*1985*	*1995*
Sundri	2151.05	1905.14	*51.9*	*46.3*
Gewa	1169.57	1318.28	*28.2*	*32.1*
Goran	663.03	648.05	*16.0*	*15.8*
Others	72.42	125.34	*1.7*	*3.0*
Open Areas	86.53	115.45	*2.1*	*2.8*
Total	**4142.59**	**4112.27**	***100.0***	***100.0***

Source: SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin Ahmad, 1997.

Graph- 4.2 Sundarbans Mangrove Species in Area Changes in 1985 and 1995



Source: SRF area, distribution and status of forest types from 1985 to 1995 - M. Runkeland Istiaq uddin ahmad, 1997.

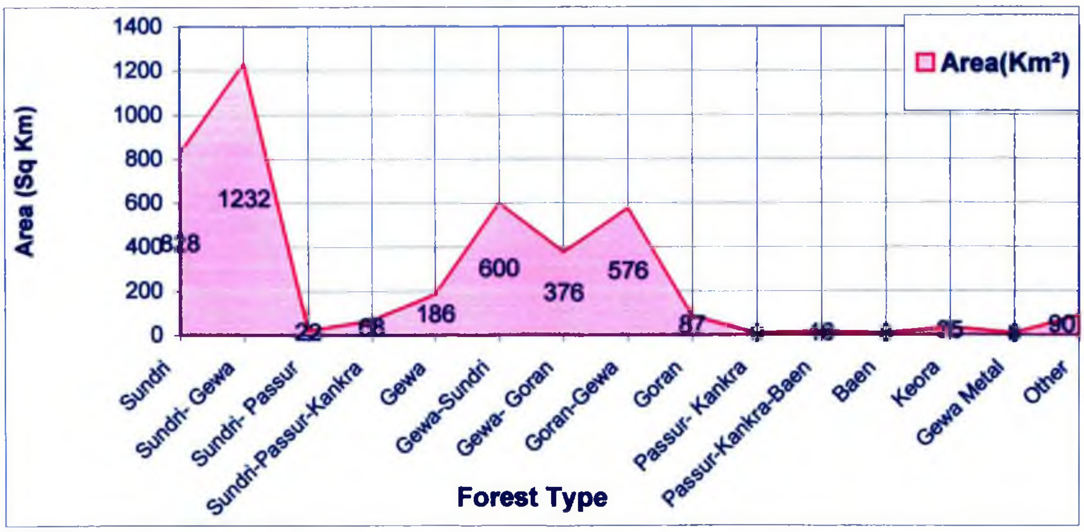
- **GORAN** ***(Ceriops decandra)***- Goran species are small evergreen trees or shrubs with coppice-like growth. Goran is found as an understudy in the central and southwestern part of the *Sundarbans*. It attains a height of 6-20 feet (1.8 m to 6.1 m). Most of the Goran species are available in the third quality forest. The leaves are decussate, clustered at the ends of the twigs, ovate to ovate oblong, entire, glabrous leathery, obtuse and a darker green above than below. The flower are bisexual. Goran is used for house posts, fencing material, tannin from bark, Charcoal of high quality, firewood for good quality and burning bricks etc.

Table-4.3 Areas of Forest Type 1985 in the *Sundarbans*

Forest Type	Area (Km^2)			*Percentage (%) of total Land*
	Production Forest	Wildlife Sanctuary	Total	
Sundri	827	1	828	*19.99%*
Sundri- Gewa	1140	93	1232	*29.74%*
Sundri- Passur	22	0	22	*0.53%*
Sundri-Passur-Kankra	68	0	68	*1.64%*
Gewa	167	19	186	*4.49%*
Gewa-Sundri	556	44	600	*14.48%*
Gewa- Goran	326	49	376	*9.08%*
Goran-Gewa	524	52	576	*13.90%*
Goran	70	17	87	*2.10%*
Passur- Kankra	9	0	9	*0.22%*
Passur-Kankra-Baen	16	0	16	*0.39%*
Baen	4	4	8	*0.19%*
Keora	26	9	35	*0.84%*
Gewa Metal	8	0	8	*0.19%*
Other	4	0	4	*0.10%*
Sub total Forest Land	**3769**	**287**	**4056**	***97.92%***
Agriculture	0	0	0	*0%*
Grass & Bare Ground	41	5	46	*1.11%*
Sandbar	31	9	40	*0.97%*
Total Land Area	**3841**	**301**	**4143**	***100.00%***

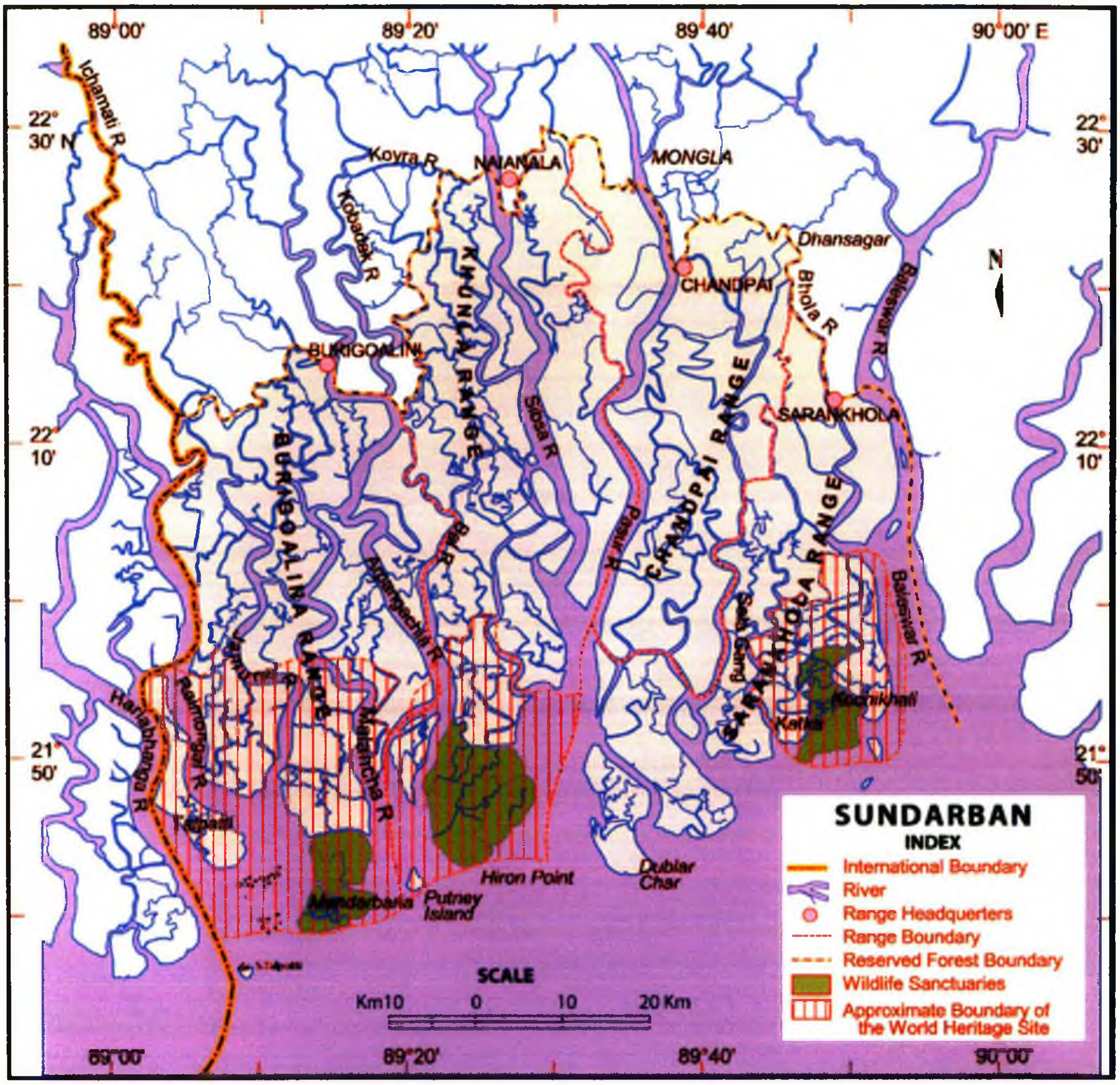
Source: *FRMP Geographic Information System derived from IRMP database as of September, 1995*

Graph-4.3 Sundarbans Forest Species Area (Sq. Km) in 1985



Source: *FRMP Geographic Information System derived from IRMP database as of September, 1995.*

Fig-4.02 Locations of three Sites of " UN World Heritage" in the *Sundarbans,* Bangladesh



Source- Modified and edited after ICUN

- **PASSUR** ***(Carapa moluccensis)-*** This is one of the principal timber trees of the *Sundarbans*. A moderate sized evergreen tree with thin grey bark, attaining height of 30-50 feet (9.1 m to 15.2 m). It is a species of moderately saltwater areas of the forests and generally found in low lying areas east of the river Arpangasia in the north tract remote from the sea surface. Passur is used for furniture, bridge construction etc. The wood is also suitable for parquet flooring, door and windows frames, shutters and boat building. The weight of the wood is 49 lbs. Per cu. ft (784 kg/ m^3).The heart wood is brownish red with darker streaks; wood is durable, heavy, strong, very heard, fined textured.

- **BAEN** ***(Avicennia officinalis)***- Baen species are trees or shrubs found on the seaward fringes of a mangrove swamp, along tidal creeks, and in the middle of the forests. Baen in the *Sundarbans* is usually 10-13 m in height but may attain greater height up to 20 m in suitable place. Baen is usually hollow and rotten. It occurs only as a scattered, isolated tree in the *Sundarbans*. Baen is used for firewood, anchor logs, leaves as fodder etc. The weight of the wood 58 lbs./cu feet (928 kg/ m^3). Wood is dark grey, hard used for planking, bears, sluices etc.

Photograph – 8 : Wildlife in the Sundarbans Mangrove Forests at Burigoalini Forest Station, Satkhira District

- **KEORA** ***(Sonneratia apetala)***- A large evergreen tree with slender drooping branches with glaucous green foliage. It attains a height of 50 feet (15.24 m) and over; Bark, black and smooth. It grows gregariously and springs up in more or less pure patches on new alluvial thrown up in form of islands or of flats in the bends of tidal rivers and estuaries. The weight of the wood is 38 lbs. Per cu. ft. (608 kg/m^3). Keora occurs in newly accreted soil in the moderate or strongly saline areas. The leaves are simple opposite, entire and leathery. The fruit is about 25 mm wide and each fruit contains numerous seeds up to even a hundred. Keora is the pioneer species in the ecological succession and therefore the principal species used for coastal afforestation Programme. The sapwood is light Grey-heart wood pinkish brown, moderately heavy, interlocked grain, fine textured. Keora is used for furniture, paneling, parts of boats, anchor logs, packing boxes etc.

- **KANKRA** ***(Bruguiera gymnorrhiza)-*** Kankra species are tall and buttressed trees. This species is found on the banks of blackish water rivers. It attains a height of 30 feet (9.1 m) to 40 feet (12.2 m). The tree is on of the largest in the mangroves and may attain a height of 35 m. The Kankra leaves are oval to elliptic-oblong, acuminate, glabrous, leathery, 8.5-9 cm wide and have obscure veins. The weight of the wood is 61 lbs. Per cft (976 kg/m³). Wood is strong, tough, extremely hard and durable. Kankra is used for heavy construction, beams, rafters, roof trusses, anchor logs, furniture, planks etc.

Photo– 9 : Golpatta *(Nypa fruticans)* on of the Important Floral Species of the Sundarbans Mangrove Forests

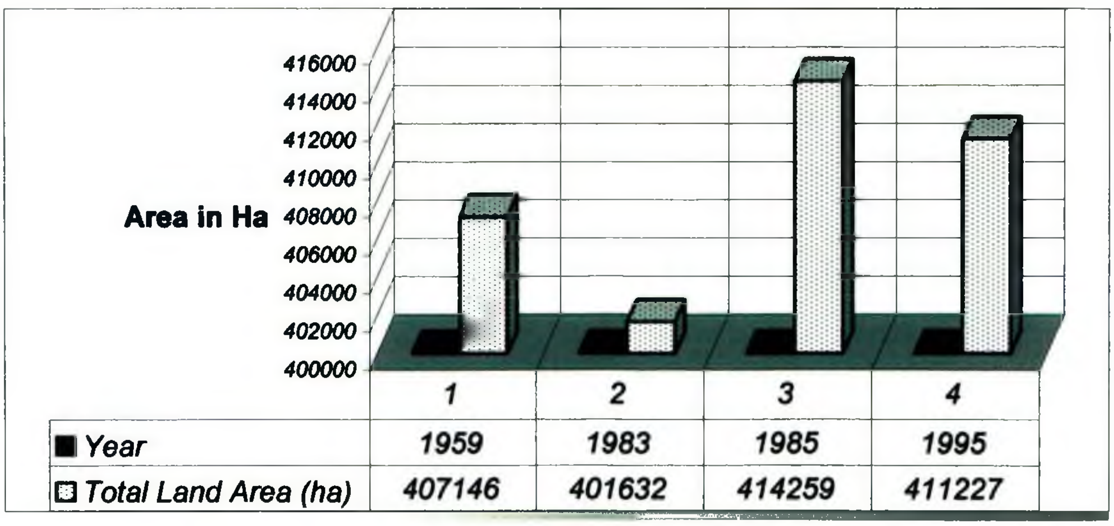
- **GOLPATTA** *(Nypa fruticans)*- Golpatta is a truckles palm with tall erect fronds and an underground stem which, is a short horizontal trunk. It has a massive, dense root system which, is better fitted to resist swift running water than most other littoral species. Golpatta generally occurs on the banks of rivers of streams and needs regular inundation. In the Sundarbans, it grows best in slightly saline and moderately saline zones; it grows on the banks of estuarine and tidal rivers and swampy localities in the interior of the forest. The leaves are 3-9m long, pinnate, green, glabrous, erect and recurred. The Golpatta is used leaves for mats, baskets, thatching houses, cigarette wrappers etc and young seeds are edible.

Table-4.4 Percentage area coverage of main Forest types 1959, 1983, 1985 & 1995 in the *Sundarbans*

Year	Forest		Non Forest		Total Land	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
1959	377612	92.75%	29534	7.25%	407146	100%
1983	395514	98.48%	6118	1.52%	401632	100%
1985	--	--	--	--	414259	100%
1995	--	--	--	--	411227	100%

Source: A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report & SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin ahmad, 1997.

Graph- 4.4 Area coverage of main Forest types 1959, 1983, 1985 & 1995 in the *Sundarbans*



Source: A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report

- **DHUNDUL** ***(Xylocarpus granatum)-*** Dhundul is a smaller size tree than Passur. This species are common on the banks of channels. The roots are superficial and often ribbon shaped with sharp edges. Dhundul species are used for pencil manufacture, making boats (upper parts), house posts, furniture etc. The fruits is used in tanning.

- **AMUR** ***(Amoora cucullata)-*** A moderate sized evergreen tree found in association with C. moluccensis mainly in low lying areas towards the north at a distance from the sea. The weight of Amur wood is 44 lbs. per cft. (704 kg/m³) red or brown in color, hard. It is used for posts (house), firewood and other purposes.

- **GARJAN** ***(Rhizophora mucronata)-*** A small to moderate sized tree, branches thick, bark fairly smooth, brown. The tree produces characteristic stilt roots. Most commonly found on outer fringes of forests where water is saline. The weight of wood is 52 lbs. Per cft (832 kg/m³). Wood red in color, hard, sometimes marked with darker bands giving quite an ornamental appearance, used as for heavy construction, tool handles and firewood. The bark is used for tanning.

- **KHLSHI** ***(Aegiceras corniculatum)-*** A large evergreen glabrous shrub or small tree common in the forests along the tidal creeks where it is frequently gregarious. Wood is hard and used only for firewood.

- **HANTAL** ***(Phoenix paludosa)-*** A common gregarious palm, found every where on or near the banks of tidal river. Height 12 feet (3.6m) to 30 feet (9.1m). The stems are used for frames of the walls local houses, fencing material, firewood and for dungaree of roofs. The leaves are used for thatching.

For timber production purposes, ODA in their inventory in 1885, mapped 14 major Forest Types on the basis of major woody species dominance and identified over 300 sub-types at scale 1:50,000. Recent evidence *(Grepin-1995; Huda-1995)* suggest that these in general remain valid and gross changes will only be determined during the FRMP systematic survey anticipated for 1996-97.

4.2 Salinity Variation of Floral Species

A saline environment is required for stable mangrove ecosystem as many species are less competitive under non-saline condition. *(Luge AE-1980)*. However hyper salinity can adversely affect mangroves in a given sites. When the salinity of surface or interstitial soil levels exceeds that prevailing in the sea where the level averages 35 ppt. This causes due to salinity and the strongly negative osmotic pressure of soil water. Salinity is also an important physio-graphical factor affecting marine and blackish water animals. Very high or low salinity will affect growth and if extreme can be lethal. According to midget (1985) the salinity growth relationships for most paneled shrimp species are as follows:

Salinity (ppt)	Growth
<5 and >40	Poor
5-15 and 30-40	Fair
15-30	Good *(Mujibur-1995)*.

The forests have been classified into three zones depending on the degree of salinity: Fresh water zone, Moderately salt water zone and salt water zone. If fresh water zone Sundri forest is of good quality with varying amount of Gewa and in moderately salt water zone there is a mixture of Gewa and Sundri with varying amounts of Goran and other species. In salt water zone the forest is closed understudy of Goran with a broken and often widely dispersed overstress of Gewa, Passur and Dhundul.

Salinity Variation of Floral Species in the *Sundarbans* are classified three types. These are-

1. **Fresh water salinity zone:** This area have 1st and 2nd class forest. Here vegetation density is very high and a lot of vegetation number. North-eastern side of the *Sundarban* are covered fresh water forest zone. This fresh water forest areas main vegetation is Sundri. Other forest are Gewa, Passur, Kankra, Golpatta etc. This fresh water salinity forest zone area is 2,87,700 acres and compartment no is 1-3, 12-15, 21-40.

2. **Moderately saline water zone:** This area have 3rd class forest. Here vegetation density is medium and medium number of vegetation. Southern part of Khulna district at *Sundarban* is covered by moderately saline water forest zone. This moderately saline water forest areas main vegetation is Sundri & Gewa. Other vegetation are Passur, Kankra, Dhundul, Keora, Jhana, Baen etc. This moderately saline water forest zone area is 4,57,870 acres and compartment no is 4-11, 17-20, 41-45.

Table-4.5 Salinity Zone With Block, Compartment, *Sundarbans* Forest Area (acre) & Percentage

Salinity Zone	Block	Compartment	Forest Area	
			(Acre)	(%)
Fresh Water	4	29,30,31,32,33,34,35,36,39,40.	135170	*13.44*
	5B	16,37,38.	46410	*4.61*
	1	1,2,13,14,21,22,23,24,25,26,27,28	147530	*14.66*
	2	3,12A,12B,15	42415	*4.22*
			371525	*36.93*
Moderately Salt Water	2	9,10,11.	60355	*6.00*
	5B	17,20.	37810	*3.76*
	3	4,5,6,7,8,45	132960	*13.21*
	5A	41.	18210	*1.81*
	6	18,19,42,43,44.	119705	*11.90*
			369040	***36.68***
Salt Water	5A	46,47	52540	*5.22*
	7	48,49,50,51.	89310	*8.88*
	8	53,54,55.	94160	*9.36*
	6	52	29485	*2.93*
			265495	***26.39***
Total			**1006060**	***100.00***

Source: *Rupantar, Sundarbans Study Group-1990 & Ak Polokey Sundarban, Asamo Helal Siddique 1st April 1998,.*

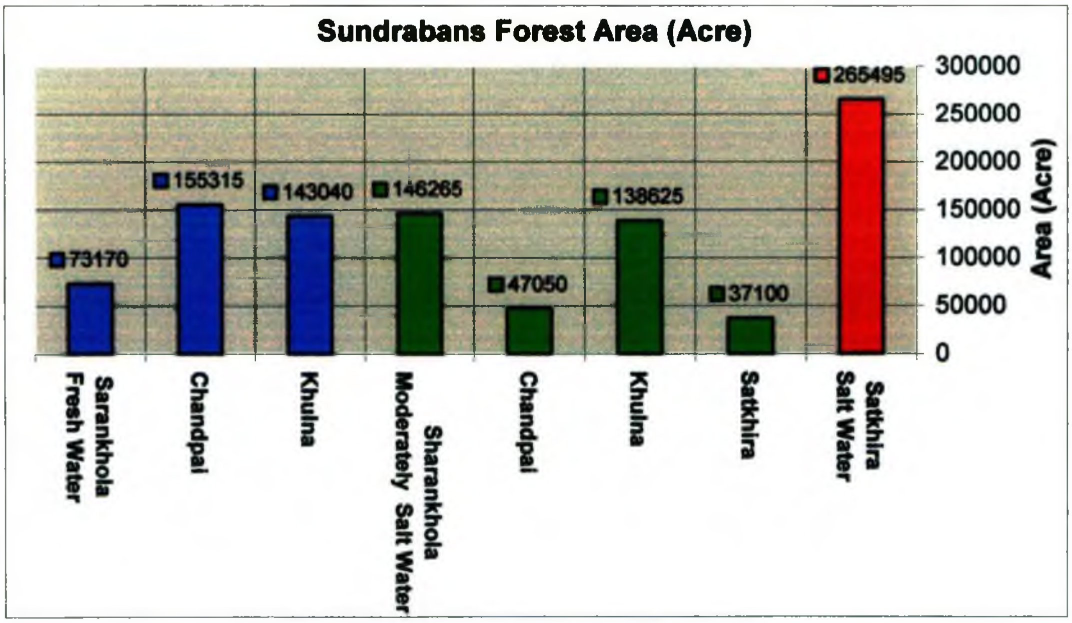
3. **Saline water zone:** This area have 4th class forest. Here vegetation density is narrow and medium number of vegetation. Southern part of Satkhira district at *Sundarban* is covered by Saline water forest zone. This Saline water forest areas main vegetation is Gewa, Goran . Other vegetation are Passur, Dhundul, Kankra etc. This saline water forest zone area is 2,65,490 acres and compartment no is 46-55.

Table-4.6 Salinity Zone With Forest Range, Compartment, Sundarbans Forest Area (acre) and Percentage

Salinity Zone	Forest Range	Compartment	Forest Area (Acre)	Forest Area (%)
Fresh Water	Sarankhola	1,2,3,12B,24.	73170	7.27%
	Chandpai	12A,13,14,15,21,22,23,25,26,27,28,29,30,31	155315	15.44%
	Khulna	16,32,33,34,35,36,37,38,39,40.	143040	14.22%
			371525	*36.93%*
Moderately Salt Water	Sarankhola	4,5,6,7,8,11,45.	146265	14.54%
	Chandpai	9,10.	47050	4.68%
	Khulna	17,18,19,20,43,44.	138625	13.78%
	Satkhira	41,42.	37100	3.69%
			369040	*36.69%*
Salt Water	Satkhira	46,47,48,49,50A,50B,51A,51B,52,53,54,55.	265495	26.39%
			265495	*26.39%*
Total			1006060	100.00%

Source: *Rupantar, Sundarbans Study Group-1990 & Ak Polokey Sundarban , Asamo Helal Siddique 1st April 1998, Khulna.*

Graph- 4.5 Salinity Zone in *Sundarbans* Forest Ranges Area (acre)



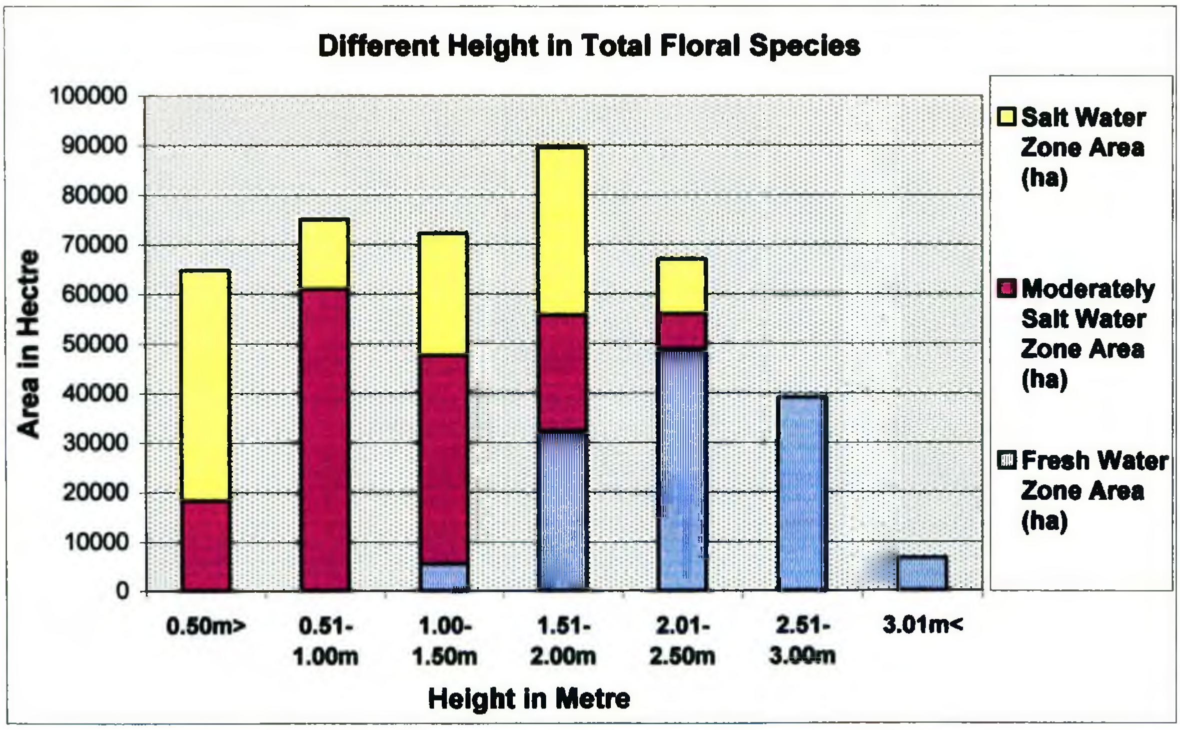
Source: *Rupantar, Sundarbans Study Group-1990 & Ak Polokey Sundarban , Asamo Helal Siddique 1st April, 1998,.*

Table- 4.7 Different Height *at Mean Sea Level in Sundarbans Mangrove Forest* and three Saline Zone in Total Floral Species in Sundarban *(hectare & percentage)*

Height mean Sea level in meter	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area of the Sundarban	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
0.50m>	–	–	18312	*4.42*	46458	*11.21*	64770	*15.63*
0.51-1.00m	–	–	61000	*14.72*	14000	*3.38*	75000	*18.10*
1.00-1.50m	5559	*1.34*	42052	*10.15*	24579	*5.93*	72190	*17.43*
1.51-2.00m	32320	*7.80*	23380	*5.64*	33830	*8.17*	89530	*21.61*
2.01-2.50m	48887	*11.80*	7092	*1.71*	11051	*2.67*	67030	*16.18*
2.51-3.00m	39060	*9.43*	–	–	–	–	39060	*9.43*
3.01m<	6720	*1.62*	–	–	–	–	6720	*1.62*
Total Area	**132546**	***31.99***	**151836**	***36.65***	**129918**	***31.36***	**414300**	***100.00***

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 4.6 Different Height at three Saline Zone by Area in Total Floral Species



Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table-4.8 *Sundarbans* Major Floral Species With different Height Variation at Mean Sea Level *(Metre)* in Area (Hectors & Percentage)

Floral Species	Height .50m> Area (ha)	Height .51-1.00m Area (ha)	Height 1.01-1.50m Area (ha)	Height 1.51-2.00m Area (ha)	Height 2.01-2.50m Area (ha)	Height 2.51-3.00m Area (ha)	Height 3.01m< Area (ha)	Total Area of the Sundarbans Area (ha)
Sundri	6524	22663	28234	41073	42613	25541	4523	171171
Gewa	26127	36210	29956	34905	19967	7233	1652	156050
Goran	29483	11505	12879	10917	2324	680	--	4445
Passur	3	25	169	784	949	2289	226	67788
Baen	4	530	135	150	163	318	8	1308
Kankra	--	--	66	618	576	1951	226	3437
Keora	925	1600	405	218	188	114	10	3460
Non Forest	1694	2467	341	845	250	934	75	6606
Total	**64770**	**75000**	**72190**	**89530**	**67030**	**39060**	**6720**	**414300**

Source- *Modified and edited after, Department of Soil Salinity, Govt. of Bangladesh & A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

4.3 Height Variation of Floral Species

The forestland areas within the Sundarbans are classified according to their productive potential into one of three site quality classes based on the mean height of the mature trees. The site quality classes are defined below along with the acre ages assigned to each:

Quality Class-l	50 ft and over	253,440 ac
Quality Class-ll	35-49 ft	231,740 ac
Quality Class-lll	25-35 ft	451,610 ac
Quality Class-lV	24 ft and below	--------------

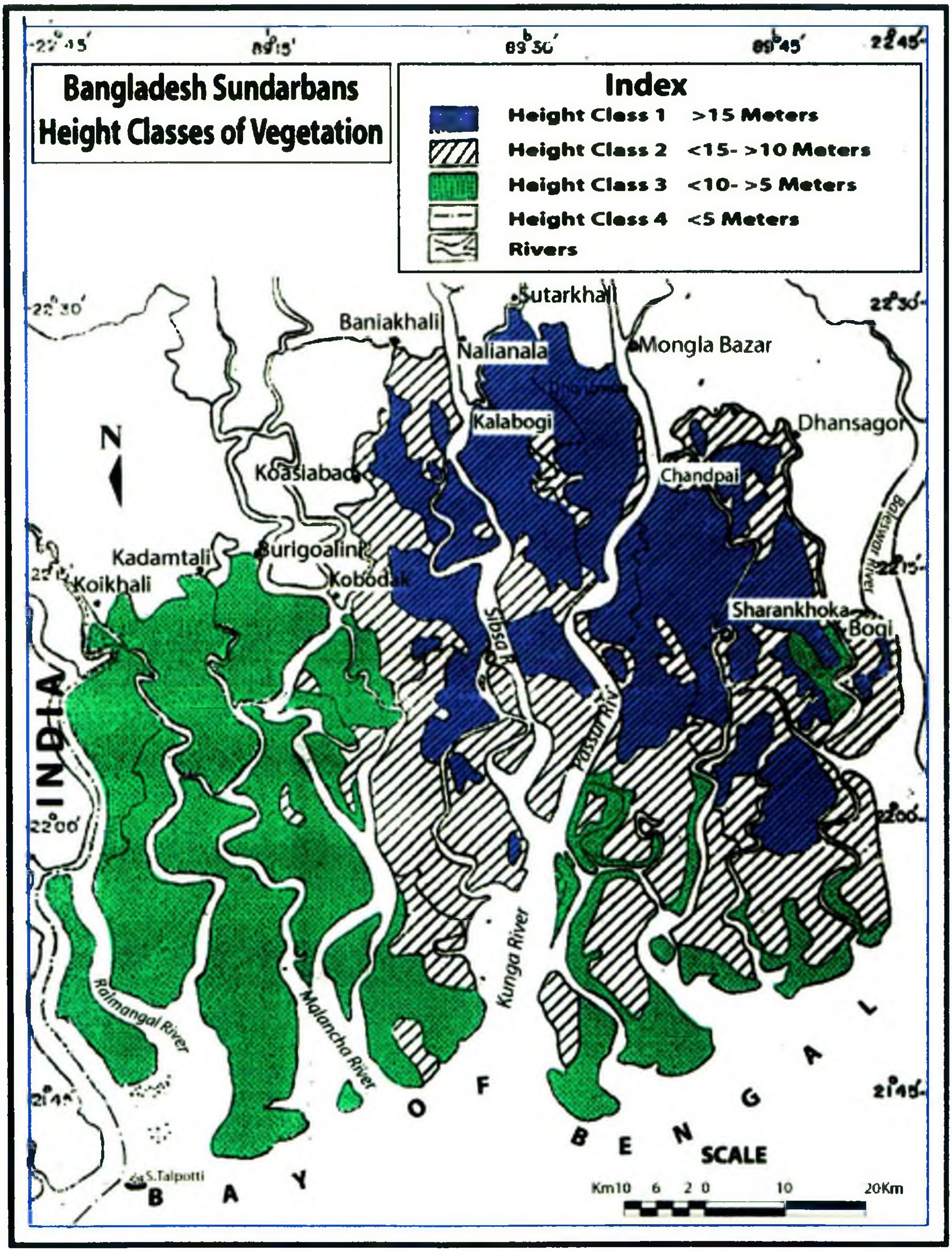
These acre ages *(special Studies Directorate, Forests, 1976)* differ significantly from those of Curtis (1933). Curtis used empirical measurement of absolute maximum height, whereas the directorate cited figures generated by photogrametric techniques, which can only determine maximum mean height.

The stand height has been described in the following height classes:

- Very low <5m
- Low 5m <10m
- Medium 10m <15m
- High >=15m

The details of the observations on height class development for the various species are given in table-4.02 for the year 1985 and 1995. For the *Sundri* dominated areas there is a slight nominal increase in the percentage of higher stands over the period from 1985 and 1995. The *Gewa* dominated areas show an obvious increase in stand height. Within the *Goran* dominated areas there is a nominal increase of the area with a height of more than 5m.

Fig- 4.03 Height classes of Vegetation in the Sundarbans observed in 1981



Source: Modified and edited after Hassan-1990, Soil Hydrology and Salinity of the Sundarbans

Table-4.9 Main Vegetation type and Height Class in 1985 and 1995

Vegetation Type	Area (in Km^2) covered by height Class											
	Height 15.00 m. and above		Height 10.00-14.99 m.		Height 5.00-9.99 m.		Height 4.99 m. & below		n. a.		Total	
	1985	1995	1985	1995	1985	1995	1985	1995	1985	1995	1985	1995
Sundri	622.12	*587.96*	199.83	*152.11*	5.99	*7.75*		*2.00*	0.51	*0.11*	828.45	*749.92*
Sundri- Gewa	92.97	*99.64*	988.34	*851.21*	151.13	*106.65*		*2.17*	0.04		1232.47	*1059.67*
Sundri- Passur	6.26	*13.12*	13.42	*7.98*	2.45	*2.95*		*0.08*			22.14	*24.13*
SundriPassurKank	48.41	*50.13*	19.34	*20.17*	0.24	*1.13*					67.99	*71.43*
Gewa			8.91	*11.34*	174.50	*187.44*		*0.28*	2.16	*0.03*	185.56	*199.09*
Gewa-Sundri	0.12	*0.15*	86.58	*344.87*	512.86	*408.38*		*3.64*	0.17		599.73	*757.04*
Gewa- Goran			4.58	*4.20*	371.14	*341.72*	.21	*0.12*			375.93	*346.04*
Gewa metal					8.36	*8.46*		*7.65*			8.36	*16.11*
Goran					0.35	*61.43*		*1.49*	86.71	*19.77*	87.06	*82.69*
Goran-Gewa		*0.16*	9.10	*0.92*	563.97	*559.71*	2.72	*4.57*	0.19		575.97	*565.36*
Passur- Kankra		*0.99*		*0.51*		*1.15*		*0.20*	9.40		9.40	*2.84*
Passur-Kankra-Baen		*7.39*		*17.03*		*0.08*			16.14	*0.67*	16.14	*25.16*
Baen		*9.36*		*0.67*		*0.38*			8.28	*1.89*	8.28	*12.30*
Keora		*70.12*		*11.89*		*0.48*		*0.09*	35.09	*0.29*	35.09	*82.87*
Tree Plantation		*0.81*		*1.24*		*0.03*		*0.09*	3.51		3.51	*2.17*
Agriculture									0.16		0.16	
Grass & Bare Ground									46.14	*69.31*	46.14	*69.31*
Sandbar									40.24	*46.14*	40.24	*46.14*
Total Forest	**769.88**	**839.82**	**1330.1**	**1424.1**	**1790.9**	**1687.7**	**2.93**	**22.36**	**248.7**	**138.2**	**4142.59**	**4112.27**
Total (%)	**18.6**	**20.4**	**32.1**	**34.6**	**43.2**	**41.0**	**0.1**	**0.5**	**6.0**	**3.4**	**100.0**	**100.0**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

4.4 Tidal Borne of Floral Species

Tidal regime is an important regulator of mangrove development. The greater tidal range, the greater vertical range available for mangrove communities (*Hutchings and Saenger, 1987*). Tidal regime exerts control on transport of oxygen to the mangrove root systems, physical exchange of soil water solution with the overlying mass of water, tidal flushing and vertical motion of groundwater table that transports detritus nutrients to the mangrove root zone *(Lugo and Shedaker-1974).*

The rivers of the region are tidal. Tides are semi-diurnal and the average time difference 12 hours 25 minutes. Average tidal amplitudes vary, the mean tidal height being about 4 meters. The height amplitudes are recorded in June-August, The lowest amplitudes are recorded in December-February. River flow and tidal currents play major roles in creating the environmental conditions in the estuaries. The net flow is seaward however, the direction of flow being reversed twice daily according to tidal cycle *(Hussain and Karim-1994).*

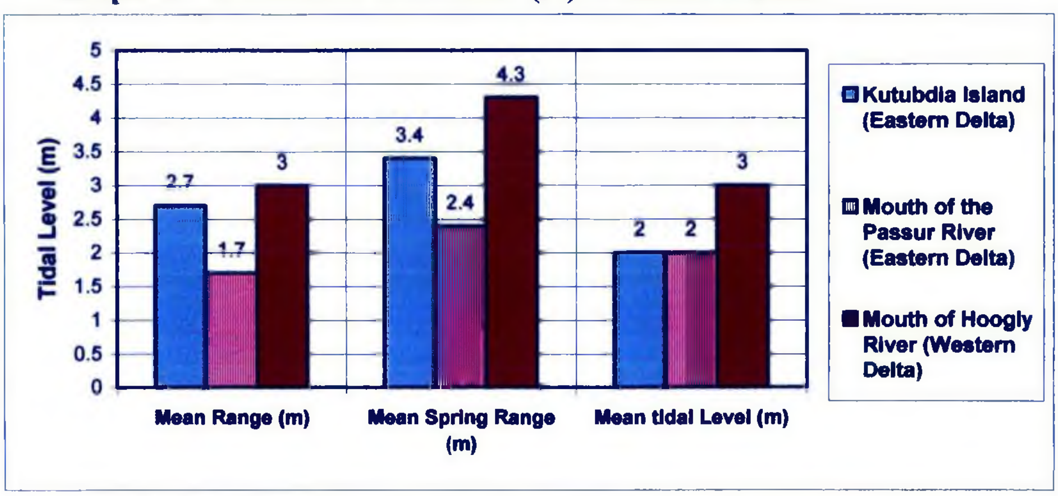
The high tide is sort in duration, lasting two to three hours, while the ebb tide flows for eight or nine hours of the 12 hour tidal cycle. Tidal flooding reaches the height level during the wet season and lowest during the dry season in February-March. Tidal flooding cyclones and monsoon floods also contribute to rise of water level in the rivers. Coincidence of high spring tides with cyclones produce what is known as 'king tides' inundating vast areas of Sundarbans forest *(Hussain and Karim-1994).*

Table-4.10 Characteristics of tides in the Sundarbans

	Mean Range (m)	Mean Spring Range (m)	Mean tidal Level (m)
Kutubdia Island (Eastern Delta)	2.7	3.4	2.0
Mouth of the Passur River (Eastern Delta)	1.7	2.4	2.0
Mouth of Hoogly River (Western Delta)	3.0	4.3	3.0

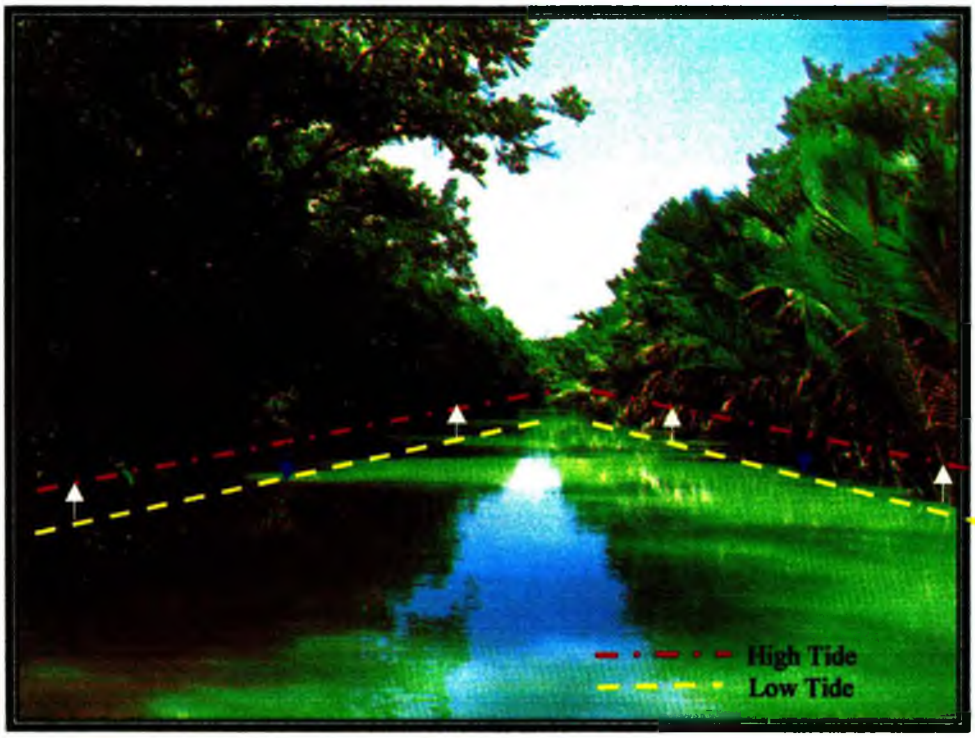
***Source:** Bangladesh Water Development Board (1977) as quoted by Scidensticker and Hai (1983).*

Graph-4.7 Sundarbans tidal levels (m) in different Areas



***Source:** Bangladesh Water Development Board (1977) as quoted by Scidensticker and Hai (1983).*

Photo – 10 : Tidal Influxes (levels high and low) Marks in the Forests



4.5 Soil Variation of Floral Species

Macnae (1968) reported the resistance in salinity level of some of the mangrove species Sadda Baen (*Avicennia marina*) and Kirpa (*Lumnitzera racemosa*) can grow in soil salinity of 90%, Goran (*Ceriops decandra*) in soil salinity of 60% and Garjan (*Rhizophora mucronata*) in soil salinity of 55%. Sonneratia apetala and S. Griffith preferably grow on the river sides and seaward fringes, adapt best is nearly normal salinity. Sonneratia caseolaris can only grow at the salinity level below 10%. Bruguiera spp. Prefer the salinity level below 25% such. B. parvi flora, B. sexangula and Kankra *(B. gymnorrhiza)* prefer 20%, 10% and 25% of salinity respectively. That most of the mangrove species are well developed and clustered on well drained edges of the tidal creeks, Gullies, Rivers and channels.

Hasan, et. al. (1988) classified soils having <2.0 mhos of electrical conductivity as non saline, 2.0-4.0 m. mhos of electrical conductivity as slightly saline and >4.0 mhos of electrical conductivity as moderately saline.

Table-4.11 Data on dry Season the Ganges tidal Floodplain ***(Sundarbans and its surrounding)*** **soils of Bangladesh**

Location			Name of the Soil Series	General Soil Type					Sub Soil Texture				Drainage
Compartment/ Village	Range/ Thana	District		Calcareous Alluvium	Calcareous Brown Floodplain Soils	Gray Floodplain Soils	Acid Sulphate Soils	Calcareous Dark Gray Floodplain Soils	Silt Loam	Silty Clay	Silty Clay Loam	Clay	
Com-55	Kadamtala Range	Satkhira	RAMGATI	✓					✓				Poor
Com-38	Nalianala Range		AJOA		✓						✓		Poor
Com-23	Chandpai Range		RAMGATI		✓				✓				Poor
Com-6	Sarankhola Range		BAJOA	✓							✓		Poor
Dhumghat	Shamnagar	Satkhira	KAMALKATI				✓					✓	Poor
Baranpara	Baitaghata	Khulna	BARISAL			✓				✓			Poor
Bajoa	Dacope	Khulna	DACOPE					✓			✓		Poor
Khejurbaria	Morrelgonj	Bagerhat	JHALAKATI					✓			✓		Poor
Maserkhaterpar	Patharghata	Barguna	JHALAKATI			✓					✓		Poor

Source: *Coastal Saline soils and their management in Bangladesh – Z. Karim, S.M.Saheed, A.B.M.Salauddin, M K.Alam, BARC, Firmgate, Dhaka, Jan-1982, The City Press, Dhaka.*

Table-4.12 Data on dry Season Salinity of the Ganges tidal Floodplain ***(Sundarbans and its surrounding)*** **soils of Bangladesh**

Location			Salinity Ec (mhos/cm)/Salt contents (PPM)			Salinity class			
Compartment /Village	Range /Thana	District	Top Soil	Sub Soil	Substratum	Highly S.	Saline	Moderate	Slightly S.
Com-55	Kadamtala Range	Satkhira	56.0/-	19.0/-	22.0/-	✓			
Com-38	Nalianala Range		22.0/-	10.5/-	12.0/-	✓			
Com-23	Chandpai Range		8.0/-	7.5/-	9.0/-		✓		
Com-6	Sarankhola Range		10.5/-	8.5/-	12.5/-		✓		
Dhumghat	Shamnagar	Satkhira	8.5/3735	4.5/1651	8.2/3557		✓		
Baranpara	Baitaghata	Khulna	2.3/1032	2.8/1306	8.6/7619				✓
Bajoa	Dacope	Khulna	3.2/1484	1.5/647	6.0/2151				✓
Khejurbaria	Morrelgonj	Bagerhat	3.0/1164	0.7/273	1.1/369				✓
Maserkhaterpar	Patharghata	Barguna	7.4/1923	3.0/632	4.0/912			✓	

Source: *Coastal Saline soils and their management in Bangladesh – Z. Karim, S.M.Saheed, A.B.M.Salauddin, M.K.Alam, BARC, Firmgate, Dhaka, Jan-1982, The City Press, Dhaka.*

Photograph – 11 : Support Roots of the Local Mangrove Forests in Sundarbans

4.6 Ecological Succession

Bangladesh has on of the largest mangrove ecosystems in the world. The Sundarbans, an enormous tract of mangrove forests, is a dynamic, fragile, complex ecosystem in delicate balance with the factors of soil water and environment. On newly formed lands, flooded by every tide, Keora is usually the first tree species that comes up, following by Baen and Golpatta. As the ground level rises by accretion, and the land then is only occasionally flooded by tide, Sundri makes its appearance. Sundri for the Sundarbans is the climax species. The succession is mainly influenced by the changes that take place in the soil.

Griffith (1933), observed two types of successional stages, one initiating from (a) Sand dunes and the second from (b) saline swamp. More recently, Nasker and Guha Bakshi (1987) found the following successional phase from swampy mangrove to dry evergreen forest along with the associated species in each phase:

Phase- ① Swampy mangrove or inter tidal mangrove zone.

Phase- ② Tidal mangrove (Ridge forest) zone.

Phase- ③ True mangrove zone.

Phase- ④ Non littoral zone.

Phase- ⑤ Xyrophytic non-mangrove zone and dry evergreen forest. In this final stage the tree of Acacia sp. Calotropis sp. Casuarina and prosopis sp. are dominated *(Mujibur-1995).*

Table- 4.13 Different Types of Plant in Varieties Forest Species of Sundarbans Mangrove Forest

Type of plant	Vernacular Name				
Tree	Baen	Kankra	Gewa	Sundri	Passur
	Bon lichu	Keora			
Small Tree	Dhalchaka	Amur	Sadda Baen	Kumb, Kumba	Khalisha, Khalshi
	Dagor	Ban Jam,	Bharal, Bhaela	Bon Bokul	Serpoli, Setpoli
	Gura, Gural	Kirpa, Kripa	Narikili	Karanja, Karanj	Batla, Batul
	Choyt barai	Choyla, Ora	Jhao, Nonajhao	Dhundul	Jam
Different Tree	Jir	Gab	Garjan, Jhanna		
Shrub	Lota Sundri	Goran	Shingra	Bhola	Serpoli, Setpoli
	Khalisha, Khalshi				
Scandent Shrub, Armed Shrub	Sitka, Sitki	Achet	Bon notoy	Sundri Lota	Chanda Katta
	Kutum Katta				
Grass	Kucha, Kusha	Nol Gash	Nol Khagra	Dhanshi	
Climber	Gila Lota,	Abetaa	Agusha	Doyal	Khali Lota
	Bowali Lota	Golgoti Lota	Jermani Lota	Chanda Lota	
Palm *(Different)*	Golpatta	Hantal			
Fern	Deki Lota	Hoda, Hodo,	Tiger Fern		
Herb	Hargoza	Bon Gash			
Others	Shamu Lota	Porgassa	Kewa Katta		

Source: *Claffey and Sandom (1985).*

4.7 Sundarbans Reserve Forest Plant Communities

In the past attempts have been made to ascribe one or two species dominants to represent community types and efforts were made to link these to variations in salinity and ground elevation and to define some successional types but with little true quantitative indication of relative frequency *(IUCN-1994)*. Since there were no composite data on water depth, salinity concentration, duration and distribution, point data only, and no comprehensive elevation data were available, description of the plant communities must be taken as generalizations only. The vegetation associations and their quantitative spatial distribution in the *Sundarbans* Reserve Forests will only emerge with improved hydrological data elevation mapping at levels of resolution compatible with needs of ecological site facet analysis.

Forestal (1960) and Chaffey et. al.(1985) showed that many plant communities can be identified in *Sundarbans* among which the following groups were established.

1. Heritiera- Excoecana-Xylocarpus community group.
2. Heritiera-Xylocarpus-Bruguira community group.
3. Excoecana- Heritiera-Ceriops community group.
4. Heritiera community group.
5. Excoecana community group.
6. Ceriops community group.
7. Sonneratia community group.

Forest types for production forestry however are a different matter since the concern here is to assess individual commercial species dominance in terms relevant to timber production, stems per unit area, volume, height, incremental growth. According site class and absolute distribution of commercial species rather than plant associations are key criteria. At present the *Sundarbans* Reserved Forest provides a strong and stable natural bastion for the settled hinterland against the impact of storms and tidal surges *(IRMP-1998)*.

Chapter -5

Influence of Morphological changes on Floral Species

Chapter -5
Influence of Morphological changes on Floral Species

5.1 Relief Features

Mangrove forests in their natural condition are extremely resilient to fluctuations in mean sea level. Mangroves have coped with sea level changes during the past 10,000 years, which suggests that they can survive rates of sea level rise or fall up to 10 to 15 mm/year. In general future rates of sea level rise, which are predicted to be a maximum of 10 mm/year, are thought unlikely to endanger mangrove forest ecosystems *(woodroffe-1990).*

However, the considerable natural resilience of mangrove forests to sea-level rise is seriously compromised in Bangladesh by two factors.

First, the possible future land ward migration of the *Sundarban* as sea level rises, is likely to be initiated by land downers and farmers who will not wish to see their land reverting to mangrove.

Second, the resilience of the *Sundarban* ecosystem depends on its health and therefore, its ability to withstand the stresses imposed by climate change and sea level rise.

With or without land ward migration of the *Sundarban*, future climate change and sea level rise may modify the composition and location of mangrove species. Such modifications will be controlled by the relative changes in sea level and the impute of fresh water as they affect the areas of the *Sundarbans* characterized by fresh water, moderately salt-water and salt-water species. Sundri and other mangrove species are presently affected by increasing salinity levels thought to be due to combination of natural causes and water abstraction at the Farakka Barrage.

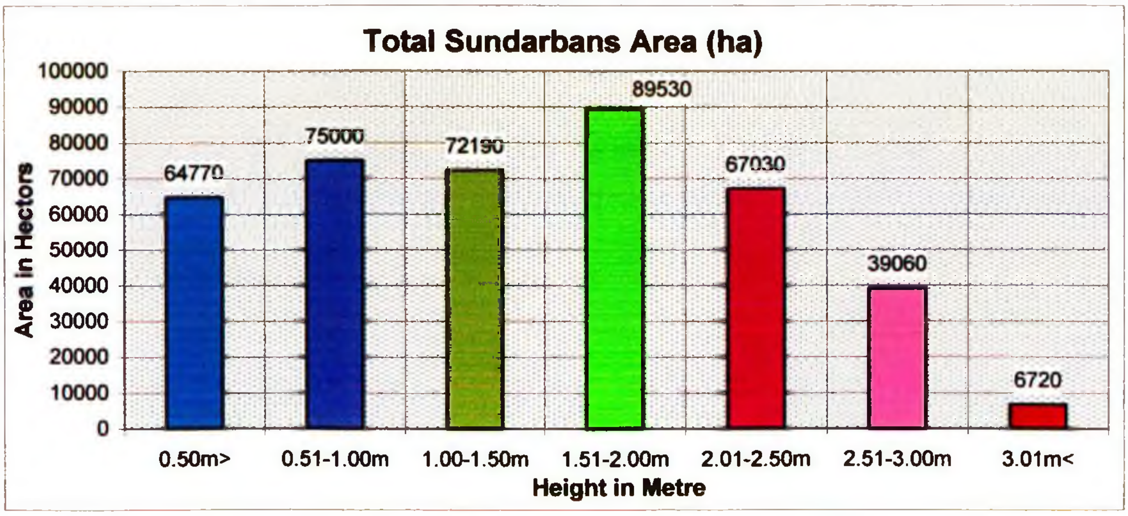
The polders in the west coastal zone were built to increase agricultural productivity by isolating land from rivers, the majority of which are saline in the southwest. The polders generally only receive rainwater, except in some land ward areas where river water is non-saline and can be used for supplementary irrigation. Excess freshwater is drained out through sluices at low tide. Polder are particularly

Table- 5.1 Height at mean Sea level in meter with Compartment (*Different Saline one*), & Total Sundarban Forest Area *(Hectors)* & Percentage

Height in meter from Mean Sea Level	Compartment			Total Area	
	Fresh Water Zone	Moderately Salt W. Z.	Salt Water Z.	Area (ha)	%
0.50m>	—	44,45,56	49,53,54,55	64770	*15.63*
0.51-1.00m	—	6,7,8,9,18,43,44,45	51,52,53	75000	*18.10*
1.00-1.50m	3	4,5,9,11,17,18,19	48,50,51,52	72190	*17.43*
1.51-2.00m	1,2,14,15,16,38	10,19,20,42	46,47,50,52	89530	*21.61*
2.01-2.50m	22,23,24,29,33,34,36,37,39,40	41	46	67030	*16.18*
2.51-3.00m	25,26,28,30,31,32,33,35,36	—	—	39060	*9.43*
3.01m<	27,28,31,32	—	—	6720	*1.62*
Total Area (ha) (%)	**132546** *(31.99%)*	**151836** ***(36.65%)***	**129918** ***(31.36%)***	**414300**	***100.00***

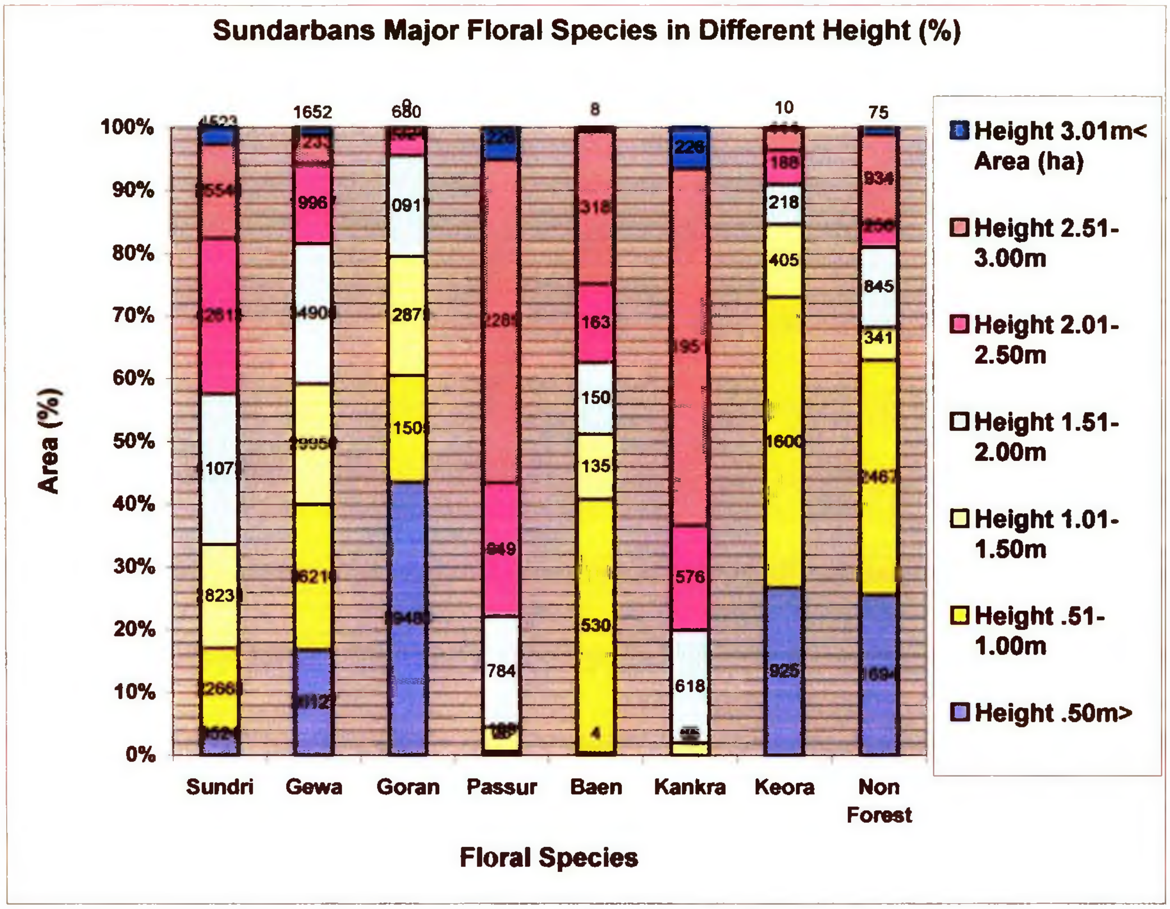
Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 5.1 Height in Meter by Total Sundarbans Forest Area (Hectors)



Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph-5.2 Sundarban Major Floral Species With different Height Variation *(Percentage)*



***Source:** A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

sensitive to two factors that may be affected by future climate changes and sea level rise: changes in the land ward boundary and seasonal distribution of saline water and changes to low tide levels. Enhanced rainfall in all seasons would directly increase the supply of freshwater to the polders. The configuration and depth of rivers in the southwest could be altered in the future due to changes in the volumes of freshwater and tidal waters from rainfall increases and sea level rise, respectably.

5.2 Changing in the Land formation in Floral Species by Tide Wave and Current

Tides are very long waves that are caused by either periodic or a periodic action of certain forces. If the tide- producing forces. If the tide producing forces are of astronomical origin, such as the periodic gravitational attraction of the sun and moon, tides as known as astronomical tides.

Spring tides are those of greatest amplitude which are produced by the combined forces of the sun and moon at the time of the new and full moons. i.e. when the sun, moon and earth in time.

Neap tides are those of least amplitude which are developed when the moon is the first or third quarter. i.e. 90° always from the sun.

Semi-diurnal tides in the Bay of Bengal are semi-diurnal i.e. two high tides and two low tides occur in about every 24 hours 50 minutes *(Israil-1994).*

The *Sundarbans* are of recent origin. Today's the *Sundarbans* was under the sea water and the estuarine islands of the swamp-forest represent the outcome of specific phase of the delta building activity by the network of the Ganges system. The process incorporates periodic contact between the Riverine and marine sediments, moving from two opposite directions. Which ultimately has created favorable situation for rapid estuarine depositions, resulting in the emergence of coastal land block at or near the sea-level separated from each other by numerous off-shoots or creeks of the distributaries of the Ganges system. The numerous cross-channels owe their extend to the lateral spill effect produced by the marine (*Tide Wave and Currents*) and fluvial forces.

5.3 Process of Erosion, Deposition and Transportation and Changing in *Sundarban*

Erosion is the process by which soil particles are detached from the soil surface. Transportation is the process of moving these detached soil particles to another location. Deposition is the process of dropping these soil particles at a new location. Erosion, transportation and deposition are natural process, which have sculptured many of the topographic features of the present landscape. These processes have been functioning throughout geologic history. This type of normal or geologic, erosion is generally beneficial, because it proceeds at a rate slower than that at which new soil is being formed and it helps to keep the soil in a productive condition. This natural balance is easily destroyed by a change in the density or character of the native cover, which may result in accelerated erosion.

Erosion is of two general types sheet erosion and channel erosion. The latter includes rill and gully erosion as well as stream-channel erosion. The relative quantities of soil movement resulting from sheet and channel erosion are highly variable. Generally, sheet erosion is higher in areas of high rainfall, while channel erosion is greater in more arid regions. The rates of erosion depend upon the length and degree of slope rainfall intensity, type and density of vegetal cover and the inherent erodibility of the soil.

Table-5.2 Study of the movement of Osohalines of different concentration *(micro-mhos)*

Passes through situation by different location	December, 1993	January, 1994	February, 1994	March, 1994	May, 1994
Sahiker Khal	6000			20000	
Gewa khali	6000		12500	20000	20000
Charak khali	7500			20000	
Patkusta	7500		12500	20000	
Kadamtala		10000		15000	
Burigoalini		10000		15000	
Khaikhali		10000		20000	
Chunkari		10000		20000	
Kobadak p.o.		10000		20000	
Kalagachia		10000		15000	
Dhangamari			7500	10000	12500
Chandpai			7500	10000	10000
Sutakhali			7500	12500	15000
Nalian			10000	12500	20000
Chaliabogi			10000	12500	12500
Kalabogi			10000		15000
Baniakhali			12500	12500	20000
Kakraharani			15000		
Dhansagar				7500	
Kassiabad				15000	20000
Koyra				20000	
Harani				20000	
Munshiganj				20000	
Khasitana				20000	

Source: *Integrated Resource Development of the SRF of Bangladesh, Muhammad Ismail, UNDP/FAO. June-1994, Khulna.*

Soil particles may be detached either by the impact of raindrops falling on the bare soil or by water flowing over the soil surface. Raindrops striking the bare soil act like miniature bombs to break up soil aggregates and spatter soil particles as much as 0.60m. into the air. This spattering effect of rainfall is evidence by soil deposits on foliage.

The velocity of flowing water is an important factor since the kinetic energy varies as the square of the velocity. Slope is an important factor since varies as the square root of the slope. Water will flow down 40% slope with twice the velocity of that on 10 percent slope. Vegetation acts to reduce erosion by slowing down the velocity of water flowing over the soil surface. Since erosion is caused by overland flow, the effect of vegetation in reducing and retarding overland flow also operate to reduce erosion *(Israil-1994).*

5.4 Coastal Area of the *Sundarbans* and Associate Floral Species

"The *Sundarban*"—The largest single compact single mangrove forest of the world lies in Bangladesh on of the south western part of greater Khulna, it covers nearly 60,000 ha. The southeastern part, the Chakaria *Sundarban* in Cox's Bazar has a mangrove forest area of 7,500 ha. The coastal belt among Barisal, Patuakhali, Noakhali and Chittagong districts has about 0.11 m ha mangrove forest. All these mangrove and their ecosystems are extremely rich in aquatic flora and fauna particularly with varieties of shrimps and flnishes.

As mangrove forests play of a significant role in coastal ecology as well as in spawning and nursing of most of the marine biomes, their destruction causes coastal erosion, changes in the pattern of sedimentation, shore line configuration and vulnerable to natural calamities.

The coastal process are influenced by a combination of interaction factors, comprising parameters, micro and macro-tidal cycles and long shore currents found in the coastal tract of Sundarbans which vary during the pre-monsoon, monsoon and post monsoon periods. They are also affected by tropical cyclones. Field experiments have shown that the coastline is changing in the reclaimed areas due to high rates of cliff erosion.

Biological factors play a significant role in the coastal evolution of the *Sundarbans*. A variety of habitats are found in the *Sundarbans* including beaches, estuaries, mangrove swamps, tidal flats and tidal creeks, coastal dunes and back dunes areas. The mangrove vegetation of the inter tidal environment assists in the creation of new landmass and the inter tidal vegetation has an important role in swamp morphology. The activities of mangrove fauna in inter tidal mudflats, mangrove substrate and beaches, develop micro-morphological features which are very significant for trapping sediments and mangrove seeds. The morphology and evolution of the eolian dunes are controlled by an abundance of xerophytic vegetation. Creeper and grassy vegetation play an important role in stabilizing sand dunes *(Bhattacharya and Chowdhery-1985).*

Photograph- 12 :Fishing- Boats in the Off-shore Coastal waters in the Bay of Bengal along the Sundarbans

** **Quantitative Analysis**

"Statistical tests for investigating the relationship between the land-levels and Floral species in Sundarbans.

Table – 5.03 shows the result of the Chi-square test (X^2 - test) applied to reveal the relationship between the topographic elevations (viz. – land-heights) and prevalence of mangrove species (viz.- Sundri tree) in the study areas. The final result essentially exhibits and negative correlation. In other words, the X^2 - test equation stands at 6 degree of freedom with 0.05% level of significance and an ultimate X^2 tabulated value of 12.592 reading which clearly indicates that in respect of land level (viz.- height) and occurrence of the *Sundri*-trees these exists no relationship.

Table–5.03 Does some ranges of different height variation at mean sea level (meter) on the total Sundarbans Mangrove forest area and Sundri Species in the Sundarbans area.

Height variation of mean sea level in meter	Total Sundarbans Area (Km^2)	Sundri Species Area (Km^2) (O)	Expected value (E) = $\frac{HeightwiseSundarbansArea \times TotalSundrispecies}{TotalSundarbansSpeciesArea}$
0.50m>	*648*	65	$\frac{648 \times 1712}{4143} = 310$
0.51-1.00m	*750*	227	$\frac{750 \times 1712}{4143} = 310$
1.00-1.50m	*722*	282	$\frac{722 \times 1712}{4143} = 298$
1.51-2.00m	895	411	$\frac{895 \times 1712}{4143} = 370$
2.01-2.50m	670	426	$\frac{670 \times 1712}{4143} = 277$
2.51-3.00 m	391	255	$\frac{391 \times 1712}{4143} = 162$
3.01 m <	67	45	$\frac{67 \times 1712}{4143} = 28$
	Total Area =4143	$\sum(O) = 1712$	$\sum(E) = 1712$

Here, O = Observed Value
E = Expected Value

We Know, $$X^2 = \sum\left[\frac{(O-E)^2}{E}\right]$$

$$=\left(\frac{(65-267)^2}{267}+\frac{(227-310)^2}{310}+\frac{(282-298)^2}{298}+\frac{(411-370)^2}{370}+\frac{(428-277)^2}{277}+\frac{(255-162)^2}{162}+\frac{(45-28)^2}{28}\right)$$

$$= (147.31 + 22.22 + 0.86 + 4.54 + 80.15 + 53.39 + 10.32)$$

$$= 318.79$$

H_0 (Null Hypothesis) – There is no relation to different height from mean sea level with Sundri species at total Sundarbans Mangrove forest area.

H_A (Alternative Hypothesis) - There is relationship to different height from mean sea level with Sundri species at total Sundarbans Mangrove forest area.

df (degrees of freedom) = N — 1= 7 — 1 = 6

df = 6 and 0.05% level of significance

X^2 tabulated value = 12.592.

Comments

Statistical examinations viz. Chi Square (X^2) test (Hypothesis test) has been conducted understood the role of height in meter of total Sundarbans Mangrove forest area and Sundri Species at Sundarbans . The test reveals negative relationship in the occurrence of said species in selected Sundri species which show that the-

X^2 calculated value > X^2 tabulated value. So null hypothesis is rejected. According to height in meter at mean sea level is not relation to growing the Sundri species at Sundarbans. Species are difference in density of species, height distribution of vegetation in Sundarbans, Geo-morphological & soil condition, hydrological condition, environmental impact and other process.

**** Quantitative Analysis**

"Statistical tests for investigating the relationship between the land-levels and Floral species (*Goran*) in Sundarbans.

Table – 5.04 shows the result of the Chi-square test (X^2 - test) applied to reveal the relationship between the topographic elevations (viz. – land-heights) and prevalence of mangrove species (viz.- Goran tree) in the study areas. The final result essentially exhibits and negative correlation. In other words, the X^2 - test equation stands at 6 degree of freedom with 0.05% level of significance and an ultimate X^2 tabulated value of 12.592 reading which clearly indicates that in respect of land level (viz.- height) and occurrence of the Goran-trees these exists no relationship.

Table –5.04 Findout weather the surface land area in (Sq. km) has any impact on the Goran species in (sq. km) regeneration in the seven height variation of mean sea level at Sundarbans Mangrove forest.

Height variation of mean sea level in meter	Total Sundarbans Area (Km^2)	Goran Species Area (Km^2) (O)	Expected value (E) = $\frac{HeightwiseSundarbansArea \times TotalGoranspecies}{TotalSundarbansSpeciesArea}$
0.50m>	*648*	*295*	$\frac{648 \times 678}{4143} = 106$
0.51-1.00m	*750*	115	$\frac{750 \times 678}{4143} = 123$
1.00-1.50m	*722*	129	$\frac{722 \times 678}{4143} = 118$
1.51-2.00m	895	109	$\frac{895 \times 678}{4143} = 146$
2.01-2.50m	670	*29*	$\frac{670 \times 678}{4143} = 110$
2.51-3.00 m	391	7	$\frac{391 \times 678}{4143} = 64$
3.01 m <	67	0	$\frac{67 \times 678}{4143} = 11$
	Total Area =4143	$\sum(O) = 678$	$\sum(E) = 678$

Here, O = Observed Value
E = Expected Value

We Know,

$$X^2 = \sum\left[\frac{(O-E)^2}{E}\right]$$

$$=\left(\frac{(295-106)^2}{106}+\frac{(115-123)^2}{123}+\frac{(129-118)^2}{118}+\frac{(109-146)^2}{146}+\frac{(23-110)^2}{110}+\frac{(7-64)^2}{64}+\frac{(0-11)^2}{11}\right)$$

$$=(336.99 + 0.52 + 1.03 + 9.38 + 68.81 + 50.77 + 11.00)$$

$$= 478.50$$

H_0 (Null Hypothesis) – There is no relation to different height from mean sea level with Goran species at total Sundarbans Mangrove forest area.

H_A (Alternative Hypothesis) - There is relationship to different height from mean sea level with Goran species at total Sundarbans Mangrove forest area.

df (degrees of freedom) = N — 1= 7 — 1 = 6

df = 6 and 0.05% level of significance

X^2 tabulated value = 12.592.

Comments

Statistical examinations viz. Chi Square (X^2) test (Hypothesis test) has been conducted understood the role of height in meter of total Sundarbans Mangrove forest area and Goran Species at Sundarbans . The test reveals negative relationship in the occurence of said species in selected Goran species which show that the-

X^2 calculated value > X^2 tabulated value. So null hypothesis is rejected. According to height in meter at mean sea level is not relation to growing the Goran species at Sundarbans. Species are difference in density of species, height distribution of vegetation in Sundarbans, Geo-morphological & soil condition, hydrological condition, environmental impact and other process.

5.5 Height Variation of Land level and Effect on Floral Species

The mangrove forests of the *Sundarbans*, in their natural condition, are extremely resilient to fluctuations in mean sea level. However, over-exploitation of forest resources is decreasing their natural resilience, leaving the forests increasing susceptible to possible climate and sea level changes will be modifications to the forest from human use. The pressure on forest resources will increase as the coastal population expands and if unsustainable forest use continuos. The future of the forest under such multiple threats is uncertain. Sustainable management is vital to protect the forest resource now and to better the affects of climate changes and sea level rise in the future.

Table-5.5 Height Variation from means Sea level Rise *(meter)* With Saline Zone by Floral Species in the Sundarbans Mangrove Forest at Bangladesh.

Height mean Sea level in meter	Fresh Water Zone		Moderately Salt W.Z		Salt Water Zone		Total Sundarban	
	Major Species	*Minor Species*	Major Species	*Minor Species*	Major Species	*Minor Species*	Major Species	*Minor Species*
0.50m>	--	--	Gewa Sundri	*Goran Keora Passur*	Goran Gewa	*Keora Sundri G.Metal Baen*	Goran Gewa Sundri	*Keora G. Metal Baen Passur*
0.51-1.00m	--	--	Gewa Sundri Goran	*Keora Baen Passur*	Goran Gewa	*Sundri*	Gewa Sundri Goran	*Keora Baen Passur*
1.01-1.50m	Sundri Gewa	*Passur*	Sundri Gewa	*Goran Keora Passur Kankra Baen*	Goran Gewa	*Sundri Baen Keora G. metal*	Gewa Sundri Goran	*Keora Passur Baen Kankra G.metal*
1.51-2.00m	Sundri Gewa	*Keora*	Sundri Gewa Goran	*Passur Kankra Keora*	Gewa Passur Sundri	*Passur Kankra Baen Keora*	Sundri Gewa Goran	*Passur Kankra Keora Baen*
2.01-2.50m	Sundri Gewa	*Passur Keora Kankra Baen*	Gewa Sundri Goran	*Baen Passur*	Gewa Sundri Goran	*Passur Kankra Baen Keora*	Sundri Gewa Goran	*Passur Kankra Keora Baen*
2.51-3.00m	Sundri Gewa Passur Kankra	*Goran Baen Keora*	--	--	--	--	Sundri Gewa Passur Kankra	*Goran Baen Keora*
3.01m<	Sundri Gewa	*Passur Kankra Keora Baen*	--	--	--	--	Sundri Gewa	*Passur Kankra Keora Baen*

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Height variation of the Floral Species in the *Sundarban* are following classifications-

1. **First class forest:** Its vegetation average height is above 15.3 meters. Like-fresh water forest in Bagerhat districts.

2. **Second class forest:** Its vegetation average height is above 10.7-15.3 meters. Like-fresh & moderately fresh water forest in Bagerhat districts.

3. **Third class forest:** Its vegetation average height is above 6.1-10.7 meters. Like- moderately fresh water forest in Khulna districts.

4. **Forth class forest:** Its vegetation average height is below 6.1 meters. Like- highly saline water forest in the south western part at Satkhira districts.

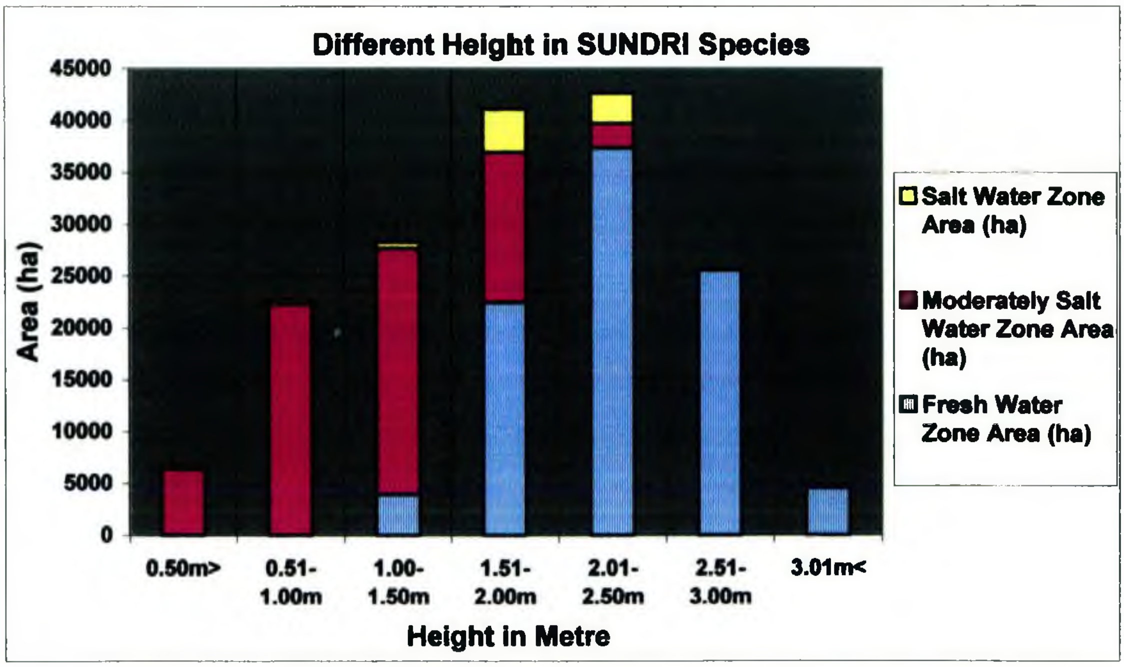
Photo- 13 : Elevated Land-surface in the *Sundarbans* Mangrove Forests Exhibit the Geomorphic Variations in the Ecosystem

Table- 5.6 Different Height *at Mean Sea Level in Sundarbans Mangrove Forest* and three Saline Zone in Sundri Species *(hectare & percentage)*

Height mean Sea level in M.	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area of the Sundarban	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
0.50m>	–	–	6393	*3.73%*	131	*0.08%*	6524	*3.81%*
0.51-1.00m	–	–	22261	*13.01%*	402	*0.23%*	22663	*13.24%*
1.00-1.50m	3951	*2.31%*	23704	*13.85%*	579	*0.34%*	25234	*16.49%*
1.51-2.00m	22409	*13.09%*	14456	*8.45%*	4208	*2.46%*	41073	*24.00%*
2.01-2.50m	37310	*21.80%*	2354	*1.38%*	2949	*1.72%*	42613	*24.90%*
2.51-3.00m	25541	*14.92%*	–	–	–	–	25541	*14.92%*
3.01m<	4523	*2.64%*	–	–	–	–	4523	*2.64%*
Total Area	**93734**	***54.76%***	**69168**	***40.41%***	**8269**	***4.83%***	**171171**	***100.00%***

***Source:** Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985,- Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 5.3 Different Height at three Saline Zone by Area in Sundri Species



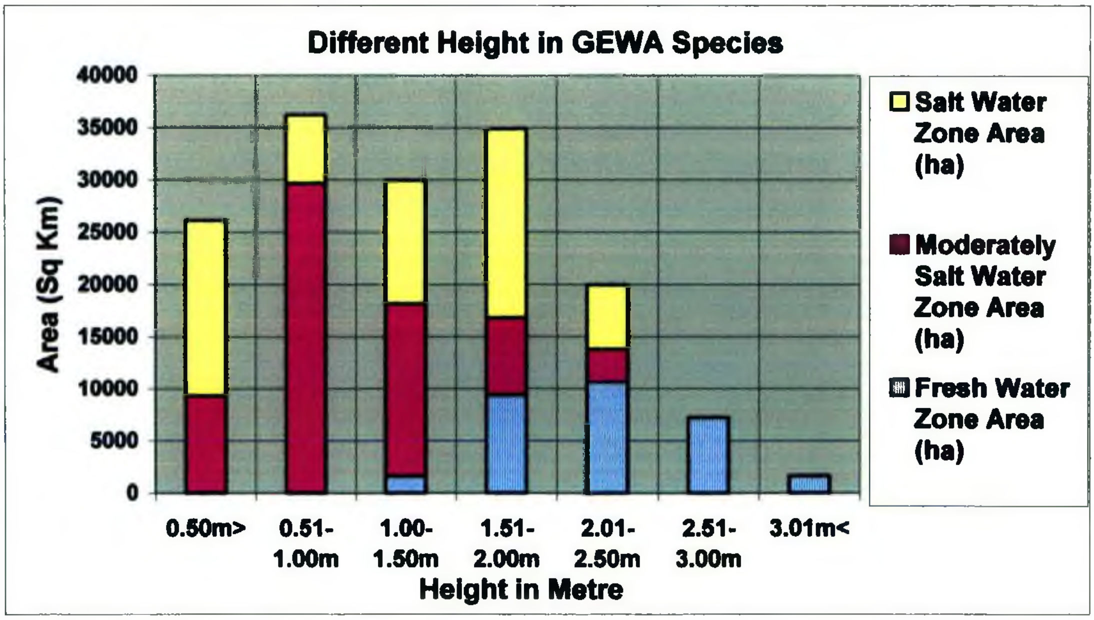
***Source:** Modified and edited after, A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 5.7 Different Height *at Mean Sea Level in Sundarbans Mangrove Forest* and three Saline Zone in Gewa Species *(hectare & percentage)*

Height mean Sea level in meter	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area of the Sundarban	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
0.50m>	–	–	9294	*5.96*	16833	*10.79*	26127	*23.20*
0.51-1.00m	–	–	29677	*19.02*	6533	*4.19*	36210	*23.20*
1.00-1.50m	1604	*1.03*	16578	*10.62*	11774	*7.55*	29956	*19.20*
1.51-2.00m	9346	*5.99*	7454	*4.78*	18105	*11.60*	34905	*22.37*
2.01-2.50m	10633	*6.81*	3183	*2.04*	6151	*3.94*	19967	*12.80*
2.51-3.00m	7233	*4.63*	–	–	–	–	7235	*4.63*
3.01m<	1650	*1.06*	–	–	–	–	1650	*1.06*
Total Area	**30466**	***19.52***	**66186**	***42.41***	**59396**	***38.06***	**156050**	***100.00***

Source: *Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 5.4 Different Height at three Saline Zone by Area in Gewa Species



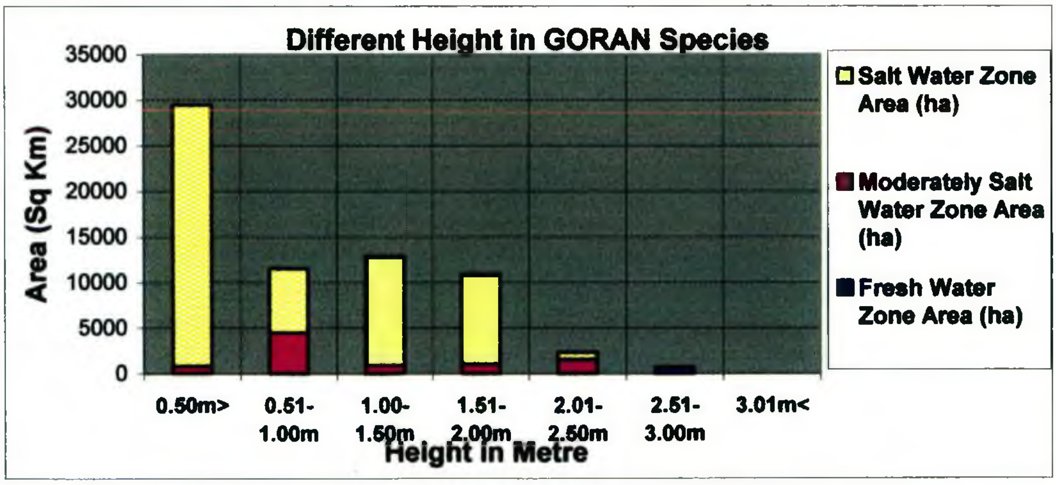
Source: *Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table- 5.8 Different Height *at Mean Sea Level in Sundarbans Mangrove Forest* and three Saline Zone in Goran Species *(hectare & percentage)*

Height mean Sea level in m	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone		Total Area of the Sundarban	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
0.50m>	–	–	799	*1.18*	28684	*42.31*	29483	*43.49*
0.51-1.00m	–	–	4477	*6.60*	7028	*10.37*	11505	*16.97*
1.00-1.50m	–	–	905	*1.34*	11974	*17.66*	12879	*19.00*
1.51-2.00m	–	–	1007	*1.49*	9910	*14.62*	10917	*16.14*
2.01-2.50m	2	–	1532	*2.26*	790	*1.16*	2324	*3.43*
2.51-3.00m	680	*1.00*	–	–	–	–	680	*1.00*
3.01m<	–	–	–	–	–	–	–	–
Total Area	**682**	***1.00***	**8720**	***12.87***	**58386**	***86.13***	**67788**	***100.00***

Source: *Modified and edited after A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Graph- 5.5 Different Height at three Saline Zone by Area in Goran Species



Source: *Modified and edited after, A Forest inventory of the Sundarbans,Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

5.6 Role of Vegetation on Shaping up of the Floral Species in the *Sundarbans*

The whole area of the *Sundarbans* are basically a cluster of numerous deltaic islands separated each from others by innumerable tidal creeks, estuaries and streams of different size and shape. This forest is a virgin savanah.

Photograph- 14 : Numerous Breath-roots of Sundarbans that are Regularly Inundated and Sub-merged by the Tidal waters Reveal the Geomorphic as well as the Hydrological Situation of the Mangroves

The mangrove vegetation is characteristically present in river estuarine and sea coasts where the land meets the sea the major components of mangrove swamps are the salt tolerant trees. ***Prain (1903),*** divided the entire *Sundarbans* into three zones namely-

(a). Southern coastal strip and south western part consisting of mangrove species.

(b). Central zones of Heritiera fomes and

(c). Northern eastern part of the savanah type vegetation.

*According to him, the present species found near different locations were as follows-

(a) Fresh mud banks of rivers -Keora *(Sonneratia apetala)*.

(b) Banks of larger rivers -Kankra *(Bruguiera gymnorhiza)*, Goran *(Ceriops Spp)*, Gura *(Rhizophora and Kandelia Spp)*.

(c) Banks of smaller canals -Kalshi *(Aegiceras corniculatum)*, Chandra katta *(Dalbargia spinosa)*, Dhundul *(Xylocarpas granatum)*, & Ora *(Sonneratia caseolaris)* etc.

(d) Banks of narrow channels - Khalshi *(Aegiceras)*, and Lota Sundri *(Brownlowia)*.

(e) Banks of narrowest channels -Golpatta *(Nypa fruiticans)* *(Mujibur, 1995)*.

Human interactions, i.e., endorsements in the deltaic mangrove forests, reclamation of the swamps and newly formed islands, massive deforestation in the Sundarbans and coastal afforestation activities, construction of embankments, cross-dams, roads and withdrawal of the Ganges water have been significantly affecting the morphological setting of the delta in Sundarbans Mangrove forest area.

Chapter -6

Influence of Hydrological Situation on Floral Species in Sundarbans

Chapter -6

Influence of Hydrological Situation on Floral Species in Sundarbans

6.1 Tidal Influence

The Gangetic delta in general is a tide-dominated delta system in which the normal pro-gradation of the delta is modified by incoming and outgoing tidal currents *(Thom-1982)*. Tidal patterns along the coast of the Bay of Bengal are variable both in amplitude and time of onset. The mean tidal range at the mouth of the Hoogly river in India is 9.7 ft and the mean spring tide range is 14.1 ft. To the east at the mouth of the Passur rivers, the respective ranges are 5.7 ft and 7.9 ft. During the June to October monsoon season, there is a general rise in sea level of approximately 3 ft in the northern part of the Bay of Bengal. The elevated stage level causes flooding by saline water in the western Sundarbans and flooding by freshwater in the eastern *Sundarbans*. It is during this time that silting occurs.

About one third of the forest consists of water bodies in the forms of rivers, channels and tidal creeks. The forest land is highly influenced by tidal interactions because of the presence of these water bodies. The forest receives freshwater and sediment from a number of distributaries of the Ganges.

Tidal swamp forests comprise the following mangrove forest types:

a) Mangrove scrub forest.
b) Mangrove forest.
c) Blackish water mixed forest (Heriteira).
d) Salt water mixed forest.
e) Palm swamp.

The rivers have a micro-tidal range, the major characteristics of which are summarized in table-6.1 for three stations along the Passur rivers. The tides are semidiurnal & mixed with a well marked diurnal in equality, which is greatest at the spring tides in June-August.

Table-6.1 Range of tidal height above CD in three reference stations inside Sundarbans

	Name of the Stations		
	Mongla	**Sundrikata**	**Hiron point**
Mean Sea level	2.141	2.434	1.744
Mean High water of neap tides	2.784	2.993	2.206
Low level of high water of spring tide	2.928	3.200	2.400
Maximum level of high water of sparing tide during dry season	3.190	3.440	2.700
Mean high water of spring tides	3.468	3.665	2.887
Maximum level of high water of spring tide during monsoon	3.680	4.070	3.300

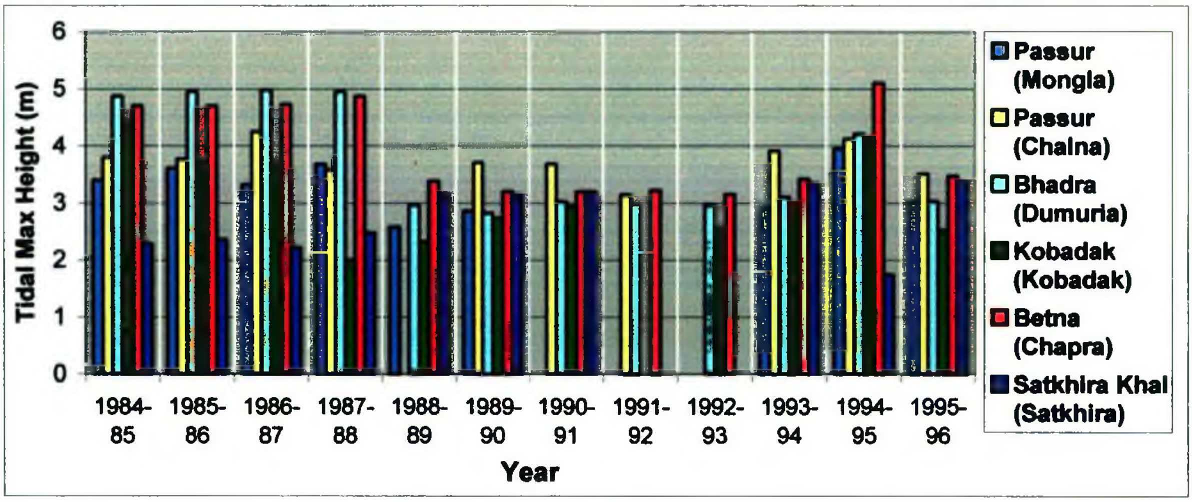
Source: *Integrated Resource Development of the SRF, Bangladesh, UNDP/FAO-1995.*

Table-6.2 Tidal Variation (Tidal Range) at Selected River Station (in meter) in difference year

Tidal Range	**Passur** *(Khulna)*		**Passur** ***(Mongla)***		**Passur** ***(Chalna)***		**Bhadra** ***(Dumuria)***		**Kobadak** ***(Kobadak)***		**Betna** ***(Chapra)***		**Satkhira Khal** ***(Satkhira)***	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1984-85	2.89	1.12	3.40	1.48	3.80	1.50	4.87	1.95	4.44	1.57	4.70	2.00	2.28	.69
1985-86	2.90	1.02	3.61	1.37	3.77	1.67	4.95	1.70	3.76	1.53	4.70	1.60	2.36	.48
1986-87	2.77	.70	3.32	1.30	4.25	1.25	4.98	1.65	3.72	1.61	4.73	1.50	2.22	.59
1987-88	2.85	.80	3.68	1.35	3.58	1.80	4.95	1.60	2.00	1.00	4.87	1.74	2.48	.56
1988-89	3.41	.54	2.58	1.40	---	---	2.96	2.19	2.32	1.92	3.38	2.32	3.15	.11
1989-90	2.95	.59	2.86	1.41	3.71	1.12	2.82	2.13	2.73	1.92	3.20	2.14	3.16	.13
1990-91	3.15	.74	---	---	3.68	1.27	3.02	1.98	2.93	1.84	3.20	2.40	3.20	.35
1991-92	3.15	.72	---	---	3.14	1.26	2.98	1.76	---	---	3.22	2.20	---	---
1992-93	3.10	.72	---	---	---	---	2.97	1.56	2.56	2.30	3.15	2.40	---	---
1993-94	3.25	.63	2.90	1.40	3.91	1.43	3.10	1.14	3.00	2.04	3.42	.62	3.35	.81
1994-95	3.17	1.30	3.95	1.60	4.12	1.54	4.21	1.92	4.17	1.53	5.10	1.91	1.74	.27
1995-96	3.15	.82	3.03	1.45	3.51	0.00	3.03	2.00	2.53	0.00	3.47	2.07	3.37	1.32

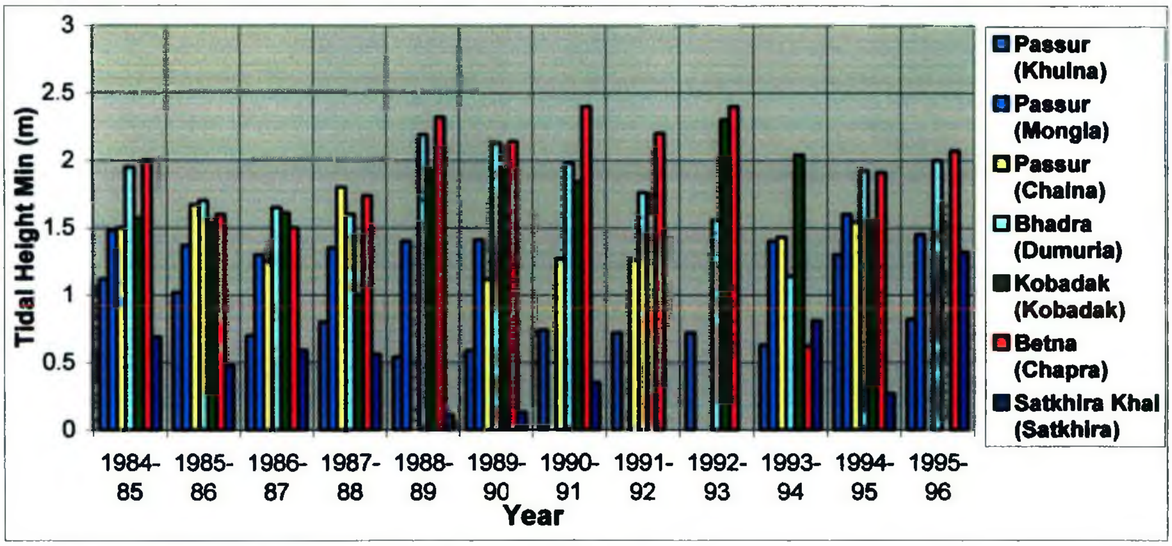
Source: *Bangladesh water development Board.*

Graph-6.1 Maximum Tidal Variation (Tidal Range) at Selected River Station (in meter) in difference Year



Source: Bangladesh water development Board.

Graph-6.2 Minimum Tidal Variation (Tidal Range) at Selected River Station (in meter) in difference year



Source: Bangladesh water development Board.

6.2 Surface water quality

P^{H} in river waters varies little. *Karim (1988)* reported the pH range from about neutral to salinity alkaline (6.5-8). The surface water flow in the rivers of the *Sundarbans* area mainly comes from the Ganges-Padma. The other sources of surface water flow in the rivers are the runoff forms the local catchment areas. Salinity is the amount of dissolved salts present in water. In tropical estuaries salinity is an integrated index of mixing process of rainfall, freshwater surface and subsurface flow, tidal water and evaporation.

Eleven sites distributed throughout Sundarbans. It was revealed that salinity pattern shows both seasonal and spatial variation. Due to the existence of numerous cross connecting channels linking catchment areas and estuaries intermixing pattern of river salinity is very complex. Rise and fall of salinity in all the rivers do not take place simultaneously. All these studies indicated the dependence of river salinity of *Sundarbans* on the hydrological regime and catchment characteristics in the upstream.

Data on long term salinity from all the rivers passing through the *Sundarbans* is lacking. Table-6.3 shows the salinity change in rivers along some locations lying at the northern boundary of *Sundarbans*. Present salinity increase has been attributed to the decrease of freshwater in the rivers due to commissioning of Farakka Barrage and abstraction of surface water for irrigation and other human uses.

Table-6.3 Shows the height monthly salinity *(micromhos)* of river at selected stations near *Sundarbans* during dry period

Stations	**Water year**	**Monthly salinity *(micromhos}***		
		March	**April**	**May**
Khulna	1968	340	450	1000
	1976	7200	13500	13600
Mongla	1968	7500	NA	NA
	1976	12500	16500	18500
Nalianala	1968	3850	6000	7000
	1976	6800	9000	9300
Morelganj	1968	345	600	400
	1976	4750	6500	8500

Source: *Khan, 1983.*

Variation in chloride of river water is in good agreement with conductivity variation both seasonal and spatial. *(Karim-1988).*

Data on the mineral contents of river water from the *Sundarbans* is very scanty *karim (1988)* observed that contents of Na, K and Ca content is lower in the eastern rivers than the western part. Lowering of the mineral content of the river water was marked in the post monsoon season due to dilatory effect of rainwater. All these indicate that fresh water discharge pushes the salinity limit down wards and play a dominant role in nutrient mixing pattern in the rivers of *Sundarbans*. Through rainfall is almost uniformly distributed throughout the area, on seasonal basis higher salinity in the western region is due to low discharge of freshwater than the rivers in the east.

6.3 Surface Runoff Flow and Infiltration Capacity

The flow from the Ganges comes through Gorai which, splits from the Ganges 16 km down stream of the Hardinge bridge. Gorai than Passur through Kushtia and Faridpur districts and divides at Bardia in the Jessore district. One portion *(16% of the flow)* meets the Haringhata *(Baleswar)* estuary system as Madhumati River and the other *(85% of the Flow)* passes through Halifax cut to join the Passur system as Nabaganga River. The minimum daily flow has decreased to 43% while the maximum daily flow *(peak flow)* has increased to 112%.

Table-6.4 Mean monthly of river water *(in cumecs)* in two locations representing east and west part of the catchment of *Sundarbans* rivers

Locality	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kamarkhali	343	164	107	177	181	525	2684	4415	3944	2007	1024	621
Jikargacha	6	5	4	4	4	9	16	21	25	22	13	18

Source: *BWDB. Based on series 1964-1989 excluding pre-Farakka period.*

Table-6.4 shows the mean monthly flow of surface water in two stations at the upper catchment of *Sundarbans*. The rivers of eastern part of *Sundarbans* are linked with the flow from Kamarkhali and the rivers of the western part are linked with the flow at Jikargacha a respective station for the western area. The rivers in the eastern part receive more freshwater flow than the rivers in the western part of the forest.

Mean monthly available stream flow varies from 190 m^3/sec in March to 7650 m^3/sec in august. Cross border flow from India through the *Matabhanga river* varies from 1.7 m^3/sec in April to 124 m^3/sec in September. Significantly sources during the driest month, March, are the Gorai river (57%) a distributary of the Ganges, The Ganges – Kobadak intakes (27%) and the Mathabanga river (16%).

- Depending on the changing pattern of hydrological regime particularly the availability of freshwater flow, Karim 1994 divided the *Sundarbans* at present into 3 broad subsystems:

  1. **Western subsystem:** This area represents western part of Aura Sibsa and east of Raimangal. The area is connected with upper moribund part of Kobadak Betna rivers system. This area has lost connections with the Ganges long ago and does not receive any surface water flow from upstream excepting the local runoff water from the catchment areas of this river system.

  2. **Central subsystem:** This area represents east of Aura Sibsa and west of the Passur river. The area is connected with the Ganges through the Gorai river. The catchment areas of this subsystem have been extensively plodder resulting sedimentation in the *Sundarbans* forest area downstream. The forest plants particularly Sundri in this area also suffering from intense mortality due to top-dying.

  3. **Eastern subsystem:** The area east of the Passur river and west of the Baleswar river represents this subsystem. This area receives freshwater from the Ganges through Gorai-Madhumati and from the lower Meghna. At present the area supports the luxuriant forests remaining in the *Sundarbans.*

6.4 River Discharge, Flow and Velocity

Upland discharge has a very significant influence on salinity penetration. Due to little or no upland discharge during the dry season, March-April, tidal water may invade for inland bringing saline water. The simulation of a 50 cumecs water discharge at Farakka Barrage during the dry season shows that the effect on the forest would be negligible. Simulation of the past Farraka situation with a 200 cumec discharge during the dry season show a winder change in water salinity inside the forest. However this do not explain totally the degradation of the forest in the center north. Running the model further is necessary to understand the hydrology of this area and its effect on long term salinity level *(Grepin-1995).*

The Ganges is directly responsible for flushing Khulna region and distributes its water to the Rupsha-Passur and other small rivers in this region mostly through the Gorai-Madhumati. Hence, any withdrawal of Ganges water at Farakka and upstream in Indian will be pushed further inward in the Khulna region. At Hardinge bridge where the minimum discharge was 1770 m/sec on the 30th March, 1975; only 21 days before Farakka operation, it dropped down to only 436 m/sec 26th March, 1989.

Table-6.5 Inventory of Water Level, Discharge and Salinity Data

SL No	Location	River Name	DataType			Gauge Type					Source	1994					1995		
			Water Level	Discharge	Salinity	Self Recording conductivity/Tem/Press Cell	Self Recording Press Cell	Automatic Water Level Gauge	Manual Water Level Gauge	Salinity Sample		August	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Jamuna Entrance	Jamuna	α		α	✓					SWMC					✚	✚	✚	
2	Mandarbaria	Malancha Entrance	α		α		✓			✓	SWMC					✚	✚	✚	
3	Balur Gang	Malancha Entrance			α	✓					SWMC		✚	✚	✚				
4	Hiron Point	Passur	α		α			✓		✓	BIWTA	✚	✚	✚	✚	✚	✚	✚	✚
5	Kochikhali	Baleswar	α		α	✓					SWMC		✚	✚	✚	✚	✚	✚	
6	Khepupara	Tetulia	α					✓			BIWTA	✚	✢	✢	✚	✚	✚	✚	✚
7	Chitalkhali	Shahabazpur	α					✓			BIWTA	✢	✢	✢	✢	✢	✢	✢	✢
8	Baruria	Padma	α	α					✓		BWDB	□	□	□	□	□	□	□	□
9	Bhairab Bazar	U. Meghna	α	α					✓		BWDB	□	□	□	□	□	□	□	□
10	Patharghata	Bishkhali	α					✓			BWDB	✚	✚	✚	✚	✚	✚	✚	✚
11	Nalianala	Sibsa	α						✓		BWDB	✚	✚	✚	✚	✚	✚	✚	
12	Basantapur	Kanksiali	α						✓		BWDB	✚	✚	✚	✚	✚	✚	✚	✚
13	Mongla	Passur	α					✓			BIWTA	✚	✚	✚	✚	✚	✚	✚	✚
14	Khaikhali FS	Jamuna	α		α				✓	✓	SWMC	□	✚	✚	□	✚	✚	✚	✚
15	Dingmari FS	Dingmari K.	α		α				✓	✓	SWMC			□	□	□	□	□	□
16	Kadamtala FS	Dumkoli	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
17	Kobadak FS	Kobadak	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
18	Gayakhali FS	Sona Khal	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
19	Koyra FS	Koyra	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
20	Mrigamari FS	Sela Gang	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
21	Bogi FS	Baleswar	α		α				✓	✓	SWMC				□	□	□	□	□
22	Supati FS	Supati Khal	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
23	Harintala FS	Sela Gang	α		α				✓	✓	SWMC	□	□	□	□	□	□	□	□
24	Chandbaria	Raimangal	α		α	✓					SWMC			✚					
25	Katka Khal	Betmar Gang			α					✓	SWMC	□	□	□	□	□	□	□	□

Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

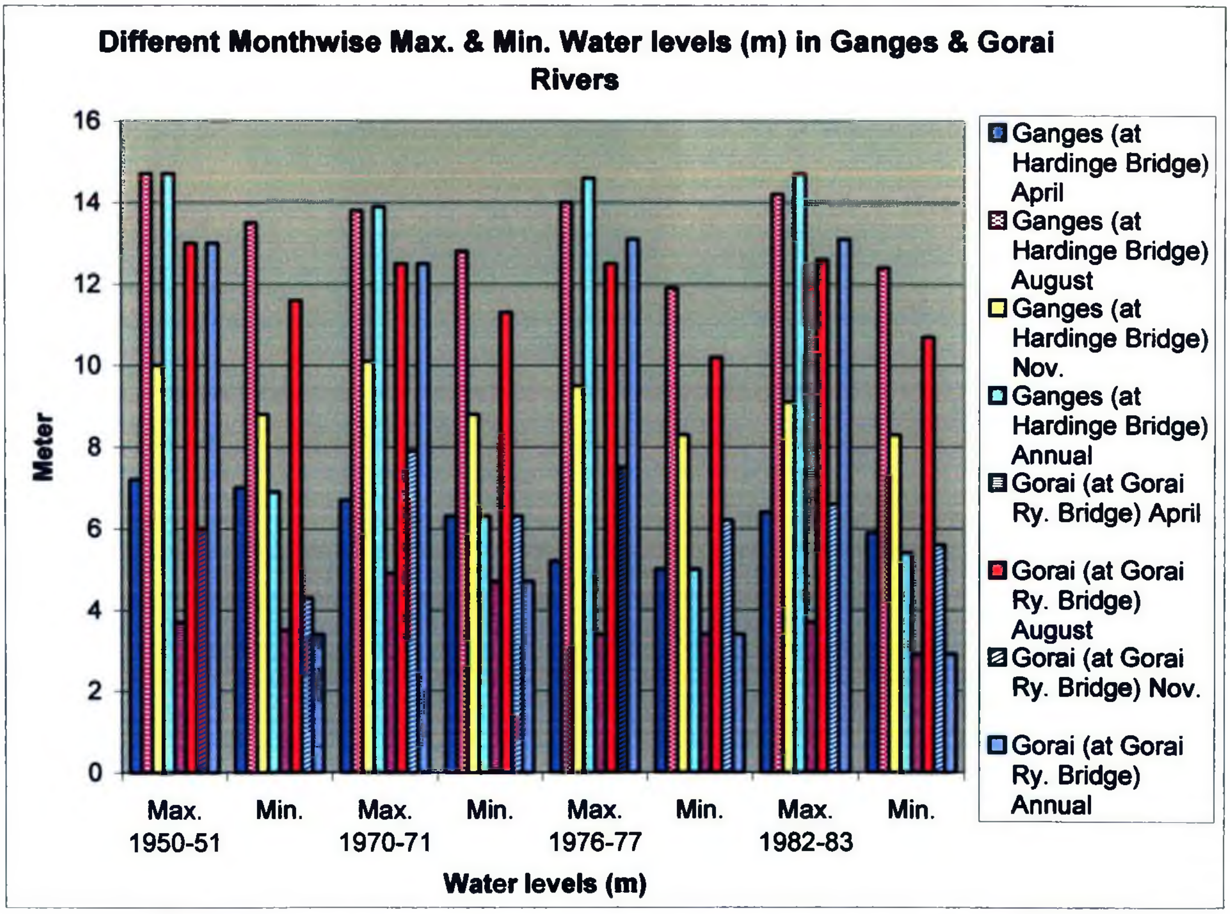
✚ Continuous Data-24 hrs/day. ✢ discontinuous Data->12 hrs/day. □ discontinuous Data-<12 hrs/day

Table-6.6 Water Levels of the Ganges (*at Hardinge Bridge*) and Gorai (*at Gorai Ry. Bridge*) in meters

Year		Ganges (*at Hardinge Bridge*)				Gorai (*at Gorai Ry. Bridge*)			
		April	August	Nov.	Annual	April	August	Nov.	Annual
1950-51	Max.	7.2	14.7	10.0	**14.7**	3.7	13.0	6.0	**13.0**
	Min.	*7.0*	*13.5*	*8.8*	***6.9***	*3.5*	*11.6*	*4.3*	***3.4***
1970-71	Max.	6.7	13.8	10.1	**13.9**	4.9	12.5	7.9	**12.5**
	Min.	*6.3*	*12.8*	*8.8*	***6.3***	*4.7*	*11.3*	*6.3*	***4.7***
1976-77	Max.	5.2	14.0	9.5	**14.6**	3.4	12.5	7.5	**13.1**
	Min.	*5.0*	*11.9*	*8.3*	***5.0***	*3.4*	*10.2*	*6.2*	***3.4***
1982-83	Max.	6.4	14.2	9.1	**14.7**	3.7	12.6	6.6	**13.1**
	Min.	*5.9*	*12.4*	*8.3*	***5.4***	*2.9*	*10.7*	*5.6*	***2.9***

Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

Graph-6.3 Maximum & Minimum Water Levels (m) of the Ganges and Gorai River



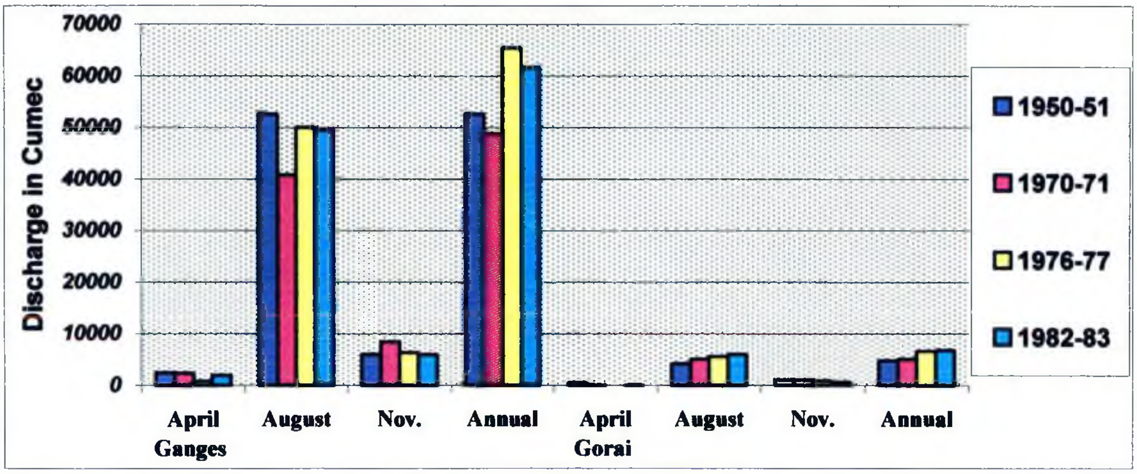
Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

Table-6.7 Discharges of the Ganges (*at Hardinge Bridge*) and Gorai (*at Gorai Ry. Bridge*) in Cumec

Year		Ganges (*at Hardinge Bridge*)				Gorai (*at Gorai Ry. Bridge*)			
		April	August	Nov.	Annual	April	August	Nov.	Annual
1950-51	*Max.*	2420	52600	6000	**52600**	453	4190	1070	**4770**
	Min.	*1950*	*28800*	*4240*	***1950***	*402*	*2910*	*636*	***244***
1970-71	*Max.*	2360	40800	8430	**48700**	85	5070	1020	**5070**
	Min.	*2030*	*24400*	*4810*	....	*59.4*	*3200*	*478*	***59.4***
1976-77	*Max.*	775	50000	6340	**65400**	.736	5600	866	**6620**
	Min.	*696*	*19300*	*3200*	***696***	*.283*	*2670*	*410*	***.283***
1982-83	*Max.*	1890	49500	5960	**61600**	42.3	6030	590	**6810**
	Min.	*1250*	*18600*	*3850*	***695***	*7.5*	*3220*	*325*	***4.25***

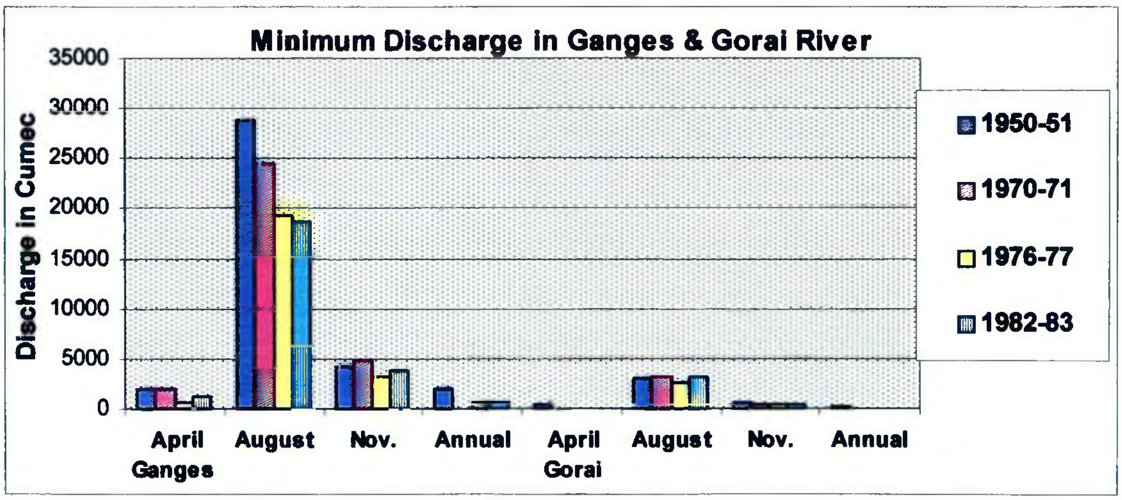
Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

Graph-6.4 Maximum Discharges in Cumec of the Ganges & Gorai River



Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

Graph-6.5 Minimum Discharges in Cumec of the Ganges & Gorai River



Source: *BWDB, Surface Water Hydrology. (For all water levels and discharges data)*

Snedaker et al 1977 have summarized the role of fresh water from the Ganges through the distributaries discharge into *Sundarbans* estuaries as follows:

-as a salt water dilettante.

-in modifying water temperature.

-in protecting fry, shrimp and shell-fish and other biota.

-in regulation of marine animals.

-as a moderator of concentration dependant reactions in salt water.

-as a carrier for primary nutrients and metabolic waste removal.

-in maintaining a salt wedge and mixing zone.

-in the vertical movement and distribution of organism.

-as related to times of arrival and departure at migrating species.

-in the delivery of all ochthonous materials to estuaries as a function of precipitation, drainage and topography.

-as a cutting and filling mechanism *(Mujibur-1995).*

6.5 Groundwater Flow and Capture

The *Sundarbans* is influenced by tides that are semi-diurnal. The soil of the *Sundarbans* is saline due to tidal interactions, although the salinity is low compared to soil salinity in other mangrove forest of the world *(Karim-1988).* Soil salinity, however is regulated by a number of other factors including surface runoff and groundwater seepage from adjacent areas, amount and seasonally of rainfall, evaporation, groundwater recharge and depth of impervious subsoil, soil type and topography etc. It is found that, conductivity of subsurface soil is much higher than that of surface soil *(Claffey-1985).* Using the salinity scale established by *Walter (1971).*

*The forest areas have been divided into **three** zones based on soil salinity *(Karim-1988)*:

1. **Oligohaline *(or miohaline)* Zone:** this zone is characterized by the soil containing less than 5 ppt of NaCl salt. The Oligohaline zone occupies a small area of the north-eastern part of the forest.

2. **Mesohaline Zone:** The zone is characterized by NaCl content within the concentration range of 5 to 10 ppt in soil. This zone covers the north-central part of the forest.

3. **Polyhaline Zone:** The NaCl content of the soil in this zone is higher than 10ppt. This zone covers the western portion of the forest.

Table-6.8 The general vegetation types in respect to soil salinity zone

Salinity zone	Land form types	Vegetation type/major species
Oligohaline	Mudflat (outer zone)	Mixed Passur Kankra *(Nol khagra)*, *(N. fruticans)*.
	Mudflat (interior) Mudflat-ridge (levees)	Gewa *(E.agallocha)*. Pandanus foetidus *(kewa katta)*.
	Backswamps	**Stratum-A**: Sundri(H. fomes D), *(S. Apetala)*, Baen*(A. Officinalis)* **Stratum-B**: Gewa *(E. agallocha)*. **Stratum-C**: Shingra *(C. ramiflora)*
Mesohaline	Mudflat (interior)	*(P. coarctala), (N. fruticans), (S. apetala), Gewa (E. agallocha).*
	Mudflat (inclined slope)	*(N. fruticans), (S. apetala), (S. caseolaris), Baen (A. officinalis), Sundri (H. fomes), Baen (E. agallocha), Goran (C. decandra), etc.*
	Backswamps	Sundri *(H. fomes)* in association with Amur *(A. cucullata)* and Kankra *(B. gymnorhiza)* as undergrowth.
Polyhaline	Mudflat (outer zone)	Upper stratum- *(S. apetala)*, Khalshi *(A. corniculatum)* with Hargoza *(A. ilicifolius)* as undergrowth. Sadda Baen *(A. marina)* in sea fronts with Khalshi *(A. corniculatum)* and *(S. apetala)*.
	Backswamps (at low elevations)	Mixed growth. Gewa *(E. agallocha)* in upper story and Goran *(C. decandra)* as undergrowth. Sparse canopy with degraded quality.

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

6.6 Estuarine

In the southwestern region, the principal ecological feature is the presence of the largest mangrove forest in the world, known as the Sundarbans. The entire Sundarbans forest is criss-crossed by intricate network of large and small rivers, canals and creeks. The total area is estimated to be 1,75,600 ha *(Ali-1991b)*, but total estuarine area is estimated to be 5,51,828 ha and total rivers area is estimated to be 4,79,735 ha in Bangladesh. The whole forest area is inundated by tidal water twice everyday. Water is estuarine with a wide range of salinity's. Rivers in the *Sundarbans* forest at their northern-ends receive freshwater inflow from the upper portions of the rivers, while the south they meet the saline water of the Bay of Bengal. The water in the Sundarbans is rich in detritus and nutrients, supporting a large variety of both cartilaginous and bony fishes, shrimps, crabs etc.

The larger rivers while passing through the *Sundarbans* forest joins together and forms estuary at the confluence where they meet near the sea. Within the present boundary of the Bangladesh *Sundarbans* four such estuaries has been designated that connects each other and receive flow from the upstream through a large number of distributaries. From east to west these are:

1. Bangra estuary:
2. Kunga estuary:
3. Malancha estuary:
4. Raimangal estuary:

Photograph – 15 : A Beautiful Typical Photograph of the Tidal/Creek of Sundarbans

Estuarine fishes are Parshe *(Mugil parshe)*, Khorsul *(M. corsula),* Bhangon Bata *(M.tade)* belonging to the family Mugilidae; Bhetki *(Lates calcarifer)* belonging to Centropomidae, and number of species under the families Toxtidae, Leiognathidae, Sciaenidae, Scatophagidae, Taeniodidae and Gobiidae. Some of these estuarine fishes come upstream into freshwater habitats.

6.7 Surface Drainage System/pattern

Both surface and sub-surface drainage is essential in order to reclaim salt affected soils. In low lying *Sundarbans* saline areas due to heavy concentrated rainfall in the months of monsoon season, flat topography, low infiltration rate and lack of well defined drainage system periodic water logging takes place. Alternate drainage systems and or water storage tanks to control the excess water should be examined.

In some areas persistence of high water table with poor quality ground water calls for sub-surface drainage. Due to marine origin and impeded drainage soils within these areas are highly saline and create unfavorable conditions for crop growth. Work should be done on the efficiency of sub-surface drainage in some strongly saline soils with high water table.

6.8 Vegetation type and Distribution

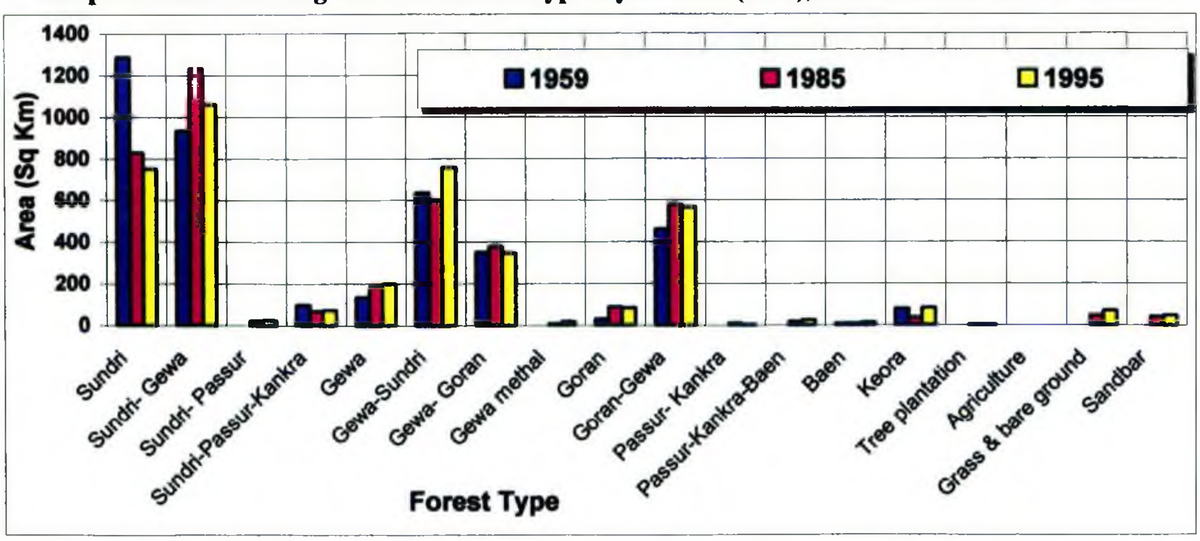
The trees of the *Sundarban* forests are peculiar to tidal swamps and can thrive in brackish water and clayey soil. The degree of salinity in the water of the surrounding rivers has, however produced a marked influence upon the plants. On the basis the forests which have fallen to the share Pakistan period may be divided into two zones by a line drawn from the Kobadak forest station on the northern boundary to the mouth of the Katka khal on the sea face. The area to the east of the line is the freshwater forest and west is the moderately & salt water forest.

Table-6.9 Percentage area coverage of main Floristic types classified by Forestal (1959), 1985 and 1995 in the Sundarbans

Forest Types	Species composition		Area expressed as a area & percentage of the total Forest Area (%)					
			Forestal 1959		1985		1995	
	Species	(%)	Area (Km²)	(%)	Area (Km²)	(%)	Area (Km²)	(%)
Sundri	Sundri	75+	1286.58	31.6	828.45	20.0	749.92	18.2
Sundri- Gewa	Sundri-Gewa	50-74 26-50	933.44	24.4	1232.47	29.8	1059.67	25.8
Sundri- Passur	Sundri-Passur	50-74 26-50	.00	0.0	22.14	0.5	24.13	0.6
Sundri-Passur-Kankra	Sundri-Passur-Kankra	26-50 20-40 20-40	97.72	2.4	67.99	1.6	71.43	1.7
Gewa	Gewa	75+	134.36	3.3	185.56	4.5	199.09	4.8
Gewa-Sundri	Gewa-Sundri	50-74 26-50	635.15	15.6	599.73	14.5	757.04	18.4
Gewa- Goran	Gewa-Goran	50-74 26-50	350.15	8.6	375.93	9.1	346.04	8.4
Gewa metal					8.36	0.2	16.11	0.4
Goran	Goran	75+	28.50	0.7	87.06	2.1	82.69	2.0
Goran-Gewa	Goran-Gewa	50-74 26-50	460.07	11.3	575.97	13.9	565.36	13.7
Passur- Kankra	Passur-Kankra	40-60 40-60	.00	0.0	9.40	0.2	2.84	0.1
Passur-Kankra-Baen	Passur-Kankra-Baen	20-40 20-40 20-40	.00	0.0	16.14	0.4	25.16	0.6
Baen	Baen	90+	8.14	0.2	8.28	0.2	12.30	0.3
Keora	Keora	90+	77.36	1.9	35.09	0.8	82.87	2.0
Tree plantation					3.51	0.1	2.17	0.1
Agriculture					.16	0.0		
Grass & bare ground					46.14	1.1	69.31	1.7
Sandbar					40.24	1.0	46.14	1.1
Total			**4071.46**	**100.0%**	**4142.59**	**100.0%**	**4112.27**	**100.0%**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report & SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin ahmad, 1997.*

Graph-6.6 Area coverage of main Floristic types by Forestal (1959), 1985 & 1995 in the Sundarbans



Source: A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report & SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin ahmad, 1997

The southwestern part of the Bengal delta is covered by a belt of extensive and dense mangrove forest, the *Sundarbans*. The natural vegetation of the Sundarbans is forest composed of halophytic tree species, which can loosely be termed mangroves. In general, the forest in the northern and eastern parts of the *Sundarbans* which are those better supplied with freshwater. Prain (1903) lists 334 species of tree and other plants from the *Sundarbans* but many of these are recorded either from what is now the Indian *Sundarbans* or from the sites of former habitation.

The three plant families which, with Heritiera spp. From the Sterculiaceae, can be regarded as key components of the mangrove flora throughout the world are the Avicenniaceae, Rhizophoraceae and Sonneratiaceae *(Christensen-1982)*. The first of these is represented in the Sundarbans by Baen and Sadda Baen and possibly by other, as yet unidentified, species or varieties in the same genus. The second is represented by Goran, Gurae, Jhana and Kankra and the third, Sonneratiaceae, by Keora and Ora. Sundri is a species if Heritiera.

The canopy Closure has been interpreted 1985 and 1995 in three classes

- Low canopy closure (10% <30%)
- Medium canopy closure (30% <70%)
- High canopy closure (>= 70%)

Detailed listings of the observations on the canopy closure are given in table- 6.12. The table list the respective values for each vegetation type. They show for each of the species the percentage of area falling into different canopy closure classes in 1985 and 1995.

According the Canopy Closure (%) of Sundri dominated areas with low and medium density increased over the period in 1985 and 1995. But high density the Canopy Closure (%) of Sundri shows decrease. The Gewa dominated areas shows basically no difference in their density between 1985 and 1995. In the Goran dominated area there is a remarkable difference in the canopy closure between 1985 and 1995.

Table-6.10 Main Vegetation type and Canopy Closure in 1985 and 1995

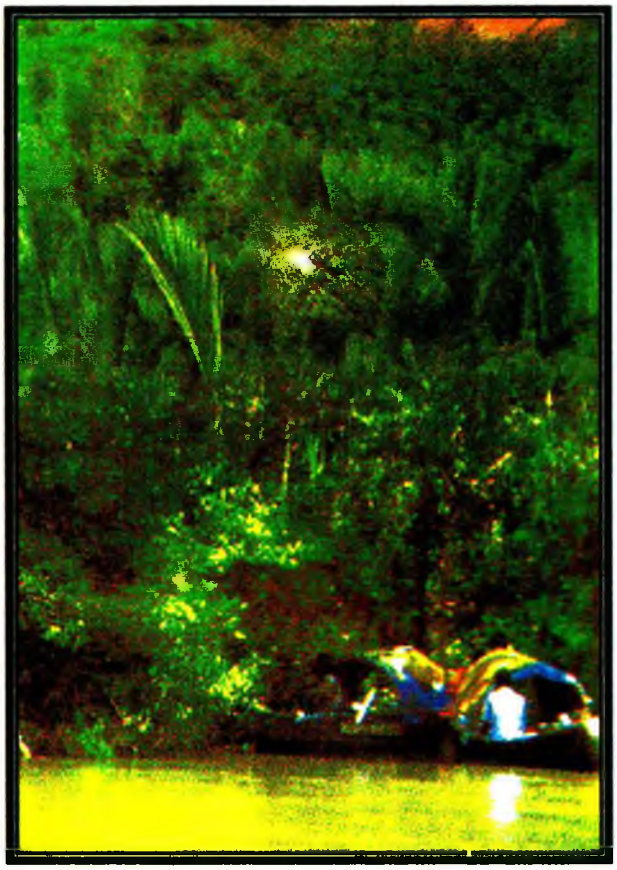
Forest Type	Canopy Closure (%) Area in Km^2								Total Sundarbans Forest Area in Km^2	
	>70%		<70%->30%		<30%->10%		No density			
	1985	1995	1985	1995	1985	1995	1985	1995	1985	1995
Sundri	658.69	525.96	154.35	197.59	14.91	26.26	0.51	.11	**828.45**	**749.92**
Sundri- Gewa	1015.01	697.79	197.63	326.11	19.79	35.77	0.04		**1232.47**	**1059.67**
Sundri- Passur	5.10	8.33	16.66	13.42	0.38	2.38			**22.14**	**24.13**
Sundri-Passur-Kankra	33.77	37.46	31.61	32.30	2.61	1.52		.15	**67.99**	**71.43**
Gewa	132.07	150.28	30.64	39.81	20.47	8.97	2.38	.03	**185.56**	**199.09**
Gewa-Sundri	421.50	533.69	153.41	189.83	24.64	33.52	0.17		**599.73**	**757.04**
Gewa- Goran	127.24	82.30	233.81	237.17	14.87	26.57			**375.93**	**346.04**
Goran-Gewa	194.98	92.01	370.25	412.94	10.75	60.41			**575.97**	**565.36**
Goran	55.04	11.31	26.96	56.31	5.06	15.08			**87.06**	**82.69**
Passur- Kankra		.51	7.08	.80	2.32	1.34		.19	**9.40**	**2.84**
Passur-Kankra-Baen	9.93	3.95	3.87	14.55	2.34	6.65			**16.14**	**25.16**
Baen	1.31	2.76	5.74	3.51	1.22	6.03			**8.28**	**12.30**
Keora	15.04	21.04	20.06	44.23		17.60			**35.09**	**82.87**
Gewa metal			8.36	.76		15.35			**8.36**	**16.11**
Agriculture							3.51		**3.51**	
Grass & bare ground	0.30						45.84	69.31	**46.14**	**69.31**
Sandbar							40.24	46.14	**40.24**	**46.14**
Tree Plantation		1.57		.49		.11	.16		**.16**	**2.17**
Total Forest	**2669.97**	**2168.95**	**1260.41**	**1569.82**	**119.38**	**257.57**	**92.83**	**115.93**	4142.26	4112.27
Total (%)	**64.5**	**52.7**	**30.4**	**38.2**	**2.9**	**6.3**	**2.2**	**2.8**	**100.0**	**100.0**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report & SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel and Istiaq uddin Ahmad, 1997*

6.8.1 Water depth and Floral Species

The Sundarbans water is mainly saline. There is 102 islands in the Sundarbans area of which some 58 are inhabit ed. Soil in the Sundarbans is very fertile. But the degree of salinity is not constant in the soil and water of this forest. The degree of salinity varies from year to year and season to season. This has a negative effect. However the general tendency is that salinity increasing. This increase in salinity is a serious threat to the environment and inhabitation in the Sundarbans.

Photo – 16 : Natural Vegetation Type at Sundarbans in Estuarine sides



Quantitative Analysis

"Statistical Analysis of Variance (Kolmogor- Smirnov K-S – test) has been done to examine the relationship between land-levels and quality of water in the *Sundarbans* Mangrove. The result of the K-S test reveals (table- 6.11) that the relation in Moderately Saltwater zone (Km^2) & Saltwater zone (Km^2) were negative.

Table : 6.11 Does some ranges in height (m) at mean sea level Floral species occur between the Moderately Saltwater & Saltwater zone in the Sundarbans Mangrove Forest.

Height variation of mean sea level in meter	Moderately Salt Water Zone Area (Km^2)	Salt Water Zone Area (Km^2)
0.50m>	183	465
0.51-1.00m	610	140
1.00-1.50m	421	246
1.51-2.00m	234	338
2.01-2.50m	71	111
	N_1 = 1518	N_2 = 1299

Ans.- Hypothesis is weather the height at mean sea level are difference from Moderately Saltwater & Saltwater zone (*Km²*) in the Sundarbans Mangrove Forest.

Percentage

	0.50m>	0.51-1.00m	1.00-1.50m	1.51-2.00m	2.01-2.50m
Moderately Salt Water Zone Area (Km^2)	12	40	28	15	5
Salt Water Zone Area (Km^2)	36	11	19	26	8

Cumulative Percentage point

	0.50m>	0.51-1.00m	1.00-1.50m	1.51-2.00m	2.01-2.50m
Moderately Salt Water ZoneArea (Km^2)	0.12	0.52	0.80	0.95	1.00
Salt Water Zone Area (Km^2)	0.36	0.47	0.66	0.92	1.00
*Difference(**D**)*	*0.24*	*0.05*	*0.14*	*0.03*	*0.00*

Maximum difference (**D**) = 0.24

Level of Significance 0.05%

We know,

$$\text{Critical value of Maximum difference } (\mathbf{D}_C) = 1.36 \times \sqrt{\frac{N1+N2}{N1\times N2}}$$

$$= 1.36 \times \sqrt{\frac{1518+1299}{1518\times 1299}}$$

$$= 1.36 \times \sqrt{\frac{2817}{1971882}}$$

$$= 1.36 \times 0.0378$$

$$= 0.051$$

H_O(Null Hypothesis) - Moderately Saltwater zone & Saltwater zone height areas is no difference in Floral Species.

H_A (Alternative Hypothesis) - Moderately Saltwater zone & Saltwater zone height areas is difference in Floral Species.

Comments-

Statistical examinations viz. Kolmogoro- Smirnov **(K-S)** – test (Hypothesis test) has been conducted understood the role of height in meter of Moderately Saltwater zone & Saltwater zone species area at Sundarbans Mangrove Forest in the study areas. The test reveals negative relationship in the occurrence of said species in selected Sundarbans Forest species which show that the-

$\mathbf{D > D_C}$. So null hypothesis is rejected. So salinity zone wise height in meter at mean sea level species growing are not same. Species are difference in density of species, height & depth distribution of vegetation in Sundarbans, Geo-morphological & soil condition, hydrological instruction, environmental impact and other process.

6.8.2 Salinity and Floral Species

Fresh water zone is the smaller zone located in the north east corner of the *Sundarbans* with the dominant tree species being Sundri, and some variable component of the Gewa and Golpata. This subsystem is gradually becoming smaller due to lower amounts of freshwater flows and consequent saline instruction particularly during the dry season. It cannot spread inland due to the human habitation on the inland border.

Moderate saline or brackish zone comprises a main part of the *Sundarbans* in the central and southeast parts and is characterized by being saline for part of the year and less saline of fresh during the months. The main tree species is Gewa with varying amounts of Sundri. This zone has been expanding into freshwater zone, as the freshwater flows decreased overtime and consequently the saline front moved inland.

Saline water zone comprises the southern and western parts of the *Sundarbans* and is characterized by high salinity throughout the year. The main tree species is the Goran, Sundri trees, if present, are usually stunted and grow poorly in this zone.

Quantitative Analysis

"Statistical Analysis of Variance (Snedecor's Variance Ratio test or **F**– test) has been done to examine the relationship between quality of water Study area and the rate of occurrence of different forest species in the *Sundarbans* Mangrove. The result of the F- test reveals (table-6.12) that the relation in selected forest area were negative.

Tabie-6.12 Different Floral Species were taken for three Selected area *(Study area –1 Compartment-46 ; Study area –2 Compartment-35 ; Study area –3 Compartment-45)* and effect was measured in the Sundarbans Mangrove Species area for sq. km distribution.

Forest types	Study area –2 , Khulna Koyra Range area		Study area –3, Sarankhola Range area		Study area –1 , Satkhira Range area	
	Area (ha)	*Area (Km²)*	*Area (ha)*	*Area (Km²)*	*Area (ha)*	*Area (Km²)*
Sundri	475	5	100	1	22	-
Sundri- Gewa	2016	20	3947	40	64	1
Sundri- Passur	105	1			241	2
Sundri-Passur-Kankra	1775	18			25	-
Gewa			2703	27	589	6
Gewa-Sundri	628	6	980	10	7539	75
Gewa- Goran			925	9	895	9
Goran-Gewa					584	6
Goran			14	-	42	1
Passur- Kankra	202	2			765	8
Passur-Kankra-Baen	787	8			157	2
Baen					36	-
Keora	40		595	6	4	-
No Forest	214	2	708	7	90	-
Total land of Mangrove Forest		Σx_1 =62 N_1 =08		Σx_2 =100 N_2 =07		Σx_3 =110 N_3 =09

Source: Modified after *Chaffey, Miller,.Sandom.-1985*

Here,

F = F test or Snedecor's Variance Ratio test (Analysis of variance)

N = Number of sample (N_1=Number of Column 1, N_2=Number of Column 2, N_3=Number of Column 3)

Σx =Sum of total areas (Σx_1 =Sum of Column 1, Σx_2 =Sum of Column 2, Σx_3 = Sum of Column 3)

$N = N_1 + N_2 + N_3 = 8+7+9=24$

$\Sigma x = \Sigma x_1 + \Sigma x_2 + \Sigma x_3 = 62+100+110=272$

$$N\bar{x}^2 = \frac{\sum x^2}{N} = \frac{(272)^2}{24} = \frac{73984}{24} = 3082.67$$

We Know,

Sum of Square total Group **(SST)** $= \Sigma_1 \Sigma_j x^2{}_1 J - N\bar{x}^2$

$= (5^2+20^2+1^2+18^2+6^2+2^2+8^2+2^2+1^2+40^2+27^2+10^2+9^2+6^2+7^2+1^2+2^2+6^2+75^2+9^2+6^2+1^2+8^2+2^2) - 3082.67$

$= 9306 - 3082.67$

$= 6223.33$

df (degrees of freedom) = N − 1 = 24 − 1 = 23

We Know,

Sum of Square between the Group **(SSB)** $= \Sigma^{n}_{i=1} \Sigma_j x^2{}_1 J - N x^2$

$$= \frac{62^2 + 100^2 + 110^2}{8} - 3082.67$$

$$= \frac{3844 + 10000 + 12100}{8} - 3082.67$$

$$= \frac{25944}{8} - 3082.67$$

$= 3243 - 3082.67$

$= 159.33$

df (degrees of freedom) = Total Group − 1 = 3 − 1 = 2

Sum of Square with in a Group **(SSW)** = SST − SSB = 6223.33 − 159.33 = 6064

df (Total degrees of freedom − Between the Group df) = 23 − 2 = 21

Anova table-

Sources of Variation	**Sum of Square**	**df = degrees of freedom**	**Mean Sum of Square**	Fraction $= \frac{Greatvalue}{Lesservalue}$	**0.05% Value of rate**
SSB	159.33	2	79.67	3.62	3.47
SSW	6064	21	288.76		

F calculated value > **F** tabulated value

Null Hypothesis $\mathbf{H_0}$ is **rejected.**

Comments

Statistical examinations viz. - F test or Snedecor's Variance Ratio test (Analysis of variance) has been conducted to understood the role of salinity in the dispersion of *Sundarbans* Forest in the study areas. The test reveals negative relationship in the occurrence of said species in the study area. So, three selected area is difference of *Sundarbans* Mangrove Species. Thus it can be taken for grant that in the *Sundarbans* Mangrove forest there exists almost no correlation in the different floral species and spatial differences in *Sundarbans* Mangrove under the study areas. However, other ecological factors may cause combined contribution in the differences in occurrences of varied species distributions in the *Sundarbans* in Bangladesh.

Table-6.13 Sundarbans Forest type of Vegetation and Selected area (Compartment-35, 45, 46) Salinity distribution (*Area (ha) of salinity unit and % of selected compartment Land)*

Forest types	Fresh water zones Selected Compartment-35		Moderately Saline water zones Selected Comparment-45		Saline water zones Selected Compartment-46	
	Area (ha)	%	*Area (ha)*	%	*Area (ha)*	%
Sundri	475	7.61%	100	1.00%	22	0.20%
Sundri- Gewa	2016	32.30%	3947	39.58%	64	0.08%
Sundri- Passur	105	1.68%			241	2.18%
Sundri-Passur-Kankra	1775	28.44%			25	0.23%
Gewa			2703	27.11%	589	5.33%
Gewa-Sundri	628	10.06%	980	9.83%	7539	68.20%
Gewa- Goran			925	9.28%	895	8.10%
Goran-Gewa					584	5.28%
Goran			14	0.14%	42	0.38%
Passur- Kankra	202	3.24%			765	6.92%
Passur-Kankra-Baen	787	12.61%			157	1.42%
Baen					36	0.33%
Keora	40	0.64%	595	5.97%	4	.00%
No Forest	214	3.43%	708	7.10%	90	0.81%
Total land of M. Forest	**6242**	**100.00%**	**9972**	**100.00%**	**11053**	**100.00%**

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

Table- 6.14 Distribution and extent of different categories of Soil Salinity in the Sundarbans Regions of Bangladesh *(in hectares)*

Thana/Upazila	Salinity Categories					Upazila Total
	Non Saline	Slightly Saline	Moderately Saline	Saline	Highly Saline	
Shamnagar	0	0	18100	15270	5200	38570
Dacope	0	0	17600	3400	2100	23100
Koyra	0	0	17840	3700	2300	23840
Mongla Port	0	0	15500	0	0	15500
Sarankhola	0	0	12280	0	0	12280

Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. –Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC*

6.8.3 Tidal Influence and Floral Species

The entire floor of the forest goes under water during the spring tide round the year and also during all the high tide in the monsoon months. It is there-fore, necessary that the trees that grow in such areas must have special adaptations. The trees have very thick leaves which reduce loss of water due to transpiration and phenumatophores which take on the function of breathing. This is because through there is water everywhere but the amount of freshwater for intake by the plant is very little, a situation called physiological drought. The mean water level of the rivers changes between wet and dry season due to the onset of the monsoon wind field and also due to the high discharge of freshwater through the river. Thus the extreme high water is high in the wet season and extreme low water is low tide the dry season

Chowdhury and Chakraborty (1973) divided the forests into four types based on tidal level as:

a) High tide.
b) Above general tide level.
c) Frequently inundated by salt water. And
d) Below the tidal level.

Quantitative Analysis

"Statistical Analysis of Variance (Kruskal Wallis **H** – test) has been done to examine the relationship between quality of water and the rate of occurrence of *Sundri* species in the *Sundarbans* Mangrove. The result of the H- test reveals (table- 6.15) that the relation in all the compartment were negative.

Table : 6.15 Compartment wise three saline zone area is variation only Sundri tree at Sundarbans Mangrove Forest Areas

Freshwater zone area (ha)	Rank	Moderately salt water zone area (ha)	Rank	Salt water zone area (ha)	Rank
1537	*24*	1588	*27*	0	*51*
1138	*30*	2960	*7*	41	*42*
2369	*18*	1913	*23*	0	*51*
2207	*20*	679	*34*	0	*51*
2503	*14*	161	*38*	0	*51*
2858	*9*	104	*39*	3	*45.5*
1629	*26*	29	*43*	3	*45.5*
2548	*12*	1155	*29*	0	*51*
328	*37*	100	*40*	0	*51*
2200	*21*	63	*41*	15	*44*
368	*36*	2938	*8*		
372	*31*	5404	*1*		
2159	*22*	744	*33*		
2237	*19*	2680	*10*		
3291	*6*	0	*51*		
2438	*16*	0	*51*		
3404	*5*	0	*51*		
5190	*2*				
1239	*28*				
2481	*15*				
2436	*17*				
475	*35*				
945	*32*				
2617	*11*				
1759	*25*				
4002	*4*				
2521	*13*				
4367	*3*				
N_A =28	R_A=531	N_B =17	R_B=526	N_C =10	R_C=483

We know,

$$\mathbf{H} = \frac{12}{N(N+1)} \sum \frac{R^2}{N} - 3(N+1)$$

$$= \frac{12}{55 \times 56}\left(\frac{(531)^2}{28} + \frac{(526)^2}{17} + \frac{(483)^2}{10}\right) - 3(55+1)$$

$$= \frac{12}{3038} \cdot (\ 10070.036 + 16275.059 + 23328.9) - 3\text{X}56$$

$$= 193.54 - 168$$

$$= 25.58$$

Here,

H = Kruskal Wallis H test

N= Number of sample (N_A=Number of Column A, N_B=Number of Column B, N_C=Number of Column C)

R= Rank size (R_A=Total Rank Column A, R_B=Total Rank Column B, R_C=Total Rank Column C)

df (degrees of freedom) = 3-1= 2 , and

0.05% significant level tabulated value 5.99.and

Calculate value – 25.58

Comments

Statistical examinations viz. - Kruskal Wallis H – test (Hypothesis test) has been conducted understood the role of salinity in the dispersion of *Sundarbans* Forest (*Sundri* species) in the study areas. The test reveals negative relationship in the occurrence of *Sundri* species in the *Sundarbans* which show that the-

Calculated value > Tabulated value. So 0.05% significant level Null Hypothesis is **rejected**. For this 0.05% significant level, sampling procedure is vital difference of *Sundarbans Sundri* species growing on saline zone. *Sundri* species is difference from three saline zone at *Sundarbans*. So *Sundri* species is growing on necessity of salinity variation.

Quantitative Analysis

"Statistical Analysis of Variance (Kruskal Wallis **H** – test) has been done to examine the relationship between quality of water and the rate of occurrence of different forest species in the *Sundarbans* Mangrove. The result of the H- test reveals (table- 6.16) that the relation in all the forest area were positive.

Table : 6.16 Area (hector) wise Sundarbans Mangrove Forest distribution in different saline zone

Forest Type	Fresh Water Zone		Moderately Salt Water Zone		Salt Water Zone	
	Area (ha)	Rank	Area (ha)	Rank	Area (ha)	Rank
Sundri	62518	*1*	20518	*7*	62	*36*
Sundri- Gewa	54947	*3*	61165	*2*	403	*28*
Sundri- Passur	1109	*21*	590	*24*	241	*30*
Sundri-Passur-Kankra	5985	*13*	441	*27*		
Gewa	1297	*19*	14251	*9*	3921	*14*
Gewa-Sundri	20093	*8*	26285	*5*	12603	*10*
Gewa- Goran	6	*38*	12288	*11*	23715	*6*
Goran-Gewa			3110	*16*	54145	*4*
Goran			526	*26*	8781	*12*
Passur- Kankra	220	*32*			1110	*20*
Passur-Kankra-Baen	860	*23*			177	*34*
Baen	74	*35*	575	*25*	231	*31*
Keora	392	*29*	2653	*17*	206	*33*
Gewa Metal					10	*37*
No Forest	1643	*18*	3461	*15*	1014	*22*
	N_A =12	R_A=240	N_B =12	R_B=185	N_C =14	R_C=317

We know,

$$\mathbf{H} = \frac{12}{N(N+1)}\sum\frac{R^2}{N} - 3(N+1)$$

$$= \frac{12}{38\times 39}\left(\frac{(240)^2}{12}+\frac{(185)^2}{12}+\frac{(317)^2}{14}\right) - 3(38+1)$$

$$= \frac{12}{1482}\ (4800 + 2852.08 + 7177.79) - 3\times 39$$

$$= (0.008097 \times 14829.89) - 117$$
$$= 120.079 - 117$$
$$= 3.079$$
$$= 3.08$$

Here,

H= Kruskal Wallis H test

N= Number of sample (N_A=Number of Column A, N_B=Number of Column B, N_C=Number of Column C)

R= Rank size (R_A=Total Rank Column A, R_B=Total Rank Column B, R_C=Total Rank Column C)

df (degrees of freedom) = 3-1= 2 , and

0.05% significant level Tabulated value 5.99. And

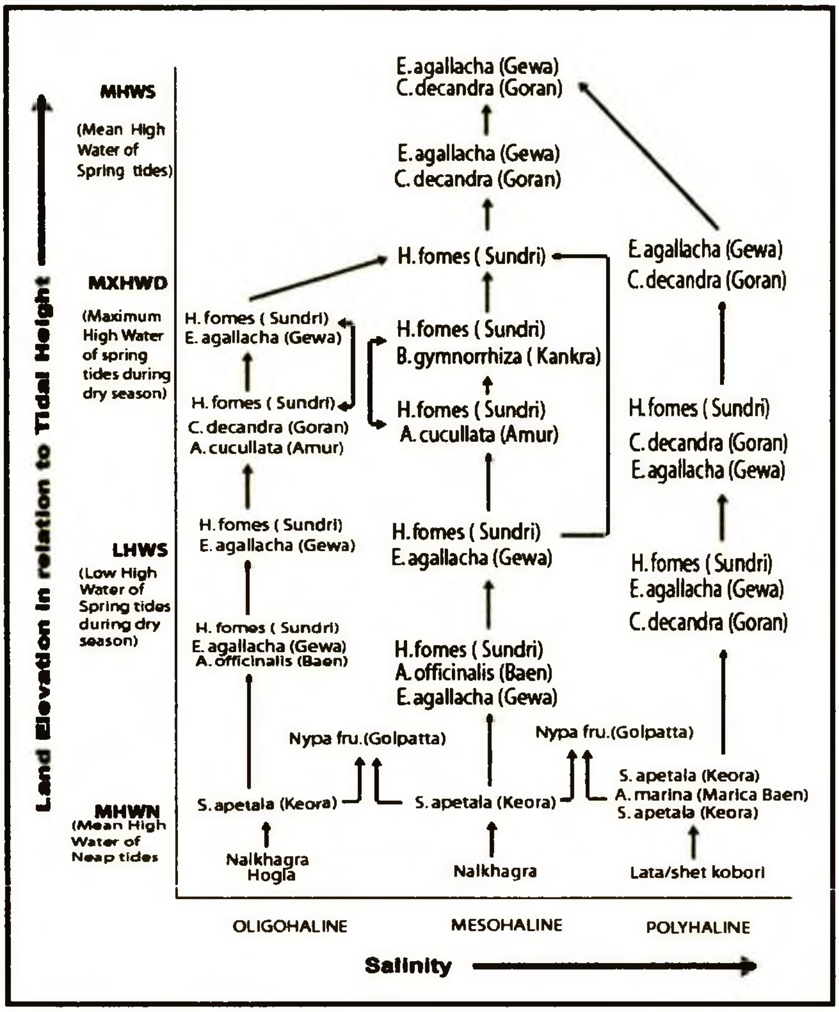
Calculate value – 3.08

Comments

Statistical examinations viz. - Kruskal Wallis **H** – test (Hypothesis test) has been conducted understood the role of salinity in the dispersion of total Sundarbans Species in the study areas. The test reveals positive relationship in the occurrence of said species in total Sundarbans Forest species which show that the-

Calculated value < Tabulated value. So 0.05% significant level for sampling procedure in Sundarbans areas, Null hypothesis is **accepted**. Because there is no difference in growing on different types of vegetation in Sundarbans. Only floral species variation is different from salinity intrusion. Different types of floral species is growing Geo-morphological, soil condition, hydrological instruction, environmental impact etc.

Fig- 6.01 Forest succession in the three salinity zones in respect to land elevation and tidal height



Source: Modified and Edited after, Karim, 1994.

6.8.4 Flood/Height of Surface and Floral Species

At present surface soils of the Sundarbans have involved from deltaic floodplain, sedimentation and tidal forest peat deposits and uniformly consist of deep, poorly drained alluvium. The surface soils are dominantly clay but they are overlain with thin layers of fresh silt to a greater or lesser expend during the monsoon flooding period. This creates of a surface soil overlay alternating layers of clay and sand (chudhury, 1962) In general, soil fertility flood increase, height of surface water, which reflects both nutrient status and physical structure, decreases from east to west and from north to south. This situation. maximum floral species are grown by different height and different situation of floral species, new formly mudflats, maximum species are grown slowly.

Table-6.17 Distribution of Mangrove Species in Sundarbans Fresh water zones selected Compartment-35 according to land-evaluation showing Area (hector), land-height and percentage of occurrences of Species Combination

Forest Type	Height 15.0 meters & above		Height 10.0-14.9 meters		Height 5.0-9.9 meters		Height 4.9 meters & below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri	147	*2.36*	328	*5.25*	–	–	–	–
Sundri- Gewa	742	*11.89*	1274	*20.41*	–	–	–	–
Sundri- Passur	70	*1.12*	35	*0.56*	–	–	–	–
Sundri-Passur-Kankra	352	*5.64*	1423	*22.80*	–	–	–	–
Gewa-Sundri	–	–	326	*5.22*	302	*4.84*	–	–
Passur- Kankra	–	–	–	–	202	*3.24*	–	–
Passur-Kankra-Baen	–	–	–	–	787	*12.61*	–	–
Keora	–	–	–	–	40	*0.64*	–	–
Total Forest	**1311**	***21.00%***	**3386**	***54.24%***	**1331**	***21.32%***	–	–
No Forest	Total Area – 214 (ha) , % of total (Com-35) Sundarbans Forest Area –3.42							
Total Forest Area	**Total Area – 6242 (ha) , % of total Sundarbans Forest Area –1.52%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table-6.18 Distribution of Mangrove Species in Sundarbans Moderately Saline water zones Selected Compartment-45 according to land-evaluation showing Area (hector), land-height and percentage of occurrences of Species combination

Forest Type	Height 15.0 meters & above		Height 10.0-14.9 meters		Height 5.0-9.9 meters		Height 4.9 meters & below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri	96	*.96*	4	*.04*	–	–	–	–
Sundri- Gewa	1	*.01*	1813	*18.18*	2133	*21.39*	–	–
Gewa	–	–	2116	*21.22*	541	*5.42*	46	*0.46*
Gewa-Sundri	–	–	9	*.09*	971	*9.74*	–	–
Gewa- Goran	–	–	4	*.04*	921	*9.24*	–	–
Goran	–	–	–	–	14	*0.14*	–	–
Keora	–	–	–	–	595	*5.97*	–	–
Total Forest	**97**	***0.97%***	**3946**	***39.57%***	**5175**	***51.90%***	**46**	***0.46%***
No Forest	Total Area – 708 (ha) , % of total (Com-45)Sundarbans Forest Area –7.10%							
Total Forest Area	**Total Area – 9972 (ha) , % of total Sundarbans Forest Area –1.55%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Table-6.19 Distribution of Mangrove Species in Sundarbans Saline water zones Selected Compartment-46 according to land-evaluation showing Area (hector), land-height and percentage of occurrences of Species combination

Forest Type	Height 15.0 meters & above		Height 10.0-14.9 meters		Height 5.0-9.9 meters		Height 4.9 meters & below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri	--	--	--	--	22	*0.20*	--	--
Sundri- Gewa	--	--	12	*0.11*	52	*0.47*	--	--
Sundri- Passur	3	*0.03*	--	--	238	*2.15*	--	--
Sundri-Passur-Kankra	--	--	--	--	25	*0.20*	--	--
Gewa	--	--	--	--	589	*5.33*	--	--
Gewa-Sundri	--	--	408	*3.69*	7131	*64.62*	--	--
Gewa- Goran	--	--	--	--	895	*8.10*	--	--
Goran-Gewa	--	--	--	--	584	*5.28*	--	--
Goran	--	--	--	--	42	*0.38*	--	--
Passur- Kankra	--	--	--	--	765	*6.92*	--	--
Passur-Kankra-Baen	--	--	--	--	157	*1.42*	--	--
Baen	--	--	--	--	36	*0.33*	--	--
Keora	--	--	--	--	4	*0.04*	--	--
Total Forest	**3**	***0.03%***	**420**	***3.80%***	**10540**	***95.36%***	--	--
No Forest	Total Area – 90 (ha) , % of total (Com-46) Sundarbans Forest Area –0.80%							
Total Forest Area	**Total Area – 11053 (ha) , % of total Sundarbans Forest Area – 2.75%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

6.8.5 Changing in Hydrology &Changing in Floral Species

Peculiarity of *Sundarban* is that it is a cluster of low lying deltaic islands. There are innumerable meandering creeks passing through the forest. These creeks not only carry water and flood the forest but also help immensely the extraction of forest produces.

Beach type of forest is in general found above the high tide mark on sandy soil and may merge into agricultural land or upland forest. Sand dune and beach vegetation is mostly scrub like with a high presence of stunted tree growths. These coastal forest ecosystems forest are adapted to growing conditions that are often difficult as a result of edaphic or climate extremes *(strong winds, salinity, lack or excess of humidity).* A slight change in the ground water level of example might eliminate the existing scrub vegetation. Sand dunes and beach vegetation have an important role inland stabilization and thus prevent the silting up of coastal lagoons and rivers as well as protecting human settlements further inland from moving sand dunes. The dominant animal species on the adjacent beaches are crabs and molluses. The beaches are also very important as breeding sites for sea turtles.

Table-6.20 Statistics by Species Group of Mangrove Forest in Sundarbans Compartment –35 (Total Area 6426.30 ha) according to Forest division: No of tree (Nearest 10) and No of tree/ha by diameter class (cm). Date-27-01-1998

Species Group	Tree by Diameter class							
	15-20	20-25	25-30	30-40	40-50	50-60	60+	Total
Sundri	103310	129140	58230	8920	–	–	1880	301480
Gewa	28650	3760	–	–	–	–	–	32410
Keora	55100	17530	26300	19410	5640	1880	1880	127730
Baen	47430	73260	26300	16910	9860	5640	16910	196290
Other Tree Species	86880	114110	77010	46490	3760	1880	1880	332010
Total	**321360**	**337800**	**187840**	**91730**	**19250**	**9390**	**22540**	**989910**

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V. Rvilla, Istiaq Uddin Ahmad DCF (RIMS) & MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Table-6.21 Statistics by Species Group of Mangrove Forest in Sundarbans Compartment –45 (Total Area 9290.60 ha) according to Forest division: No of tree (Nearest 10) and No of tree/ha by diameter class (cm). Date-27-01-1998

Species Group	Tree by Diameter class							
	15-20	20-25	25-30	30-40	40-50	50-60	60+	Total
Sundri	360970	81310	11280	3760	–	–	–	**457320**
Gewa	127370	18330	7520	–	–	–	–	**153220**
Keora	–	15040	11280	30080	22560	9400	–	**88360**
Baen	5640	15040	–	–	–	–	–	**20680**
Other Tree Species	3760	1880	–	–	–	–	–	**5640**
Total	**497740**	**131600**	**30080**	**33840**	**22560**	**9400**	–	**725230**

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V. Rvilla, Istiaq Uddin Ahmad DCF (RIMS) & MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Table-6.22 Statistics by Species Group of Mangrove Forest in Sundarbans Compartment –46 (Total Area 10759.50 ha) according to Forest division: No of tree (Nearest 10) and No of tree/ha by diameter class (cm). Date-27-01-1998

Species Group	Tree by Diameter class							
	15-20	20-25	25-30	30-40	40-50	50-60	60+	Total
Sundri	14680	2100	–	–	–	–	–	**16770**
Gewa	59760	6290	–	4720	–	–	–	**70760**
Keora	48920	–	–	–	–	–	2100	**51020**
Baen	10480	10480	4190	4190	13100	4190	12580	**59230**
Other Tree Species	55040	68670	68670	73210	16770	2100	–	**284450**
Total	**188870**	**87540**	**72860**	**82120**	**29880**	**6290**	**14680**	**482230**

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V. Rvilla, Istiaq Uddin Ahmad DCF (RIMS) & MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Table-6.23 Stand and Stock table by species Group of Mangrove Forest in Sundarbans Compartment–35 (Total Area 6426.30 ha) Forest division : NT (No of trees/ha), Vol. (Volume in Cu m/ha)

Species Group	Tree by Diameter class															
	15-20		20-25		25-30		30-40		40-50		50-60		60+		Total	
	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.
Sundri	16.08	1.76	20.10	3.53	9.06	2.51	1.39	.64	–	–	–	–	.29	.70	46.91	9.14
Gewa	4.46	.37	.58	.07	–	–	–	–	–	–	–	–	–	–	5.04	.44
Keora	8.57	.43	2.73	.29	4.09	.80	3.02	.55	.88	.75	.29	.34	.29	.72	19.88	3.88
Baen	7.38	.56	11.40	1.73	4.09	1.05	2.63	1.12	1.53	1.20	.88	1.18	2.63	10.45	30.55	17.32
OTSpecies	13.52	1.42	17.76	3.07	11.98	3.24	7.23	3.23	.58	.45	.29	.38	.29	–	51.66	11.80
Total	***50.01***	***4.54***	***52.56***	***8.69***	***29.23***	***7.60***	***14.27***	***5.54***	***3.00***	***2.41***	***1.46***	***1.91***	***3.51***	***11.90***	***154.00***	***42.58***

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V. Rvilla, Istiaq Uddin Ahmad DCF (RIMS) and MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Table-6.24 Stand and Stock table by species Group of Mangrove Forest in Sundarbans Compartment–45 (Total Area 9290.60 ha) Forest division : NT (No of trees/ha), Vol. (Volume in Cu m/ha)

Species Group	Tree by Diameter class															
	15-20		20-25		25-30		30-40		40-50		50-60		60+		Total	
	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol	NT	Vol.
Sundri	38.85	4.03	8.75	1.74	1.21	.35	.40	.21	–	–	–	–	–	–	49.22	6.33
Gewa	13.71	1.29	1.97	.31	.81	.20	–	–	–	–	–	–	–	–	16.49	1.80
Keora	–	–	1.62	.33	1.21	.45	3.24	2.33	2.43	2.80	1.01	1.61	–	–	9.51	7.53
Baen	0.61	.05	1.62	.32	–	–	–	–	–	–	–	–	–	–	2.23	.37
O. Tree S.	0.40	.02	.20	.04	–	–	–	–	–	–	–	–	–	–	.61	.06
Total	***53.57***	***5.40***	***14.17***	***2.74***	***3.24***	***1.00***	***3.64***	***2.55***	***2.43***	***2.80***	***1.01***	***1.61***	–	–	***78.06***	***16.1***

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V Rvilla, Istiaq Uddin Ahmad DCF (RIMS) & MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Table-6.25Stand and Stock table by species Group of Mangrove Forest in Sundarbans Compartment–46 (Total Area 10759.50 ha) Forest division : NT (No of trees/ha), Vol. (Volume in Cu m/ha)

Species Group	Tree by Diameter class															
	15-20		20-25		25-30		30-40		40-50		50-60		60+		Total	
	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol.	NT	Vol	NT	Vol.	NT	Vol.
Sundri	1.36	.13	.19	.03	–	–	–	–	–	–	–	–	–	–	1.56	.17
Gewa	5.55	.43	.58	.08	–	–	.44	.13	–	–	–	–	–	–	6.58	.64
Keora	4.55	.34	–	–	–	–	–	–	–	–	–	–	.19	1.10	4.74	1.35
Baen	.97	.07	.97	.14	.39	.10	.39	.24	1.22	.98	.39	.51	1.17	3.90	5.50	5.94
Other Tree S.	5.12	.45	6.38	1.07	6.38	1.71	6.80	3.06	1.56	1.17	.19	.23	–	–	26.44	7.68
Total	***17.55***	***1.42***	***8.14***	***1.32***	***6.77***	***1.81***	***7.63***	***3.43***	***2.78***	***2.15***	***.58***	***.74***	***1.36***	***4.91***	***44.82***	***15.78***

Source: *Final Report- Forest Inventory of the Sundarbans Reserved Forest Annex Vol-2. –by J.A.V. Rvilla, Istiaq Uddin Ahmad DCF (RIMS) and MD Akbor Hossain DFO. Mandala Agricultural Development Corporation and Forest Department Feb-1998.*

Chapter -7

Human Interference on the Floral Species of the *Sundarbans*

Chapter –7

Human Interference on the Floral Species of the *Sundarbans*

7.0 Human Interference on the Floral Species of the Sundarbans

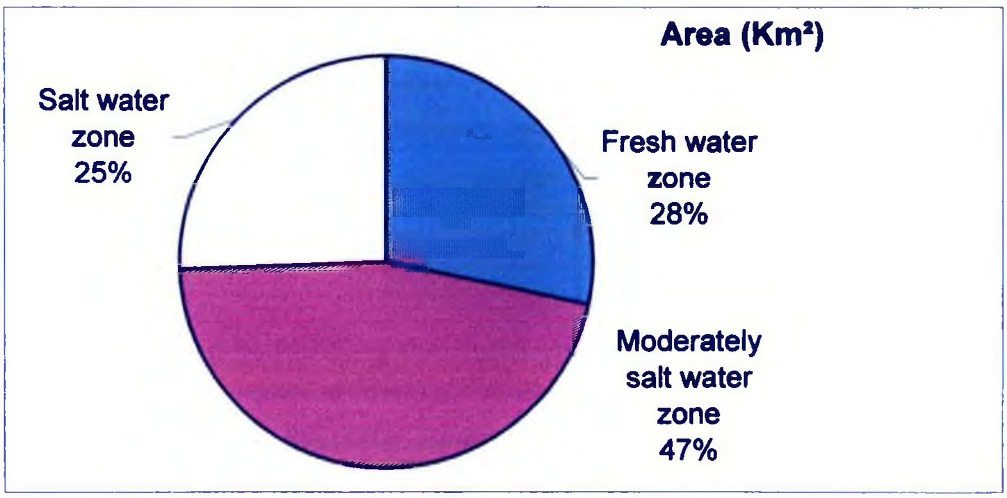
Mangrove forests are critical to the people and economy of Bangladesh *(Table-7.1)*. They supply fuel wood for domestic and industrial use, timber for industry and a range of other products. The forest is an integral part of the life cycle of many fish and shrimp species. The forest also contains many endangered species of global importance, including the Royal Bengal Tiger.

Table-7.1 Ecological zonation, characteristic species and main economic uses of the Sundarban mangrove forest.

Ecological Zonation	Area (Km^2)	% of forest area	Bangladeshi name	Main economic uses
Fresh water zone	1,124	28%	Sundri	Timber, fuel wood
Moderately salt water zone	1,823	46%	Gewa	Pulpwood, matchwood, baling board
Salt water zone	1,008	25%	Goran	Fuel wood

Source: ESCAP, 1987, after Chaffey, et al., 1985.

Graph-7.1 Ecological zonation in Area (%) of the Sundarban mangrove forest.



Source: ESCAP, 1987, after Chaffey, et al., 1985.

7.1 General Environment

The *Sundarbans* with its vast wealth of natural resources always attracted people from different parts of country as well as from abroad for multi-various economic interests. On the on hand, there are pirates, poachers and plunderers looting the scarce resources of the forests. On the other, slowly groups of people like Bawalis *(wood cutters)*, Mouals *(honey harvesters)*, grass cutters, fishermen and mollusk shell collectors converged in the area for exploiting the forest resources on which their livelihood depends. They are aware of the hazards of the forest life.

Traditionally, these forest dwellers possess the indigenous instinct and knowledge of their forefathers. They face various natural calamities like tidal surges, cyclones, rains, scorching heat, and humidity. They have to traits of poisonous snakes, wild boars, crocodiles, man-eating tigers and the pirates. The Bawalis, Mouals, grass cutters, fishermen, have to know about the tidal movement.

Bawalis, receive seasonal permits from the local forest offices, which allow them the harvest mainly the Gewa trees for paper and pulp industry. Although they move in a group, they take high risk as they enter the forest and live in make-shift houses for months in isolation.

Mouals are seasonal professionals who work for three or four months inside the forest during the flowering season. Honey collection season start s on the first day of April with an assembly prayers at Burigoalini range office. The Mouals perform the most dangerous profession. They walk bare-footed over the shula-ridden jungle floors and swim across the creeks and canals in high risk. Every year, a few of these Mouals are killed by tigers.

The Jailas, or the fishermen come to the *Sundarbans* from the neighboring districts. Offshore fishermen are almost strangers having little interaction with the forest people, while the onshore fishermen are part of the forest dwellers. The fishermen constitute the largest forest dwelling community, about 48 percent of the total forest dwellers.

The forest dwellers pay homage to certain gods and deities whom they thought to be their saviors and protectors. The popularly worship the Banbibi, Gazi Shaheb, Dakshin Ray, Pir Badar, etc.

Photograph - 17 : Illegal Lumbering in the Sundarbans : A Common Science of Human Interference in the Mangrove Eco-system

7.2 Impact of Human Ecology: (Population density, Increase, Distribution)

Sundarbans provides livelihood to about 3,00,000 people working as wood cutter, fishermen, honey collectors, Golpatta leaves, thatching grass and other minor forest produces collectors. Apart from the large number of people employed by the contractors and traders in commercial capleitation of timber and other forest produces, the local people or the people surrounding the Sundarbans and dependent on this forest for various necessities of life for timber fuel wood , boat building materials, house posts, rafters, house building materials, Golpatta leaves, sun grass, redetect. For thatching and roofing, grain for tanning fishes nets, honey wax, lime from shell, various fresh and dried fish etc.

Mangrove species can tolerate salinity up to a certain limit but they grow better if the supply of fresh water from above is abundant. If the salinity of water and soil increase, at first the quality of the trees deteriorates and then they start to die and ultimately disappear. With the decrease of the flow of light and fresh water from the upland main rivers there is always a corresponding increase of the upward flow of heavy salt carrying sea water. If the salinity of water increase due to evaporation during the dry months, there is heavy concentration of salt on the surface soil. All mangrove species have peculiar root developments. The roots do not go very deep into the soil, but spread laterally.

7.3 Encroachments of Agriculture

Agricultural Encroachment has already occurred to a limited extent on the northern and eastern boundaries and with increasing pressure in surrounding settled areas, could reach serious proportions unless checked. Fishermen's camps are a major source of disturbance and there is extensive illegal hunting and trapping. The small population of Estuarine Crocodiles remains under pressure from illegal hunting for the skin trade.

Table-7.2 Thana wise Sundarbans Forest Area surrounding Areas Occupation in percentage

Thana	Area (Sq. Km²)	Population	Sundarbans Forest surrounding areas/Thana Occupation									
			Agriculture	Agricultural labor	Non Agricultural labor	Forest	Fisheries	Transport	Business	Survices	Pc Culture	Others
Shamnagar	1964.24	265004	32.93%	25.81%	6.21%	2.34%	5.50%	1.61%	10.11%	3.38%		12.11%
Koyra	1774.41	165473	43.39%	20.42%	4.59%	3.21%	4.98%		9.46%	2.90%		11.05%
Dacope	991.58	143131	46.95%	17.26%	4.84%		2.38%		9.48%	3.44%	2%	13.26%
Mongla	1461.22	137947	21.41%	12.41%	13.39%		6.23%	1.94%	15.09%	16.27%		13.26%
Sarankhola	756.61	107856	32.94%	11.96%	7.32%	8.65%	4.27%		14.14%	5.78%		14.94%

Source: Integrated Resource Development of the SRF Khulna, Vol-1, FAO/UNDP project, Karim, 1995.

The mangrove forest also has an important buffer function, protecting the density settled agricultural areas to the north from the full force of cyclonic storms and tidal waves. Some of this storms cause a tremendous amount of damage.

7.4 Expansion of Settlements

About 3,00,000 people are working as wood cutter, fishermen, honey collections, Golpatta leaves, thatching grass and other minor forest produces collectors etc. The large number of people employed by constructors and trader of wood and other forest produces. The local people surrounding the Sundarbans depends their forest for various necessities of life and local shrimp culture. Agricultural encouragement has already occurred to a limited extend on the northern and eastern boundaries with increasing pressure in Sundarbans surrounding, settled areas, fishermen camps are a major source of disturbance and their is extensive illegal hunting and trapping.

Photograph-18 : Encroachment in Sundarbans by Mans : Illegal Temporary Settlement at Dublar char, Sundarbans

Mangrove forest of Sundarbans is very beautiful and charming scenery area. Maximum tourist person wanted to enter the Sundarbans forest area. Maximum resources are gathered in the Sundarbans surrounding areas people. This people made their house, re4staurent & hotel, different place and they cultivate their agricultural crops and shrimp culture. For this purpose, people are increasing day by day. Before 20-50 years ago Sundarbans and surrounding area was not much communication. At present, maximum people entered Sundarbans and surrounding area easily or smoothly. For this, various people settle this area.

Table-7.3 Population attributes in Sundarbans districts

Name of Districts	Household No	Household Size	Male Population	Female Population	Literacy (District)	Literacy Male	Literacy Female
Khulna	374848	5.3	1054633	956010	43.86	52.16	34.56
Satkhira	290921	5.47	812214	784964	30.54	39.73	21.00
Bagerhat	275246	5.19	732709	698622	44.33	49.54	38.86

Source: BBS Community Series.

7.5 Pollution in the Sundarbans

Bangladesh's major center for industry is at Khulna in the middle of the south-west region, and as we have seen the rivers near to Khulna were subject to large salinity changes. The increased salinity had 'injured the industrial sector'. In particular, it asserted that serious industrial disruption occurred because a power station, paper mills and jute processors were unable to use highly saline water, or used it and suffered damage. The causes of increased salinity have been discussed above; the evidence suggests that the Farakka withdrawals were to blame.

The urban centers in the coastal districts is Khulna, population 601,000. Most coastal industry is located in these centers. Both are important centers of raw material processing. Mongla is important Sea Ports that handle the bulk of export and import commodities. Important to Khulna are the paper and wood industries, which rely on the *Sundarbans* mangrove forest for raw materials.

7.6 Other Environmental Interference

The main treat to the Sundarbans come from both man-made interference in the form of tree cutting and over fishing as well as some encorachment. However the bigger treat comes from reduced flows of freshwater through the Ganges river system over the last few decades particularly during the dry season which has led to a definite inward migration of the salinity front causing the different species of plants and animals to the adversely affected.

The phenomena of top dying of Sundri trees is ascribed in part to the increased saltwater intrusion. A large part of the reason for this reduction in freshwater flows can be ascribed to upstream withdrawals from the Ganges both in India and in Bangladesh. However by far the major effect has been due to the diversion of the water at Farraka in India. The impact of climate changes will be to make the salt water wedge move further upstream and together with lower stream flows the freshwater vegetation's will be deplete rapidly. The rate of saltwater instruction will also affected the ability of the ecosystem to adapt. The higher climate change scenario will not allow enough time to adapt.

Future changes to the ecology of the *Sundarban* due to climate changes, sea level rise and continued resource exploitation could affect the forest ability to reduce the tidal and wave energy from the Bay of Bengal. Although it is clear that the sensitivity of the Sundarban to future environmental change have been increased through gradual increases in salinity and unsustainable resource management, no accurate predictions of future change to the *Sundarban* have been made.

7.6.1 Changes in Sundarbans Ecosystem

The *Sundarbans* is managed under sustained yield for more than 100 years. Harvesting of timber in the recent past, Geomorphological changes, increased salinity etc, have affected the Sundarbans eco-system. Top dying of Sundri trees in some compartments is bringing changes in the floristic composition. Harvesting of shrimp fry in large quantity is causing immense damage to fish population.

The dominant biological feature of mangrove ecosystems in a relatively low degree of species diversity, especially of plants, compared with neighboring tropical communities *(forests, savannas, or grasslands).* Generally speaking, mangroves are trees and bushes growing below the high water level of spring tides.

Photograph- 19 : Sunset in Rushmela in Dublar char, Sundarbans

7.6.2 Erosion and Siltation of the Sundarbans

Erosion and compensatory accretion are occurring continually along the banks of all larger rivers, but the rivers of the *Sundarbans* are more stable than the main streams of the Ganges *(Das-1985).*

7.6.3 Forest Exploitation

The lean season flows in the Padma cannot reach any part of the *Sundarbans* and the Farakka withdrawals cannot thus have harmful effects on forestry in Bangladesh. The Sundarbans demonstrated that during the six month dry season, precipitation falls short of evaporation and transpiration by 20 inches. This water is made up the rivers and Khals of the area but, in the dry season, water levels are at their lowest and the brackish water becomes increasingly saline as upstream flow reduces. The authors commented that if the freshwater flow were to be reduced further than normal the equilibrium of the forest could be destroyed. The forest showed evidence of recent extensive damage in localized areas, through the damage appeared to have been initiated at some previous time, possibly as long as five years ago and deterioration of the forest was continuing. Three possible causes of deterioration were cited: insufficient freshwater, increased salinity and chlorinate , and insufficient nutrients.

Photo-20 : The Primary Economic Activity in Sundarbans : Gathering of House Building Material (viz. Golpatta) from the Mangrove

7.6.4 Shrimp Culture

At present the forest ecosystem of this forest has been destroyed and shrimp culture has been developed the whole area except some poor patches of mangroves among the banks of the canals. Shrimp farming has been expanding rapidly. At present, as a valuable foreign exchange earning commodity of Bangladesh, Shrimp ranks third. Shrimp yield, per unit area from the coastal aquaculture ponds are very low; the weighted average for all shrimp growing areas about 120 kg/ha. Shrimp farms are primarily located in Bagerhat (29%), Satkhira (19%), Khulna (19%) and Cox's Bazar.

In *Sundarbans* region, maximum (50% approx.) of the shrimp farms is of the 'Bheri' type. 'Bheri' or 'gher' is an area impounded by earthen dyke with facilities for exchange of tidal water, managed alternately with rice cultivation from August to December, and shrimp and fin-fish culture from January to July *(Das-1990).*

7.6.5 Cyclone & Storm in Coastal Area

Cyclone storms are an important features of Bangladesh climate and have caused great suffering to people and damage to structures in the cyclone path. The presence of mangrove forest along the coastal areas act as shelter-belt against cyclone and tidal bore. A fact proved any doubt during the last cyclone and tidal bore that battered the coastal zone in Bangladesh.

Two different types of cyclones form in the Bay- one is the tropical cyclone, which forms during the pre and post monsoon season, and the other is the monsoon depressions which develops during the SW monsoon season. Dynamically they are different. Tropical cyclones are the most destructive. Some example of them the May 1985 Urir Char cyclone, the November 1970 cyclone.

Cyclones generally cause damage in three ways:

1) *Storm surges,*

2) *Flooding due to excessive rainfall and*
3) *Wind blowing away house and ships.*

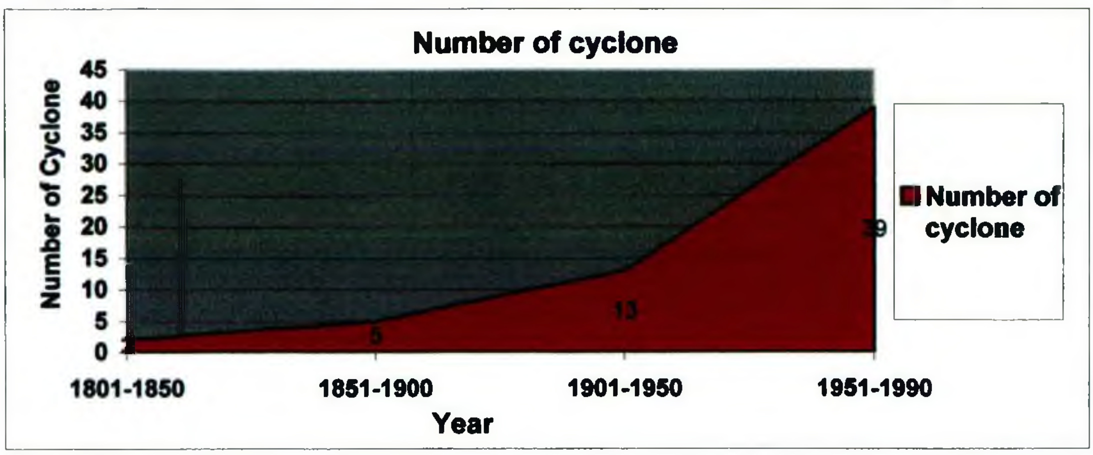
About 905 of cyclone causualties are caused by storm surges generated by cyclones *(Das-1990).* Comparatively a more destructive and a less predictable natural disaster that hits the coastal region is tropical cyclone. It causes an enormous damage to property and loss of life in the coastal region every year. In fact, the damages by cyclones are caused by strong winds associated with it and by the tidal waves or storm surges. During the last 190 years, tropical cyclones hit the coastal region for about 59 times. A fifty years interval frequency of cyclone occurrence shows that the number of cyclones is rapidly increasing over time. During the period cyclone attacked the Sundarbans coast 16 times *(Nazem-1990).*

Table-7.4 Major cyclone storms hit in the coastal region of Bangladesh during 1801-1990

Period	Number of cyclone
1801-1850	2
1851-1900	5
1901-1950	13
1951-1990	39
Total	**59**

Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. – Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

Graph-7.2 Major cyclone storms hit in the coastal region of Bangladesh during 1801-1990

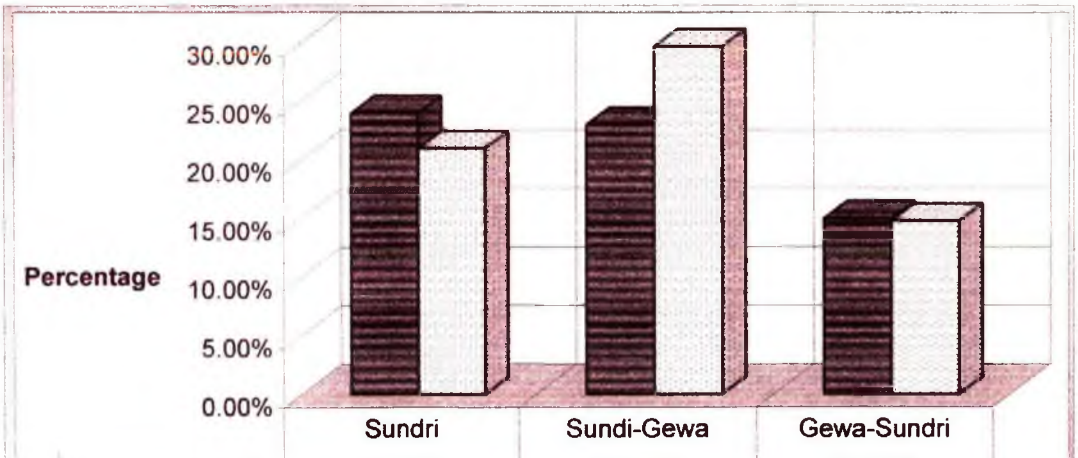


Source: *Salinity problems and crop intensification in the Coastal Regions of Bangladesh. – Z.Karim, S.G.Hussain, M.Ahmed-1990. Dhaka. BARC.*

7.6.6 Blast & Top dying of trees of the Sundarbans

The *Sundarbans* is an ancient mangrove forest. It is not known accurately when the forest appeared first but is understood that it is about 2000 years old. There have been varied degrees of human encroachments to the forest from time to time. Sundri and Gewa are the most important commercial tree species of the *Sundarbans*. Sundri top dying trees were sporadic around 1933. Preliminary study made on the incidence of Top-dying of Sundri trees suggest that taking as whole of the forest types in which Sundri is the major species, approximately 17% of the stem are moderately or severely affected by Top-dying. The area in Gewa-Sundri forest in which Gewa rather than Sundri is predominant species has remained almost same (table-7.3). Sundri is the characteristic species of the fresh water and Gewa is that of the moderately saltwater zone of the forest.

Graph-7.3 Comparison of the cover type area is percent



	Sundri	Sundi-Gewa	Gewa-Sundri
Forestal (1960)	24.00%	23.00%	15.00%
ODA (1985)	21.00%	29.70%	14.80%

Source: ESCAP, 1987, after Chaffey, et al., 1985.

Chowdhury (1968) reported the occurrence of Sundri top dying severity of the problem drew attention of many concerned persons in 1973. *Gisbon (1975)* failed to point out the cause of the disease. Quantitative data regarding the extent of top dying was presented by *Cliffey et al. (1985)*. An attempt was made to correlate Sundri top dying with soil salinity. Withdrawal of Ganges water at Farakka was, in his opinion, one of the possible causes for the increase in salinity in the *Sundarbans*. Severely affected top dying areas are, in fact, distributed in slightly saline to non saline zones as presented by *Claffey et al. (1985)* and shown in table-7.5. Small number in fig-7.01 indicate BFRI's sampling sites while the large number indicate compartment numbers *(Hassan-1990).*

Top dying as stated by different workers may be due to pathological or edifice reasons. Siltation in the eastern part of the *Sundarbans* has possibly accelerated since the completion of polders in the coastal areas. This might have caused a change in the hydro-ecological condition of the region. Top dying starts with a decline or death of foliage and twig. Gradually the symptoms of infection extend downward. This gives a stag header condition to the affected trees *(Gibson-1975).*

Photo- 21 : Top Dying Disease of the Sundarbans : Epidemic of Floral Species due to increase in Salinity in the Mangroves

The distribution of top dying trees in 2099 sample plots, as was observed by *Claffey et al.(1985)* are summarized in table- .

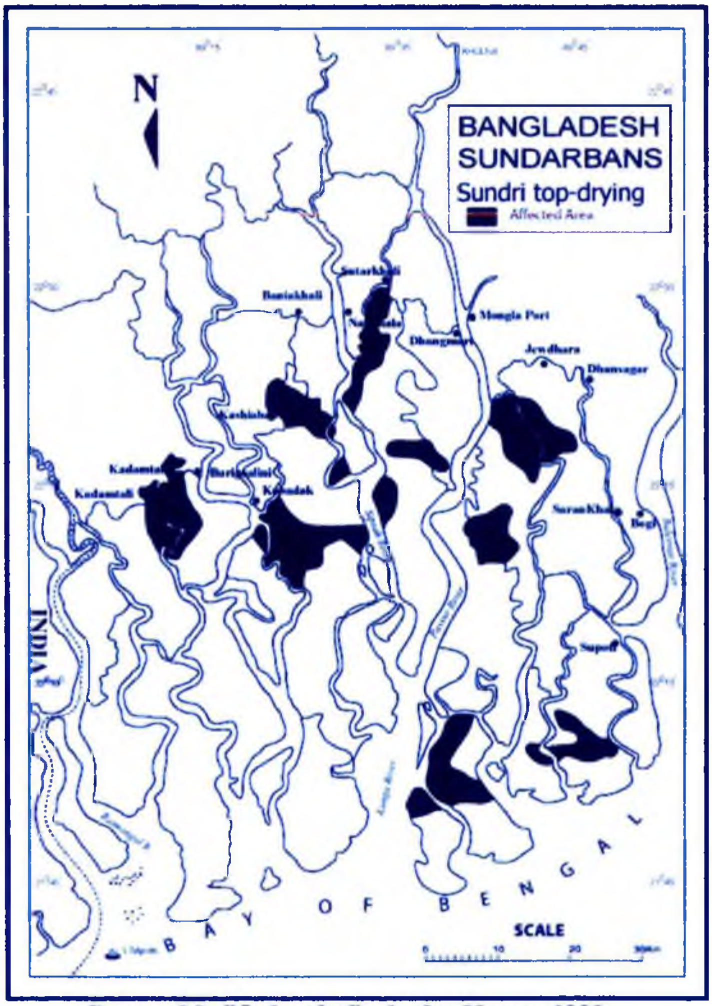
Table-7.5 Percentage distribution of top dying affected Sundri trees in four ranges

Trees affected (%)	Sarankhola Range (%)	Chandpai Range (%)	Khulna Range (%)	Burigoalini Range (%)
Sample plots not having Sundri as a major species	***26***	***30***	***17***	***74***
>70	1	1	2	3
<70->40	3	5	7	8
<40->10	37	29	40	10
<10	33	35	34	5
Total	**100**	**100**	**100**	**100**

Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri- Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong,1990.*

Notes: > equal to or more than, < less than.

Fig 7.01 Sundarbans showing the top dying of Sundri



***Source: Modified and edited after** Hassan-1990,*

7.6.7 Salinity effects

In the South-west, salinity levels are likely to change in the polders due to sea-level rise and increased rainfall. However, because sea level rise will act to increase salinity, whereas increased rainfall will act to decrease salinity, the net effect on polders and other agricultural areas is uncertain.

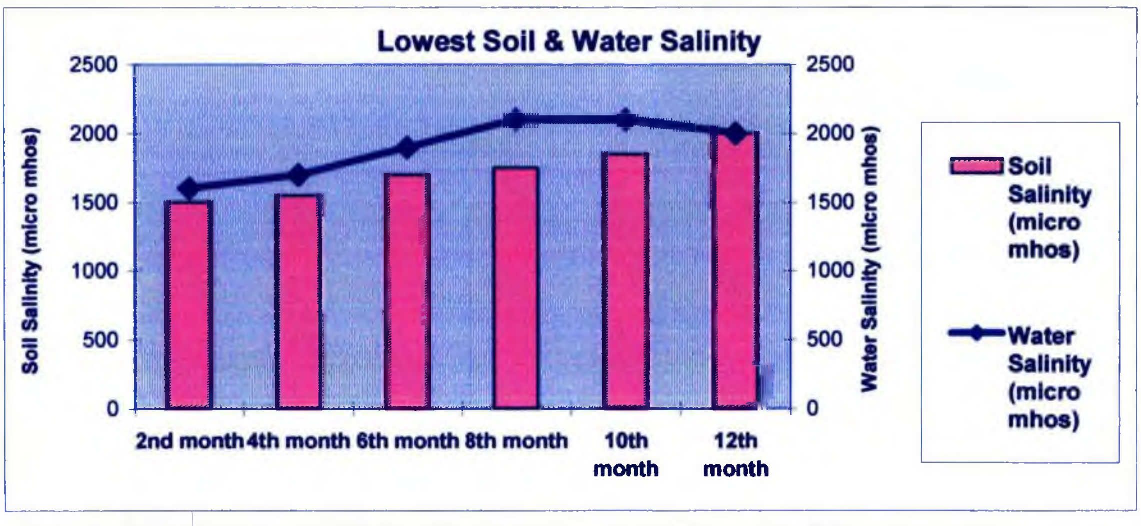
Mangrove forests seems less likely upland forests to benefit directly from the conjectured temperature and rainfall. For mangrove species, seasonal changes in levels of soil and water salinity appear to be more critical.

Table-7.6 Effect of Salinity on regeneration (Month wise)

Period	Soil Salinity (micro mhos)		Water Salinity (micro mhos)	
	Lowest Salinity	*Highest Salinity*	*Lowest Salinity*	*Highest Salinity*
2nd month	1500	4500	1600	44000
4th month	1550	5400	1700	46000
6th month	1700	5400	1900	48500
8th month	1750	6000	2100	49000
10th month	1850	7000	2100	48000
12th month	2000	7400	2000	49000

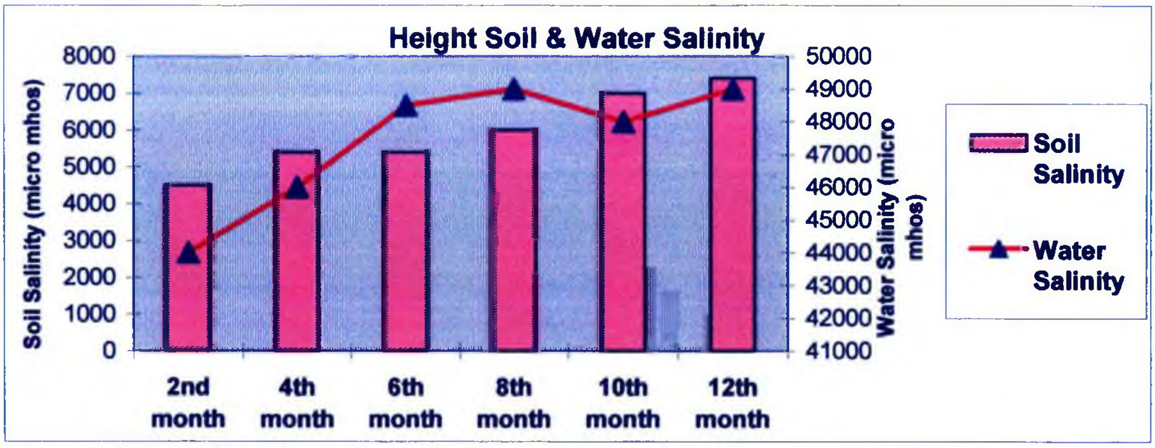
Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri- Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong, 1990. .*

Graph-7.4 Effect of Lowest Soil & Water Salinity on regeneration in Month wise



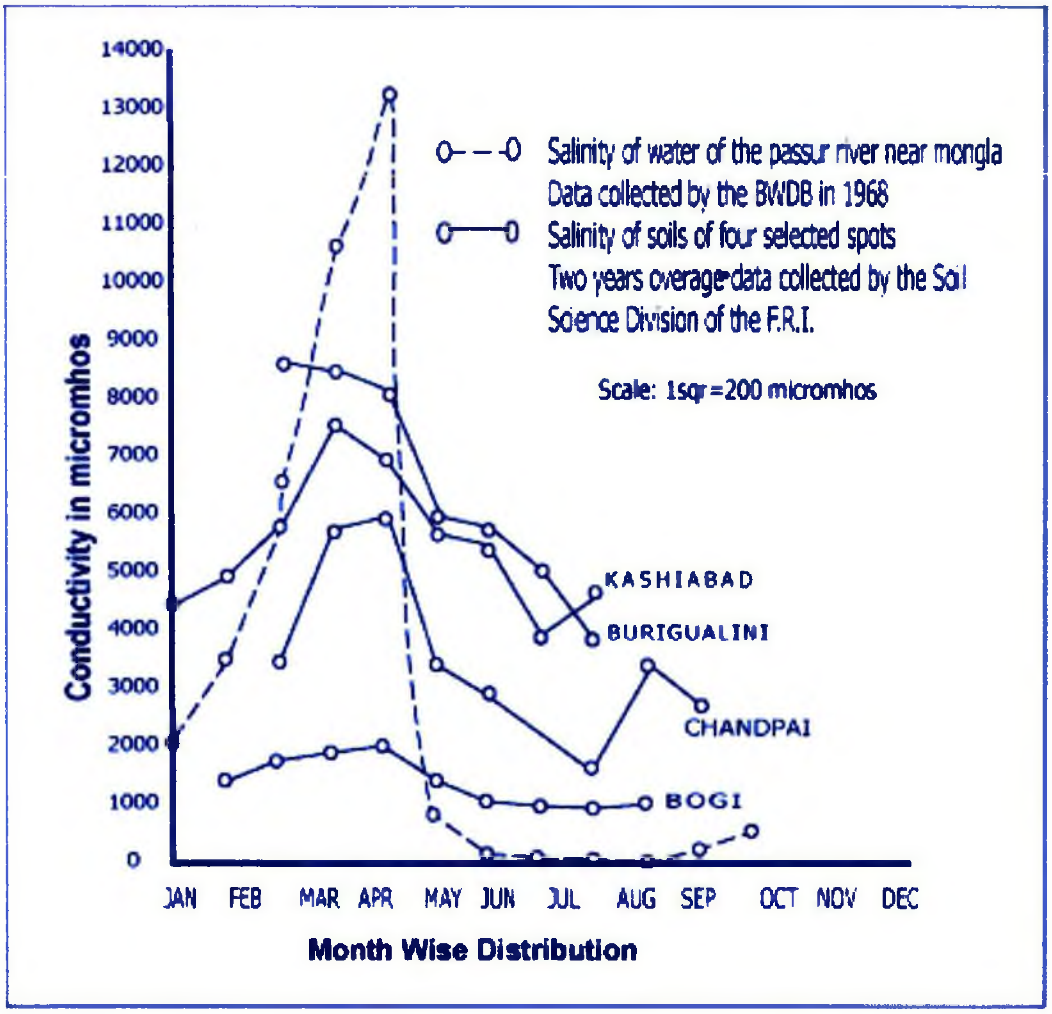
Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri- Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong, 1990. .*

Graph-7.5 Effect of Height Soil & Water Salinity on regeneration in Month wise



Source: *Soil hydrology and Salinity of the Sundarbans in relation to Top dying, regeneration and survival of Sundri- Hassan, Mazumder, Nurul & Emdad, BFRI, Chittagong, 1990. .*

Graph-7.6 Graphic representation of the seasonal flexion of salinity in Sundarbans (Soil & surface water).



If salinity levels were to increase due to a rise in sea level or to a continuing diminution of dry season flow in rivers passing through the forests, salt-tolerant species, such as Goran and Keora presently living near the sea, would be expected to advance inland at the expanse of the species *(especially Sundri)* more tolerant of freshwater conditions which presently occupy interior parts of the Sundarbans. On the other hand, if increased river discharges were to push back the present isohalines, especially in the dry season, then the species succession would be in the reverse direction.

The rates of natural species succession that could occur under pressure of environmental changes are also uncertain. So is the outcome of the conflict between the accretion of sediments on existing land during a rise in sea level and so maintain the status forces tending to submerge or erode land as sea level rises and those tending to cause quality.

7.6.8 Effects of Farakka withdrawal of the Ganges of the Sundarbans

The effects of withdrawal of the Ganges water at Farakka, seasonal and annual changes in soil salinity at Bagi, Chandpai, Kassiabad and Burigoalini are being monitored by Bangladesh Forest Research Institute (BFRI).

The west coastal zone has three distinct sub-zones defined by distinctive physiographic characteristics- the *Sundarban* mangrove forest, the saline tidal floodplain *(Ganges tidal plain),* and the non- saline tidal floodplain *(Ganges tidal plain).*

Chapter -8

Critical Application of Different Government Development Programme in the Sundarbans

Chapter -8

Critical Application of Different Government Development Programme in the Sundarbans

8.1 Forest Control and Planning in the Sundarbans

People roam unhindered in deep forests of the *Sundarbans*. There is no opportunity for men to have a permanent habitation in the *Sundarbans* and there is no dwelling in the forest except the various offices of the forest department. But numerous people use the forest to earn their living. A publication of the *Sundarban* study group shows that 50,000 people visit the *Sundarbans* everyday. In the winter this number is believed to double. A set of statistics show that the number of bawalis engaged in cutting Golpata and timber is no less than one and a half lake. Bawalis gathering honey and bees wax number about 8 thousand. About 3 thousand people are engaged in gathering snails and oysters. 16 thousand workers are engaged in cutting trees and sawing timber. People connected with the timber business number one lakh 15 thousand. Besides, people of other trades depending on the *Sundarbans* number at least 10 thousand.

8.2 Transport System Development

All the market places noted above have one common feature in that they are approachable by water routes. They are located on navigable rivers and Khals. The *Sundarban* forests are traversed by a number of distributaries of the Ganges, which in their turn have split into innumerable channels before entering the sea. The channels again are interwoven by a network of Khals. Some of these Khals which join two rivers are called Bharani and are very suitable for transport particularly those which run east to west.

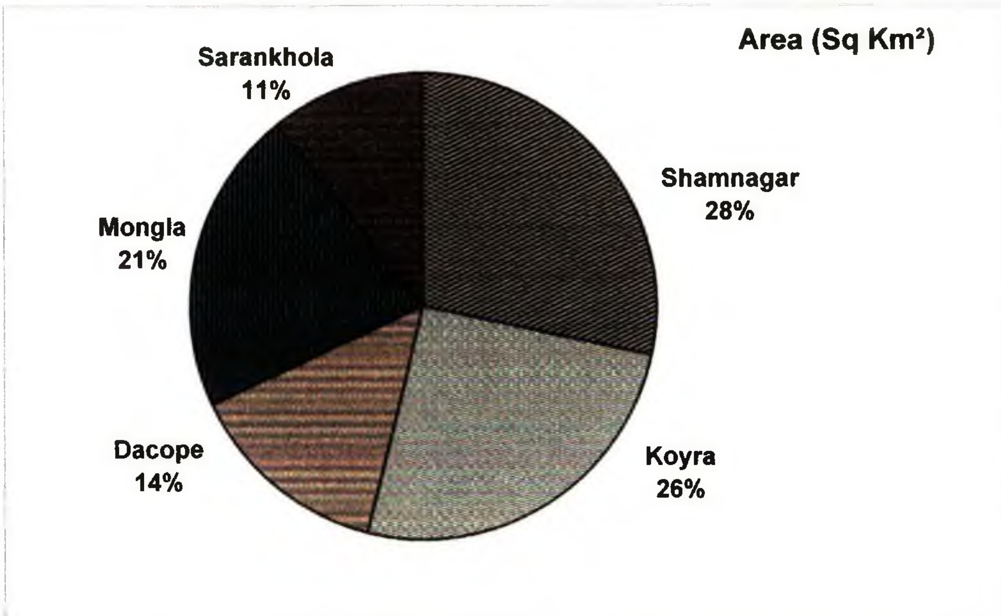
The notable stream in the *Sundarban* area the Baleswar, Rupsha, Passur, Sibsa, Arpangasia and Raimangal. The mouth of these streams are too rough. The boats dare to pass across these mouths only during the winter months when the weather is calm. For these routes the Bharani Khals are very helpful. A few of them are specially suitable to serve well frequented routes.

Table-8.1 Transport System Development in Thana wise

Thana	Area (Sq. Km²)	Pop^n in 2001	Sundarbans Forest surrounding areas/Thana wise Communicati0on system			
			Metalloid road	Semi-Metalloid road	Un metalloid road	Waterways (Nautical mile)
Shamnagar	1964.24	265004	67	35	811	73
Koyra	1774.41	165473	72.88	--	466	--
Dacope	991.58	143131	11	43	307	57
Mongla	1461.22	137947	17.50	23.50	211	130km
Sarankhola	756.61	107856	25	34	150	--

***Source**: Forest Department (Based on devre moss 1994 and forest department record).*

Graph-8.1 Area Distribution (percentage} in Sundarbans Forest surrounding areas/Thana wise



Source: Forest Department (Based on devre moss 1994 and forest department record).

8.3 Eco-Tourism Development

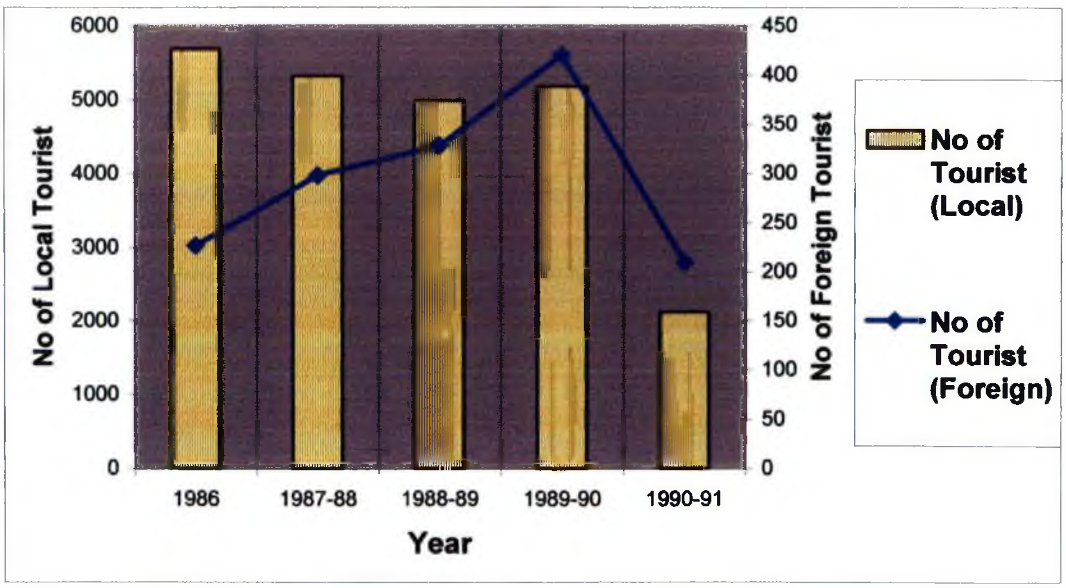
The vastness of *Sundarbans*, the types of the forest with mangrove species having spatial features, the remoteness from the habitation, the wilderness, the creeks and revolute, wildlife and sandy beaches are all elements of recreations inside the *Sundarbans*.

Table-8.2 Number of tourists Visiting Sundarbans Reserved Forest by Year

Year	Number of Tourist			Revenue Tk. (in lack)
	Local	Foreign	Total	
1986	5687	227	5914	5000
1987-88	5318	298	5616	10000
1988-89	4982	328	5310	19500
1989-90	5172	420	5592	41000
1990-91	2117	210	2327	53000
1991-92	4595	291	4886	32500
1992-93	7115	271	7386	72500

Source: Forest Department (Based on devre moss 1994 and forest department record).

Graph-8.2 Number of Local & Foreign tourists Visiting Sundarbans Reserved Forest by Year



Source: Forest Department (Based on devre moss 1994 and forest department record).

Photograph- 22 : Tourism in the Sundarbans : Tourist Rest-house at Katka inside *Sundarbans*

Photograph- 23 : Foreign Tourists in the Sundarbans : Prospect for a booming Eco-tourism in the Mangroves

Sundarbans a place of plateful of deer and tigers, varieties of birds and monkey, morning and evening symphony of wild fouls add to the attraction of *Sundarbans*. Crocodiles bushing in the Rivers banks are attraction to the visitors. Vast expenses of grassy meadows facing the sea provide opportunities for wild tracking. Beach resting with the Bay of Bengal gives the study bed to the sun batches.

The entire *Sundarbans* is a place of attraction for a local as well as foreign visitors, yet there are some places which are famous for crocodile, some for deer and some tiger. *Sundarbans* has not been developed as yet as an ideal tourist spot.

A scheme entitle "Creation of recreation centers in *Sundarbans*" has already been prepared and submitted. The scheme if approved an implemented will develop some place of *Sundarbans* in to a recreation center. This will meet a longstanding demand of the people interested to visit the forests *(Das-1990)*.

Lack of good communication and transport facilities and acute shortage of drinking water are the added problems in the management of the *Sundarbans*. Due to its unique nature, there exists a vast potential for development of eco-tourism in the Sundarbans.

8.4 Preservation of Vegetation System in the Sundarbans

The coastal mangrove forests are the multi-use natural resource of significance to the entire economy of Bangladesh. The *Sundarbans* of the west coast is the largest natural single area of mangrove in the world, covering 587,000 hectares. (fig-..) The formerly extensive Chakaria *Sundarban* of the east coast now cover less than 1000 hectares due to felling for salt pans and shrimp ponds. Another 104 to 109 thousand hectares of coastal land were planted with mangrove under the Afforestation Project. The mangrove forests supply fuel wood, timber and a range of other products. The *Sundarbans* also contains many endangered species of global importance, including the Royal Bengal Tiger.

Photo- 24 : Wildlife Watch-Tower at Hiron Point inside Sundarbans

8.5 Attraction of the Sundarban Reserved Forest

The SRF as a whole offers a unique set of attraction or "hooks" with the potential to draw visitors from all over the world. Among some of these are-

- The world largest contiguous mangrove forest and the singularity of the *Sundarbans* ecosystem.
- Large variety of visually accessible wildlife.
- Presence of charismatic mage fauna including the Royal Bengal Tiger, Estuarine, Crocodile and Ganges River Dolphin.
- The River Boat experience.
- *Sundarbans* cultural and history- the intimate connection between people and natural resource.

Photo- 25 : The Majestic Royal Bengal Tiger in Sundarbans

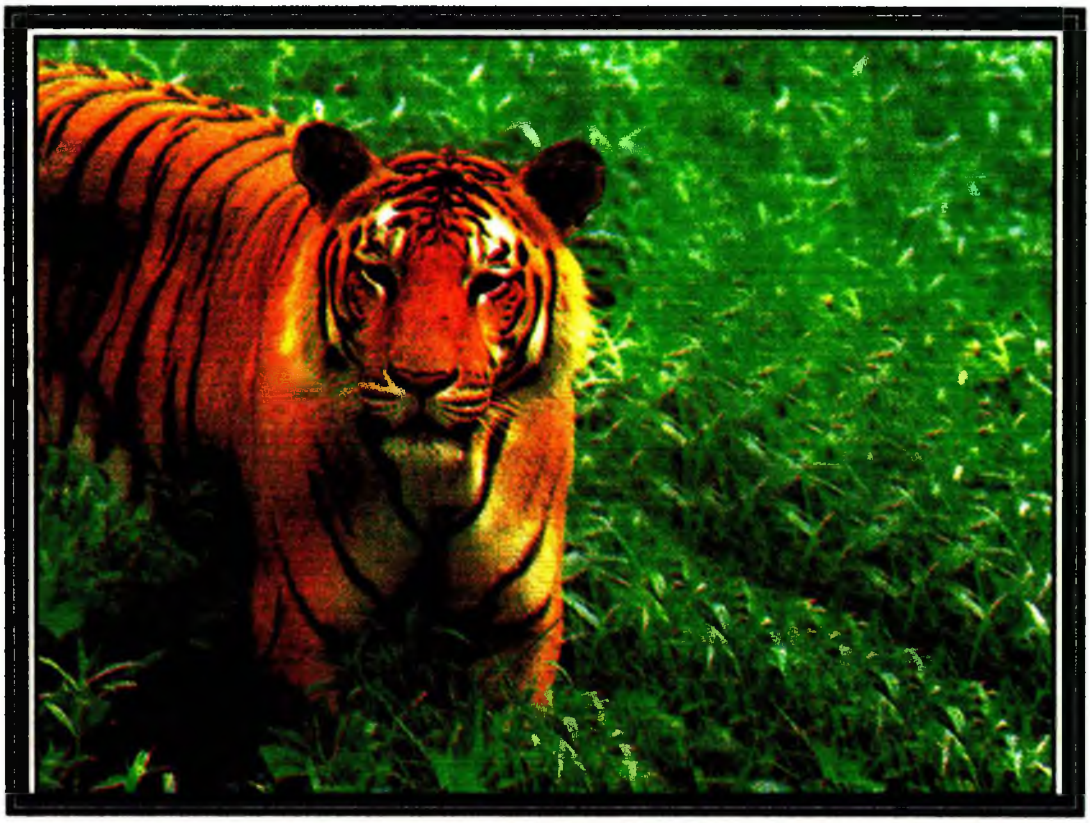


Photo- 26 : Sundarbans Spotted Deer are drinking water at Katka Forest Rest-House

Those areas of the SRF that offer the most immediate and future potential for tourism, in their order of importance are-

1. Katka Kochikhali for its beautiful Khals its flora fauna and proximity to the Bay of Bengal.
2. Mandarbaria Island for its seclusion and while sand beach.
3. Nilkamal as a main entry point of the SRF.
4. Sekhertek and Bari temples for their cultural and historic values.
5. Dubla Island for the fishing season during the Rash Mela.
6. The impact zone, for the unique cultural and economic activities of the local communities depend on the *Sundarbans*.
7. Karmajal mangrove visitor and interpretation center as a main entry point to the SRF.
8. Other SRF entry point including Andaria Bill, Champion and the Khulna visitors information center as well as Burigoalini and Sarankhola where as yet there are no facilities.

The following are important species events *(Cultural events, festivals or natural phenomena)* in the SRF that have potential to attract visitors to the area.

-Dubla Rash Mela.

-Honey collection.

-Other fishing, Hilsha fishing.

-Golpatta harvest.

-Grass cutting.

-Shell collection.

-Ridleyturtle nesting.

-Fire files.

-Bioluminescence.

8.6 Re-plantation in Surrounding Areas of the Sundarbans

The present stocking of *Sundarbans* can be improved by undertaking plantation activities at the following four types of sites within the forests:

- Natural blanks and sites covered up by useless species or weeds;
- New accretion on the banks of rivers;
- Sites adjacent to the localities due to pressure;
- Sites where the Sundri has started die back.

The blanks created due to the above causes need to be planted up with suitable species *(Das-1990).*

Normally mangrove plant species come naturally and successively and some species become stable. The land newly formed, if left undistributed will gradually start bearing a plant community. The first colonizer that will come naturally is Dhanshi, then some years later some mangrove bushes will appear. Depending on the soil condition, Sundri, Keora, Baen, Gewa and other plants will occupy the land, ultimately the dynamic mangrove ecosystem becomes established. The whole process of succession, however will take thousands of years. Afforestation, therefore could assist this mangrove succession.

8.7 Bio-Diversity Conservation in the Sundarbans

The coastal mangrove ecosystem that cover nearly 6.0 m. hectare of natural and 100,000 hectare of planted mangrove forest are the habitats of nearly 245 genera and 334 species of plants. The Khulna *Sundarbans* is the major habitat of many species of birds, amphibians, reptiles, mammals, primates and 250 species of fishes.

It is also the most important habitat of the globally endangered Royal Bengal Tiger. The present population of the Royal Bengal Tiger in the *Sundarbans* is nearly 450. This covers nearly 10 percent of the world's tiger population.

Conservation of the bio-diversity and the ecosystems leading to sustainable productivity is of great importance in view of the apprehended global climate and demographic changes. In Bangladesh, only a portion of the biological resources has been surveyed, characterized, and screened for scientific and economic values. Vast stocks of bio-diversities here the disappearing every moment due to negligence, ignorance policy deficiency and to serve the vested interests for a portion of its population. Ecosystem management apart from the role in conservation of genetic resource and bio-diversities provide climate, socio-cultural and economic contributions.

Chapter -9

Conclusion

Chapter -9

Conclusion

Natural phenomena especially, the geomorphological and hydrological situation of the surface of the Sundarbans – the largest mangrove forests of the world have enormously influenced the nature, type, distribution and composition of the floral species of the forests. The present study highlighted some of the features of the forests with special reference to the correlation between plant-composition and geomorphological and hydrological situation in different parts of the forests. The study clearly reveals that the bio-diversity of the forests is on the verge of collapse. The peculiarity of both the floral and faunal species along with their rich natural habitats have gradually been decaying. Both the natural and human interference are on increase there. Increasing human incursions and encroachments in the virgin forests have worsely been destroying the purity of the mangrove eco-system of the Sundarbans. A great number of people (i.e. around 3.0 millions) depends upon the forest-resources for their livelihood. Encroachment in the forest is inevitable and obvious for the facts that for the agriculture, habitation and collection of fodder and fuel viz. wood, - the land, trees, timber, honey, fish and house-building materials the Sundarbans is the only resort to the local inhabitants.

The economic importance of this *Sundarbans* forest lies in its exploitation and use. The *Sundarbans* provides timber, pulpwood and raw materials for industries and fuel wood for a large number of people. Match factories in Khulna and in other places of the country depend largely on *Sundarbans* raw materials. Apart from timber and wood as row materials for industrial and household use, there is a timber of other resources, like Golpata, Hental, grass, honey, beeswax etc. available in plenty in the *Sundarbans* areas. The economic value of these resources has never been evaluated for their further development *(Nazem-1990)*.

9.1 Major Finding

Mangrove forests are one of the most productive and bio-diverse wetlands on earth. Direct human impacts are further worsened by the less-readily detected but perhaps more menacing impacts which threaten the mangrove ecosystem. Massive changes in both the adjacent agricultural lands and upstream areas with construction of polders, embankments or barrages are feared to have been generating fundamental changes in the geomorphological conditions hydrological regimes of the *Sundarbans*. Changes have been taking plan in the floral distribution due to those changes in the morphological and hydrological scenarios.

The changes of freshwater flushing are visibly caused by the gradual eastward shift of the flow of the Ganges river. It is believed that the changes affecting the salinity, intensity of flooding, water logging, erosion, siltation and sedimentation may all be factors for perplexing and worrisome loss of the world's largest mangrove system of the Sundarbans.

The findings of the study reveal that the changes in slightest heights of the surface of the land and little changes of the hydrological situations viz. quantity and quality of waters can greatly effect the distribution of floral species. The composition of the species as well as the density of the forests (viz. the total occurrence of each of the species of plants per unit of land) noticeably depend upon the height or elevation of the land. For instance in the Sundarbans –the lower and regularly inundated surfaces occupy the thickest concentrations of forests. On the other hand, from and findings of the study, it is evident that the higher the land-levels -the lower the accumulations of the plant-species. However, the intensity of salinity of the forest soil and the tidal water may change the situation in place to place.

With respect of the decay of the Sundarban it is observed that many factors contribute to the loss of mangrove forest i.e. the charcoal and timber industries, legal and illegal logging, oil spill, tourism industries, unplanned development projects, urban growth pressures and mounting pollution problems—all different types of human interference. However, one of the most recent and significant causes of mangrove forest loss in the past decade has been the consumer demand for luxury shrimp, or "*prawn*", and the corresponding expansion of destructive production methods of export-oriented industrial shrimp aqua-culture along the forests belt.

The hydrological changes in the Ganges water regimes due to the commissioning to Farakka and the subsequent the decay in the discharges of the distributaries, the salinity of the *Sundarbans* is increasing – particularly in the western region. Although the role of the change in the water regime is not yet clear, but is evident that it has greatly been influencing the population of wildlife and vegetation in the region.

9.2 Problems and Prospects

Finding of the present study reveals that the extent of salinity penetration in the southwestern coastal region of Bangladesh is the result of the decrease of freshwater supply from upstream and the intensity of tidal influxes. This has appeared as a for the whole of the Sundarbans and its adjoining greater Khulna and nearby region. Salinity concentration varies not only diurnally and seasonally but also yearly. During the dry season the withdrawal of Ganges flow, associated with some climateological factors like low rainfall and high evaporation act together in favoring salinity intrusion further inland. It has been deteriorating for the last few years and thus part of the coastal region becomes unsuitable for irrigation by river water due to high saline. The construction of coastal embankment possibly has further complicated this problem.

Salinity water has already created problem for paper Industry, agricultural production and municipal supply. The depletion of some critical nutrients such as molybdenum and potassium from the estuarine soil as a result of increased salinity has brought about damage and degradation of mangrove and forest resources in the coastal region. The incidence of top dying of Sundri which seems to be increasing with rapid ecological changes rendering the site unsuitable for the species.

- High rate siltation making the rivers creeks shallow resulting in less fishing areas.
- Increase in salinity percentage in all creeks and rivers, which is detrimental to fish breeding.
- Catch of brood and immature fish in the estuaries.
- Lack of a comprehensive and integrated Management Plan. Accretion and erosion are two continuous processes in the *Sundarbans*. An accreting mangrove shore is a result of gradual sedimentation brought down by the rivers and progressive colonization of mangrove.

The *Sundarbans* afforded protection against cyclones and tidal surges. It is difficult to put a dollar figure to the protection accorded by the *Sundarbans* to the lives and properties of the people living in the hinterlands. The *Sundarbans* is important to fish living in the waterways and it serves as nursery ground for various species.

The *Sundarbans* mangrove is considered as the most productive of natural ecosystems in terms of primary productivity. The primary productivity essentially consist of mangrove tree productivity, productivity of epiphytes and benthic macro and micro algae and productivity of phyto-plankton.

The secondary productivity in the *Sundarbans* consists of productivity of terrestrial organism including herbivores, carnivores, bacteria, fungi and others as well as the productivity of the waters in terms of zoo-plankton as well as benthic productivity.

9.3 Recommendations

The present study is small venture in the researches of the natural environment of the Sundarbans. Of course, this will shed same light on the different unrevealed areas of the ecological environment of this largest mangrove forests of the world. In all considerations, it is established that the Sundarbans is endangered now. Initiatives have to be taken to save this invaluable natural resource, where the most precious member of the Cat-Family "the Royal Bengal Tigers" dwell in.

In order to improve the decaying condition of the forest and degrading land and waters of the Sundarbans – the following measures can be materialized immediately.

- *Sundarbans* administration should be reorganized. The massive tract of the divisions of *Sundarbans* should be broken into more ranges. Staffing pattern of the forest administration should be strengthened properly and reorganized scientifically.
- Initiations have to be taken to ensure the increasing and sufficient flow to the distributaries of the region from the stem-stream—the Ganges. In this respect Indo Bangladesh dialogue and regional (SAARC) and international co-operations (UNO, UNESCO) should be sought up.
- Increasing and indiscriminate human-interference including encroachment in the forests must be checked strictly.
- Forest act of 1927 should be amended immediately to effectively protect the forest throughout in Bangladesh. Initiative for pollution-control in Sundarbans should be taken-up properly.
- Forest officers in the *Sundarbans* should be vested with magisterial power to take on the spot decisions inside the remote forest areas. This will help to combat the dacoits and maintain law and order inside the forests.
- Controls and management of, aquaculture, a new parameter of mangrove management should seriously be considered.
- The *Sundarbans* deserve proper political commitment for its protection and development. This is a unique place of land and it should get proper attention of the nation.

9.4 Suggestions for Consideration & Planning

An integrated and appropriate environment- friendly planning for the conservation of bio-diversity of the Sundarbans Mangrove Forest is a must for the region. The Governmental, International and NGOs should come forward to achieve this Programme. Essential the local people should be incorporated with this ventures.

9.4.1 To Established Permanent Police Camp :

In order to check the illegal encroachment and punching of the wildlife of the Sundarbans sufficient police camps must be installed. Forest personnel's should be equipped with sufficient modern appliances to be check the illegal encroachers and poachers in the forests. Mobile police and forest-vigilance teams should work properly.

9.4.2 NGO Activities man & Forest Development

NGOs --- both local and international can play important role in the development and conservation activities in the Sundarbans region. They can help the local inhabitants by providing small and medium credits funds for generation of income that will refrain them from depend upon the forest-resources for their living. At the same time NGOs can train-up and educate the local people regarding conservation and development related aspects.

9.4.3 Increase of water Flow

In order to keep the forests alive and healthy the flow of freshwaters fauna the up-stream in the distributaries of the Sundarbans is a must. In order to maintain the optimum supply of fresh-water flow in the Sundarbans all possible initiatives have to be taken. Regular dredging of the distributaries, control of siltation of the feeder channels and increase in the share of water from the Ganges through the Farakka Barrage from India must be ensured.

9.5 Concluding Remarks

The study is based on the analysis of topographical maps interpretation, of aerial photographs and satellite imageries of different points in time. The ancient forest area of Sundarbans in 1876 has been used as the base map and to compare the subsequent changes in the coastal regions in Sundarbans at Bangladesh, the other maps viz. SPARRSO's map and other recent maps. Aerial photographs and satellite imageries has also been consulted and studied for the present study. These base materials have been to same scale on draw forming.

The analysis of different maps of the Sundarbans area shows some morphological and hydrological characteristics of the south western area in Bangladesh. Based on analysis and interpretation of topo-sheets aerial photographs and satellite imageries the spatio-temporal shifting in the Sundarbans and other coastal features have studied. The proposed study is planned to investigate the possible geo-mechanical responsible for such change, as well as to visualize its impact on geomorphology and geo-environment of the Sundarbans region.

The Sundarbans forest is a storehouse of several industrial raw materials. The *Sundarbans* forest is located in a region where copious rainfall takes place hence the regeneration of plants is an easy matter. As the area is open to the attack of cyclones from the south, at times damage is caused by these storms. But the forest absorbs this shock considerably.

In fine, this must be understood by all that, the Sundarbans, the World's Mangrove Forests is the green Lung-area of Bangladesh. A health and sound Sundarbans can help supply the life-saving environmental ingredients to the nation if we succeed to keep this Lung fresh and health. It is our prime responsibility to keep it save and sound.

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Dainik Muktakhanta, 19/1/99, 7/1/99, 03/05/99.

Dainik Ittefaq, 04/02/99, 05/04/91, 29/11/99, 26/11/99, 09/12/97.

Dainik Janakhanta, 28/09/96, 05/06/98, 19/07/98, 05/06/98, 12/03/99, 21/05/99.

Dainik Sambad, 18/08/93, 28/12/93, 21/01/97, 01/02/97, 06/07/97, 12/04/98, 07/05/99.

Dainik Inquilab, 18/06/99.

Dainik Matribhumi, 13/03/99.

Dainik Purbanchal, 10/12/98, 02/01/99.

Dainik Pratham Alo,23/04/99, 02/12/99, 03/12/99, 18/12/99, 15/01/2000.

Dainik Janmobhumi, 04/02/99.

Dainik Lokosamaj, 16/02/99.

Dainik Gonosakti, 17/12/98.

Dainik Bhorer Kagoj, 01/12/96, 04/12/96, 22/11/97, 24/01/98, 18/08/98, 14/09/98, 27/02/99.

Dainik Ajker Kagoj, 07/11/97.

Daily Star, 04/02/99.

Daily Bangladesh Observer, 06/06/91, 09/01/92, 05/06/92, 29/05/94, 06/06/94, 07/06/94, 23/12/94, 04/01/96, 07/11/96, 23/01/97, 13/02/98, 14/02/98, 26/01/99, 28/02/99.

Appendices

Extra (Big & Less important) Tables

Other Documents

Appendices

Appendix-1

Table- ❶ Sediment concentration data of Sundarbans project area Sediment concentration ***(in mg/Litre)***

River/Khal	Name of the Observation station	Range	Nov 1993	Dec 1993	Jan 1994	Feb 1994	March 1994	May 1994
Dangmari Khal	Dhangamari	*Chandpai R.*	700		500	116.7	500	500
Mirgamari Gang	Chandpai	*Chandpai R.*	1200		1200		1000	600
Aroyaber Khal	Dhansagar	*Chandpai R.*	350				150	
Sonamukhi	Gewakhali	*Khulna R.*		300		83.1	1200	100
Sibsa	Nalian	*Khulna R.*		150		450	133	500
Bhadra	Kalabagi	*Khulna R.*			250	167	140	500
Tapamari Khal	Chalia Bogi	*Sarankhola R.*		100	125	20	20	60
Bhola	Sarankhola	*Sarankhola R.*	500				200	
Bhola	Supoti	*Sarankhola R.*	200				150	
Katka Khal	Katka	*Sarankhola R.*	400				125	
Mara Passur	Dubla forest ghat	*Sarankhola R.*	200					
Chunar	Kadamtala	*Satkhira R.*			66.7		1100	
Chunar	Burigoalini	*Satkhira R.*			300		800	
Kalindi	Kaikhali	*Satkhira R.*			200		700	
Kalagachia Khal	Kalagachia	*Satkhira R.*			200		1300	
Chunar	Munshiganj	*Satkhira R.*					1700	
Hangsharaj	Charak Khali			300			1200	
Hangsharaj	Patkushta			350		267	1000	
Shaiker Khal	Shaiker Khal			100			1600	
Chunkuri	Chunkuri Tahal Farry				66.7		700	
Kobadak	Kobadak F.O.	*Satkhira R.*			133		1300	
Ball river	Kokra-harani					200	1300	
Baniakhali Khal	Baniakhali	*Khulna R.*				200	70	250
Bhadra	Sutarkhali	*Khulna R.*				600	125	500
Koyra	Kassiabad	*Khulna R.*					80	60
Shakbaria	Khasitana						900	
Baleswar	Bogi	*Sarankhola R.*	500				80	
Firingi	Firingi				40			

Source: *Integrated Management of Ganges flood plain and Sundarbans Ecosystem BRAC. July 1998.*

Appendix-2

Table- ❷ : Area difference of compartment in 1926, 1985 & 1995 (Km²)

Compart ment No	Name of Compartment	Range name	Land Area in Km²			Water area	Total area
			1926	1985	1995	1995	1995
1	Ali Banda	Sharankhola	113.65	99.81	107.88	42.35	*150.23*
2	Marabhola	Sharankhola	55.40	54.67	55.59	7.03	*62.62*
3	Aruabindi	Sharankhola	57.47	55.59	57.82	6.13	*63.95*
4	Katka	Sharankhola	64.46	63.03	65.23	6.32	*71.55*
5	Supoti	Sharankhola	54.11	51.96	51.61	55.72	*107.33*
6	Tigerpoint	Sharankhola	96.82	72.49	79.39	101.77	*181.16*
7	Betmar	Sharankhola	125.04	106.78	114.96	69.44	*184.40*
8	Passur Island	Chandpai	145.24	130.17	138.07	54.75	*192.82*
9	Kaga Baga	Chandpai	133.59	130.05	132.30	31.35	*163.65*
10	Ghusiangara	Chandpai	61.87	59.22	60.49	13.47	*73.96*
11	Patakata	Sharankhola	56.96	56.54	56.61	11.67	*68.23*
12	Harantana	Chandpai Sharankhola	21.75 37.02	57.00	21.43 36.20	3.65 3.09	*25.08* *39.29*
13	Tambulbunia	Sharankhola	56.18	55.35	55.59	8.50	*64.09*
14	Kalamola	Chandpai	41.16	41.04	43.06	5.17	*48.23*
15	Chhota Siala	Chandpai	55.92	53.48	55.76	12.69	*68.45*
16	Neshankhali	Khulna	64.72	62.66	62.81	25.63	*88.44*
17	Tintukra	Khulna	84.92	75.68	76.93	59.28	*136.21*
18	Kaga	Khulna	134.10	119.80	126.76	67.26	*194.02*
19	Jalbunia	Khulna	82.84	78.03	79.36	26.96	*106.32*
20	Gawakhali	Khulna	80.26	77.94	79.07	11.36	*9043*
21	Charputia	Chandpai	46.86	45.51	46.47	9.94	*56.41*
22	Putia	Chandpai	46.60	46.83	48.32	9.29	*57.61*
23	Kankramari	Chandpai	38.06	36.86	38.23	4.01	*42.24*
24	Nangli	Sharankhola	52.30	50.73	53.32	7.39	*60.71*
25	Anwaber	Sharankhola Chandpai	15.02 30.03	43.05	45.84	4.05	*49.89*
26	Nandobola	Chandpai	38.32	36.81	38.26	5.43	*43.69*
27	Bhola	Chandpai	39.61	39.58	4078	1.38	*42.16*
28	Mirgamari	Chandpai	41.68	41.62	42.41	3.72	*46.13*
29	Sihikari	Khulna	46.34	45.56	44.27	11.73	*56.00*
30	Jungra	Khulna	50.48	49.06	52.31	5.59	*57.90*
31	Dhangamari	Khulna	64.46	65.57	64.43	14.56	*78.97*
32	Sutarkhali	Khulna	53.07	53.58	55.45	5.38	*60.83*
33	Hatdura	Khulna	50.22	46.58	53.33	13.17	*66.50*
34	Adasain	Khulna	53.33	51.93	47.85	7.39	*55.24*
35	Jaimuni	Khulna	68.09	62.42	65.79	2094	*86.73*
36	Gandarkhali	Khulna	74.04	70.39	72.23	12.49	*84.72*
37	Slanekhali	Khulna	58.77	57.44	58.06	10.51	*68.57*
38	Jafa	Khulna	68.86	65.01	63.50	19.78	*83.28*
39	Cheilabogi	Khulna	64.46	63.01	61.52	15.40	*76.92*
40	Mankidoania	Khulna	42.20	40.32	4084	16.17	*57.01*
41	Chalki	Khulna	76.63	70.92	71.37	18.92	*90.29*
42	Bal	Khulna	77.15	70.55	71.69	31.85	*103.54*
43	Sejkhali	Khulna	108.47	108.93	111.48	59.04	*170.52*
44	Dhundal	Khulna	116.24	87.02	89.46	190.90	*280.36*
45	Dubla	Chandpai	122.97	99.52	106.45	167.22	*273.67*
46	Kalagachi	Satkhira	119.87	110.51	111.30	37.87	*149.17*
47	Chunkuri	Satkhira	108.22	101.67	104.03	13.43	*117.46*
48	Kalindri	Satkhira	85.69	79.53	80.63	25.71	*106.34*
49	Athara Banks	Satkhira	121.68	112.63	115.48	33.06	*148.54*
50	Kokomari	Satkhira	82.07	75.44	19.03 60.49	12.94 15.35	*31.96* *75.84*
51	Malancha	Satkhira	102.78	94.50	34.60 60.71	12.13 20.03	*46.73* *80.78*
52	Megua	Satkhira	123.49	119.68	117.73	45.67	*163.40*
53	Puspakathi	Satkhira	87.25	80.50	82.59	28.05	*110.64*
54	Mandarbaria	Satkhira	169.83	127.44	124.72	171.52	*296.24*
55	Raimangal	Satkhira	192.61	164.45	160.37	186.01	*346.38*
Total			**4361.23**	**4142.59**	**4112.30**	**1891.56**	***6003.86***

Source: *SRF area, distribution and status of forest types from 1985 to 1995- M. Runkel &Istiaq uddin ahmad, 1997.*

Appendix-3

Table- ❸ Hydrological data of river in various locations inside *Sundarbans* (Mean ± S.E)

Sundarbans surrounding rivers /khal/various locations	Parameters					
	Salinity (ppt)		pH		FC (mhos/cm)	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
Dhansagar	3.4±.2	Insg	6.8±.1	7.2±.1	7.0±.1	Insg
Sarankhola	3.5±.2	Na	6.5±.1	Na	7.0±.1	Na
Supati	3.4±.2	Na	8.0±.2	Na	8.5±.2	Na
Kochikhali	12.5±.3	Na	7.8±.1	Na	21.0±.2	Na
Kalabogi	12.2±.1	1.0±.1	7.6±.1	7.5±.1	24.0±.2	1.0±.2
Kalirkhal	12.0±.1	0.5±.2	7.8±.1	7.0±.1	26.0±.4	0.5±.1
Hilsamari	19.0±.3	0.5±.1	7.6±.1	6.9±.1	35.0±.2	0.5±.1
Nilkamal	20.0±.2	1.0±.2	7.7±.1	8.0±.2	43.0±.4	6.0±.1
Kadamtala	19.0±.1	7.0±.4	7.7±.1	7.0±.1	43.0±.3	13.0±.2
Kukumari	21.0±.4	7.0±.1	7.5±.1	7.0±.1	51.0±.5	15.0±.1
Chanbaria	23.0±.5	10.0±.1	7.4±.2	6.9±.1	52.0±.4	21.0±.2

Source- *FAO/UNDP Project /BGD/ 84/ 056 by Dr Ansarul Karim.*

Insg=Insignificant. **Na** = Not available.

Appendix-4

Table- ❹ Hydrological data of river in various locations inside *Sundarbans* (Mean ± S.E)

Sundarbans surrounding rivers/khal/ various locations	Parameters							
	Cl mg/l		Ca Mg/l		K mg/l		Na mg/l	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
Dhansagar	1878±86	Insg	58±13	186	48±5	2.6±.3	1320±17	170±14
Sarankhola	1949±88	Na	59±15	Na	47±3	Na	1320±34	Na
Supati	1890±112	Na	60±16	Na	48±3	Na	1330±30	Na
Kachikhali	6936±202	Na	105±14	Na	172±18	Na	3920±213	Na
Kalabogi	6735±500	495±61	250±24	36±7	188±20	10.0±.2	4460±341	390±17
Kalirkhal	6558±500	188±93	204±25	21±6	266±78	3.0±.4	3760±213	220±26
Hilsamari	30316±183	235±69	380±42	25±6	250±21	7.0±.6	6120±170	250±28
Nilkamal	10836±126	578±94	380±34	40±8	240±26	16.0±.2	6360±170	480±14
Kadamtala	10576±520	3929±207	360±28	134±26	403±19	101±19	6000±330	2120±166
Kukumari	11497±202	3688±381	450±38	130±17	405±31	87±11	6480±168	2100±52
Chanbaria	12584±250	5550±460	405±14	175±38	330±86	151±43	7200±155	2940±250

Source: *FAO/UNDP Project /BGD/ 84/ 056 by Dr Ansarul Karim.*

Insg=Insignificant. **Na**=Not available.

Appendix-5

Table- 5 Distribution of Mangrove Species in Sundarbans different Salinity zones according to land-evaluation showing Area (ha), land-height & percentage of occurrences of Species combination

Forest Type	Fresh Water Zone (Height Wise)				Moderately Saline Water Zone (Height Wise)				Saline Water Zone (Height Wise)				Total Forest Area (Height Wise)			
	>15.00 m	*10.00-14.99m*	*5.00-9.99m*	*>5.00m*	*>15.00 m*	*10.0-14.99m*	*5.00-9.99m*	*>5.00m*	*>15.0 m*	*10.-14.99*	*5.00-9.99m*	*>5.00 m*	*>15.00 m*	*10.0-14.99m*	*5.00-9.99m*	*>5.00 m*
Sundri	53869	8169	422		7270	13190	57				43		61166	21359	522	
Sundri- Gewa	9977	43681	1003		608	47094	13499			201	350		10585	90976	14852	
Sundri- Passur	571	749			20	574			3		238		594	1323	238	
Sund-Pass-Kan	4468	1436				491	10				25		4468	1927	35	
Gewa		377	1091			2559	11749	60		113	2815	36		3049	15655	96
Gewa-Sundri	29	6746	13303	22	25	1353	24437			623	12009		54	8722	49749	22
Gewa- Goran			6			30	12433	15		314	23387	38		344	35820	53
Goran-Gewa						566	2569	42		92	53889	91		658	56458	133
Goran			8				518				8789				9315	
Passur- Kankra			220								1110				1330	
Pass-Kan-Baen			860								151				1011	
Baen			74				567				231				872	
Keora			392				2666				206				324	
Gewa metal											857				857	
Total Forest	**68941**	**61158**	**17379**	**22**	**7923**	**65875**	**68505**	**117**	**3**	**1343**	**104100**	**165**	**76867**	**128358**	**189978**	**304**
No Forest	1643				3461				1014				6118			
Total Forest Area	**149143**				**145863**				**106625**				**401631**			

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

Appendix-6

Table-6 Distribution of Mangrove Species in Sundarbans Fresh water zones according to land-evaluation showing Area (ha), land-height & percentage of occurrences of Species combination

Forest Type	Height 15.00 meters and above		Height 10.00-14.99 meters		Height 5.00-9.99 meters		Height 4.99 meters and below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri	53869	36.12%	8169	*5.48%*	422	*0.29%*		
Sundri- Gewa	9977	6.69%	43681	*29.29%*	1003	*0.67%*		
Sundri- Passur	571	0.38%	749	*0.50%*				
Sundri-Passur-Kankra	4468	3.00%	1436	*0.96%*				
Gewa			377	*0.25%*	1091	*0.73%*		
Gewa-Sundri	29	0.02%	6746	*4.52%*	13303	*8.92%*	22	*0.02%*
Gewa- Goran					6	*0.00%*		
Goran					8	*0.00%*		
Passur- Kankra					220	*0.15%*		
Passur-Kankra-Baen					860	*0.58%*		
Baen					74	*0.05%*		
Keora					392	*0.26%*		
Total Forest	**68941**	46.22%	**61158**	*41.01%*	**17379**	*11.65%*	**22**	*0.02%*
No Forest	Total Area – 1,643 (ha), % of total Sundarbans Forest Area – 0.41%							
Total Forest Area	**Total Area – 1,49,143 (ha), % of total Sundarbans Forest Area – 37.13%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

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Appendix-7

Table- 7 Distribution of Mangrove Species in Sundarbans Moderately Saline water zones according to land-evaluation showing Area (ha), land-height and percentage of occurrences of Species combination

Forest Type	Height 15.00 meters & above		Height 10.00-14.99 meters		Height 5.00-9.99 meters		Height 4.99 meters & below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri	7270	*4.98%*	13190	*9.04%*	57	*0.04%*		
Sundri- Gewa	608	*0.42%*	47094	*32.29%*	13499	*9.25%*		
Sundri- Passur	20	*0.01%*	574	*0.39%*				
Sundri-Passur-Kankra			491	*0.34%*	10	*0.01%*		
Gewa			2559	*1.75%*	11749	*8.05%*	60	*0.04%*
Gewa-Sundri	25	*0.02%*	1353	*0.93%*	24437	*16.75%*		
Gewa- Goran			30	*0.02%*	12433	*8.52%*	15	*0.01%*
Goran-Gewa			566	*0.39%*	2569	*1.76%*	42	*0.03%*
Goran					518	*0.36%*		
Baen					567	*0.39%*		
Keora					2666	*1.83%*		
Total Forest	**7923**	***5.43%***	**65875**	***45.16%***	**68505**	***46.97%***	**117**	*0.08%*
No Forest	**Total Area – 3,461 (ha) , % of total Sundarbans Forest Area – 0.86%**							
Total Forest Area	**Total Area – 1,45,863 (ha) , % of total Sundarbans Forest Area – 36.32%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report.*

Appendix-8

Table- 8 Distribution of Mangrove Species in Sundarbans Saline water zones according to land-evaluation showing Area (ha), land-height and percentage of occurrences of Species combination

Forest Type	Height 15.0 meters & above		Height 10.0-14.9 meters		Height 5.0-9.9 meters		Height 4.9 meters & below	
	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area	Forest Area in hectors	% of total Sun Area
Sundri					43	*0.04%*		
Sundri- Gewa			201	*0.19%*	350	*0.33%*		
Sundri- Passur	3	*0.00%*			238	*0.22%*		
Sundri-Passur-Kankra					25	*0.02%*		
Gewa			113	*0.11%*	2815	*2.64%*	36	*0.03%*
Gewa-Sundri			623	*0.58%*	12009	*11.26%*		
Gewa- Goran			314	*0.29%*	23387	*21.93%*	38	*0.04%*
Goran-Gewa			92	*0.09%*	53889	*50.54%*	91	*0.09%*
Goran					8789	*8.24%*		
Passur- Kankra					1110	*1.04%*		
Passur-Kankra-Baen					151	*0.14%*		
Baen					231	*0.22%*		
Keora					206	*0.19%*		
Gewa metal					857	*0.80%*		
Total Forest	**3**	***.00%***	**1343**	***1.26%***	**104100**	***97.63%***	**165**	***0.15%***
No Forest	Total Area – 1,014 (ha) , % of total Sundarbans Forest Area – 0.25%							
Total Forest Area	**Total Area – 1,06,625 (ha) , % of total Sundarbans Forest Area – 26.55%**							

Source: *A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*

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Appendix-9

Table- ❾ Total Household (H/H), Population and Literacy for the villages around the Sundarbans Reserve Forests (SRF)- (0-5KM, 5-10KM, 10-12KM)

Name of the village 0-5 Km.	H/H	Population	Literacy
Banisanta Union	2704	14777	31.8
Bogi	426	2405	50.0
Burigoalini	185	1060	24.1
Chila	640	3475	30.4
Dakshin Bedkashi	262	1528	24.6
Dakshin Sutalari	304	1202	80.8
Dhansagar	1058	5359	37.7
Dupadighi	556	2895	50.8
Gabra	372	2505	27.4
Guatala	359	1909	40.1
Hadda	-	-	-
Harinagar	370	2305	27.1
Jahajghat	-	-	-
Jewdhara	1322	7209	37.2
Kailashganj	951	5047	39.3
Kainmari	492	2850	59.0
Kamanibasia	144	938	37.0
Kassiabad	-	-	-
Kharma	923	4653	40.4
Koikhali	686	3859	34.8
Maharajpur	722	4291	29.2
Majerchar	-	-	-
Manikkhali	-	-	-
Mongla	-	-	-
Munshiganj	211	1228	29.2
Murelbad	881	4988	38.1
Nalbunia	199	1072	54.3
Nalian	843	4943	31.6
Natia Bhanga	-	-	-
Parshemari	380	2204	12.0
Rainda	2458	13942	45.0
Rajapur	1142	6344	39.2
Sarankhola	2404	12792	41.9
Sutarkhali	807	4689	34.5
Uttar Bedkashi	-	-	-
Sub- total	**21801**	**120469**	**1027.6**
Average	**622.88**	**3441.97**	**29.4**

Name of the village 5-10 Km.	H/H	Population	Literacy
Arjunpur	188	1275	32.8
Bagali UP	5149	30262	37.5
Bajua	1302	7418	47.5
Bhasandal	344	1813	38.5
Dacope	522	3129	44.9
Eswarpur	615	3167	33.1
Garakhali	456	2869	28.2
Gadkumarpur	-	-	-
Haripur	197	1435	22.9
Makardhone	-	-	-
Mithakhali	363	2000	25.0
Patakhali	688	4203	22.5
Patanikhali	256	1556	40.9
Sreephakati	752	4137	36.6
Sub-total	**10832**	**63264**	**410.4**
Average	**773.71**	**4518.9**	**29.3**

Name of the village10-12 Km.	H/H	Population	Literacy
Kumarkhali	-	-	-
Mathbaria	-	-	-
Morrelgonj	839	4659	73.7
Sub-total	-	-	-
Average	-	-	-
Total (0-12 Km)	**67536.6**	**380086**	**3008.2**
Average	**1184.85**	**6787.25**	**53.71**

Total number of villages is 52. Some of the village statistics are not available. Results are calculated on the basis of BBS publication sources.

Source: Integrated Resource Development of the SRF Khulna, Vol-1, FAO/UNDP project, Karim, 1995.

Appendix-10

Table- 10 Sundarban Major Floral Species With different Height Variation at Mean Sea Level *(Meter)* in Area *(Hectors & Percentage)*

Major Species	Height .50m>		Height .51-1.00m		Height 1.01-1.50m		Height 1.51-2.00m		Height 2.01-2.50m		Height 2.51-3.00m		Height 3.01m<		Total Area of the Sundarbans	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sundri	6524	*1.58*	22663	*5.47*	28234	*6.82*	41073	*9.91*	42613	*10.29*	25541	*6.16*	4523	*1.09*	171171	41.32%
Gewa	26127	*6.31*	36210	*8.74*	29956	*7.23*	34905	*8.42*	19967	*4.82*	7233	*1.75*	1652	*0.40*	156050	37.37%
Goran	29483	*7.12*	11505	*2.78*	12879	*3.11*	10917	*2.64*	2324	*0.56*	680	*0.16*	--	--	4445	1.07%
Passur	3	--	25	*0.01*	169	*0.04*	784	*0.19*	949	*0.23*	2289	*0.55*	226	*0.05*	67788	16.36%
Baen	4	--	530	*0.13*	135	*0.03*	150	*0.04*	163	*0.04*	318	*0.08*	8	--	1308	0.32%
Kankra	--	--	--	--	66	*0.02*	618	*0.15*	576	*0.14*	1951	*0.47*	226	*0.05*	3437	0.83%
Keora	925	*0.22*	1600	*0.39*	405	*0.10*	218	*0.05*	188	*0.05*	114	*0.03*	10	--	3460	0.84%
Gewametal	10	--	--	--	05	--	--	--	--	--	--	--	--	--	15	--
Non Forest	1694	*0.41*	2467	*0.60*	341	*0.08*	845	*0.20*	250	*0.06*	934	*0.23*	75	*0.01*	6606	1.59%
Total	**64770**	***15.63***	**75000**	***18.1***	**72190**	***17.43***	**89530**	***21.61***	**67030**	***13.18***	**39060**	***9.43***	**6720**	***1.62***	**414300**	***100.00%***

Source- *Modified and edited after, Department of Soil Salinity, Govt. of Bangladesh & A Forest inventory of the Sundarbans, Bangladesh. 1985, - Dr Chaffey, F.R. Miller, J.H.Sandom. Main Report*