নিসর্গ নেটওয়ার্ক

PROJECT CONCEPT NOTE

COLLABORATIVE REDD+IFM SUNDARBANS PROJECT (CRISP)

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Government of Bangladesh
Ministry of Environment and Forests
Forest Department

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List of Acronyms

ACC	Annual Allowable Cut
ACF	Assistant Conservator of Forests
AFOLU	Agriculture, Forestry and Other Land Use
BA	Basal Area
C	Carbon
CCBA	Climate, Community and Biodiversity Alliance
CCBS	Climate, Community and Biodiversity Standards
CDM	Clean Development Mechanism
CEC	Cation Exchange Capacity
CER	Certified Emissions Reductions
CMC	Co-management Committees
CPG	Community patrol groups
CRISP	Collaborative REDD+IFM Sundarbans Project
DBH	Diameter at Breast Height
DOE	Department of Environment
DOF	Department of Fisheries
FAO	Food and Agriculture Organization of the United Nations
FD	Bangladesh Forest Department
FRMP	Forests Resources Management Project
FSP	Forestry Sector Project
FUG	Forest user group
GHG	Green House Gas
GOB	Government of Bangladesh
IFM	Improved Forests Management
IPAC	Integrated Protected Areas Co-management Project
IPCC	Inter-Governmental Panel on Climate Change
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature

LGED	Local Government Engineering Department
MOEF	Ministry of Environment and Forests
N	Number
NSP	Nishorgo Support Program
ODA	Overseas Development Administration (UK)
PDD	Project Development Design
PSP	Permanent Sample Plot
REDD	Reductions of Emissions from Deforestation and Degradation
RIMS	Bangladesh Forest Department's Resources Information Management System Unit
SFBZ	Sundarbans Forests Biogeographic Zone
SRF	Sundarbans Reserved Forests
SWMC	Surface Water Modeling Centre
UK	United Kingdom
UNDP	United Nations Development Program
USAID	United States Agency for International Development
V	Volume
VCR	Voluntary Carbon Reductions
VCS	Voluntary Carbon Standards
WB	World Bank

1. Project Overview

This document is a Project Concept Note (PCN) for a proposed reduced emissions from deforestation and degradation (REDD) and Improved Forests Management (IFM) project (hereafter referred to as Collaborative REDD+IFM Sundarbans Project, CRISP) under development for the Sundarbans mangrove ecosystem of southwestern Bangladesh. As such, it is a precursor to a formal Project Design Document (PDD) that may be submitted for validation under one or more of the international carbon standards being used for greenhouse gas (GHG) emissions reductions or removals within the frameworks of voluntary or (eventual) compliance markets for carbon offsets. Further development of the initial design presented in this Concept Note requires broader stakeholder consensus (including civil society and co-management committees) on proposed project activities, participatory monitoring systems, and finalization of community benefits distribution mechanisms. The CRISP is a proposed AFOLU project consisting of activities related to REDD and IFM in the project area through avoiding unplanned frontier deforestation and forests degradation, and improved forests management through conversion of logged forests to protected forests including protecting currently logged or degraded forests from further logging respectively.

The Collaborative Reduced Emissions from Deforestation and Degradation (REDD) and Improved Forests Management (IFM) for the Sundarbans Project applies co-management to conserve the country's 600,386 hectare Sundarbans Reserved Forest (SRF), the world's largest mangrove ecosystem, a World Heritage Site, buffer and barometer for climate change, and home to flagship species, the Royal Bengal Tiger. The project area is under the authority of the Government of Bangladesh (GoB) with the Forest Department (FD) responsible for its management and conservation under the Forest Act, and implemented through co-management with the 210 communities directly adjacent to and dependent on the SRF.

Main drivers of forest degradation and deforestation in the Sundarbans are combined anthropogenic and biotic pressures resulting in increased dependence on forests and wetlands resources. The large, dense and growing population in the reference region is highly impoverished and poor land productivity exacerbated by increasing salinity and incidence of tidal surge and cyclones increase dependence on neighboring forest and wetland resources. Weak forest protection enforcement exacerbates these adverse impacts.

CRISP addresses the identified drivers of forest degradation and deforestation through integrated and targeted project interventions including co-management between government and communities for the conservation and sustainable management of the Sundarbans combined with sustainable livelihoods development. Combined with a GoB moratorium on commercial felling, early progress of co-management has demonstrated significant success in reducing forest degradation and deforestation. CRISP intends to deepen and sustain these positive achievements by complimenting current project support with long-term financing through forest carbon markets. CRISP is unique because it addresses *inter-dependent objectives* of climate change mitigation and adaptation, biodiversity conservation, tiger conservation and sustainable livelihoods development for local community.

Climate change mitigation is achieved through reduced emissions and sequestration of GHG, carbon dioxide (CO_2) through a combination of avoided forests degradation and deforestation in the Sundarbans currently subject to mosaic forests degradation and deforestation as well as improved forest management through a permanent ban on commercial felling and rehabilitation of logged forests by bringing them under protected area status by designating as buffer zone to the three wildlife sanctuaries. *Climate change adaptation* is achieved by managing the Sundarbans forest as a natural buffer against increased incidence and impact of cyclones and tidal surge as well as potential sea-level rise and salination of agricultural lands and waters. Adaptation also includes working with local communities in the Sundarbans landscape zone to maintain embankments, extend saline resilient and tolerant food crops, and prepare emergency early warning systems.

Biodiversity conservation includes species and ecosystem protection. Key species for conservation include the Royal Bengal tiger (*Panthera tigris tigris*), Irrawaddy river dolphin (*Orcaella brevirostris*), crab-eating macaque (*Macaca fascicularis*), and other bird, fish, reptile, and other wildlife species. The Sundarbans is the last remaining habitat in Bangladesh for the Royal Bengal tiger, and provides home to a population of about 440, or about 10% of the world's last remaining tigers living in the wild. Key floral species includes sundari the occurrence of which is found decreasing over the period.

Sustainable livelihoods development provides alternative and sustainable livelihoods to the 200,000 people living in 210 villages in the Sundarbans landscape zone. This includes a conservation-linked value chain approach to manage sustainable utilization of the Sundarbans resources like honey and fisheries as well as intensification of agricultural land outside the Sundarbans with saline-resistant and/or tolerant crops. Alternative livelihoods opportunities are predicated on community commitments to support conservation of the Sundarbans.

CRISP's *co-management approach to forests conservation and sustainable development* builds off of the Government of Bangladesh's policy shift in conservation that codifies co-management as a means for sharing the rights, roles and responsibilities of forests protection and ecosystem conservation between government and resource-dependent communities. Both a national policy framework as well as a co-management platform for the Sundarbans is already in place.

A solid foundation for CRISP has been achieved through the collaboration of Forest Department and the USAID Integrated Protected Area Co-Management (IPAC) project (until May 2013) as well as the EU Sundarbans Environmental and Livelihood Security (SEALS) project (until December 2015) and GIZ Livelihood Project (until December 2015). These initiatives have prepared the institutional framework for co-management of the Sundarbans through development of recently approved Integrated Resources Management Plans (IRMP), the establishment of 4 CMCs representing all 210 target villages through Village Conservation Forums (VCF) and Peoples Forums (PF), conducting initial carbon inventories and analyses, and catalyzing early CRISP implementation. CRISP long-term financing requires BioCarbon Fund support to catalyze the sale of carbon credits by FD for the project implementation over a period of 30 years.

1.1 Title of Project

Collaborative REDD+IFM Sundarbans Project (CRISP)

1.2 Type/Category of the Project

The CRISP is a project currently being designed to meet the requirements of an Agriculture, Forestry and Other Land Use (AFOLU) project. Specifically, CRISP is hoped to qualify for consideration under the REDD category of eligible activities, in this case activities aimed at avoiding unplanned frontier deforestation and degradation, and IFM category, in this case activities aimed at conversion of logged forests to protected forests including protecting currently logged or degraded forests from further logging as defined in the Voluntary Carbon Standards (VCS) 2007.1 and VCS Tool for AFOLU Methodological Issues (published on 18 November 2008). This document is developed by largely following the approved VCS methodology : VCS Methodology VM0006 – Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation. The approved VCS Methodology VM0010 is employed for IFM. The CRISP is not being designed as a Grouped Project as defined in the VCS 2007.1.

The project area is entirely owned by the State, with the Forest Department bearing responsibility for its management and conservation under the Forest Act of 1927 and its amendments thereof. As part of nationwide efforts to implement new co-management approach, forestry officials have established community co-management councils and committees (CMCs vide the Government of Bangladesh Order No. Pa Ba Ma/Parisha-4/Nishorgo/105/Sting/398 dated 23 November, 2009) with the neighboring populations along the northern and eastern boundaries of the Sundarbans Reserved Forests.

1.2 Baseline Scenario

In a *without project scenario*, the total forest CO_2 and soil CO_2 stocks in the SRF are 204.8 and 90.4 Megatons respectively. Overall the forests CO_2 stocks are increasing (estimated over the period of 13 years, 1997-2010) at an annual rate of 4.81 ton/ha. However, this increase in forests CO_2e stocks is not uniform as over nearly 2/3rd of the SRF, the forest carbon stocks are increasing whereas over the remainder 1/3rd of the forests area (mainly on the northern periphery, adjacent to 210 project villages, where biotic pressure on the forests is comparatively high) the carbon stocks are decreasing.

The approved baseline and monitoring methodologies as per the VCS are applicable and so are employed. The CRISP is not mandated by any enforced law, statute or other regulatory framework. Given the status of the project area as reserve forests, the alternative to the CRISP would be deforestation and forests degradation. In addition to overcoming investment barriers, the project would generate alternative livelihoods benefits for the local communities through participation in forests conservation and sustainable livelihoods and monitoring activities, as well as enhancing the biodiversity of the forest ecosystems by promoting the habitats of globally unique flora including the sundari and fauna including the Royal Bengal tiger.

To demonstrate additionality of the proposed project, the project test under the CDM and the VCS is employed. Without the CRISP interventions, the state of past deforestation and forests degradation of the SRF is not expected to improve. The SRF including the three wildlife sanctuaries have been brought under co-management and REDD under the CRISP and as a result the GOB has agreed to contribute counterpart funding in order to utilize matching grant funds under the donors supported IPAC Project, SEALS Project and GIZ Livelihood Project. Though the support under these three projects will end by 2015, the policy shift brought by bringing the SRF under REDD has enabled the GOB to continue forests protection through co-management. But due to resource constraints, there are not likely to be adequate initiatives on the part of the GoB alone to sustain and enhance the SRF under REDD. As a result, the CRISP activities may not fully continue to occur in the absence of carbon finance. Moreover, in terms of investment barriers, the GoB currently lacks access to the international forest carbon markets, and with the exception of the IPAC, the SEALS and the GIZ Livelihood Project, there are currently no donor investment initiatives (under the World Bank NLTA some technical studies have recently been taken up in the Sundarbans, and some field interventions for wildlife protection are proposed in the three wildlife sanctuaries under a regional wildlife project with financial support from the World Bank).

As discussed, main factors that contribute to the deforestation and forests degradation of the SRF include inadequate forests protection, huge population that is growing, and local peoples' poverty and livelihood dependence on its natural resources. The project is working to mitigate these factors by following a co-management approach, resulting in strengthened forests protection and local community empowerment and livelihoods through CMCs. The FD field staff is being provided adequate support for enhanced forests protection by involving co-management organizations and other local stakeholders in the proposed project area and the reference region. Livelihood activities and capacity building of key stakeholders are continuing in order to address local community subsistence needs, skill development and self-employment.

1.3 Estimated GHG Emissions Reductions

Total greenhouse gas (GHG) emissions reductions or GHG removals due to CRISP accrue from I) REDD, II) IFM and III) mangrove forests soils, estimated as below:

I. Through REDD, CRISP is anticipated to generate GHG emissions reductions totaling 30,787,380 tons of forest carbon dioxide equivalent (CO_2e) during 30 years of the project implementation, compared to the baseline scenario. From the project area of 412,000 ha, the REDD program under CRISP will generate an average GHG reductions of 1,026,246 tons forest CO_2e annually over the 30-year project period. Due to the CRISP interventions the baseline forests degradation and deforestation, amounting to loss of 7.48 ton CO_2e per ha per annum, will gradually be reduced (anticipated to reduce deforestation and forests degradation with 1.5% annually) to stabilize forests to 1997 baseline level over the 30 years project period. Up to and including 2012, 2,052,492 tons forest CO_2e and up to and including 2017, 17,446,182 tons forest CO_2e will be generated as a result of the project interventions.

II. FD has historically been managing the SRF by following the sustained yield principle whereby only mean annual increment (mean annual growth) of the mangrove forests are harvested each year with a 20-years felling series formed in the 55 compartments of the SRF. This yield accruing in perpetuity due to commercial harvesting annually will no more be available when the current temporary ban on the commercial felling is made permanent as a part of important policy recommendation made in the Integrated Resources Management Plans that has on 5 December 2011 been approved by the Ministry of Environment and Forests (MOEF).

From IFM, CRISP is anticipated to generate GHG emissions reductions totaling 6,393,452 tons of forest CO_2e during 30 years of the project implementation, compared to the baseline scenario. From the project area of 412,000 ha, the IFM program under CRISP will save on an average of 213,115 tons of forest CO_2e annually over a 30-year project period. This means that up to and including 2012, 426,230 tons forest CO_2e and up to and including 2017, 1,491,805 tons forest CO_2e will be saved as a result of the project interventions. When compared to the credits accruing due to REDD as estimated above, the carbon credits due to IFM are relatively small but are included here due to important policy implication for the future management of the Sundarbans for climate change mitigation and adaptation. As this CRISP activity is mainly a one-time policy intervention, limited monitoring is needed as the GOB has already taken a final decision on making the ban on commercial felling as permanent by approving the IRMP vide their order no. PaBaMa/Parisha/207/Misc./2011 (Part-1)/139 dated 4 December, 2011.

III. Through CRISP, total annual soil CO_2e accumulation over the SRF is estimated as 105,655 ton. This means that up to and including 2012, 211,310 tons and up to and including 2017, 2017,739,589 tons of soil CO_2e will be added in the mangrove forests soils due to the project implementation.

By adding the above three estimates, the total annual GHG emission reductions due to the project implementation are estimated as 1.345 million tons CO_2e annually during the 30 years project period, 2011-2040.

Leakage is not a significant issue in the project area and the reference region as most of the FD owned forests fall within the project area only, and private homestead forests and mangrove plantations in the reference region are largely well protected by the private owners and FD staff respectively. However, an adequate risk buffer will be established in order to be able to compensate for the anticipated risk posed by non-permanence and whatever small possibility of leakage that may arise in future. As a low risk class, this buffer range could be as 10-15% as per the VCS guidelines, and so per annum 0.2 million ton CO_2e (15% of the total credits) will be kept into a pooled buffer account, thereby leaving voluntary carbon units (VCUs) amounting *1.145 million tons CO_2e annually* during the project period, 2011-2040.

1.4 Host Parties

The host party for the CRISP is the Government of Bangladesh, represented by the Forest Department (FD), the statutory body authorized, empowered, and accountable for the management of forests and forest lands held by the State. The Forest Department is one of the two technical departments within the Ministry of Environment and Forests (MOEF), established in 1865 under the Forest Act of 1865 for scientifically managing the Government forests including the Sundarbans, which was gazetted as Reserved Forest (hereafter referred to as Sundarbans Reserved Forests, SRF) in 1875 under the Act.

1.5 Background and Context

CRISP preparation was led by the protected area management specialist of the IPAC, who, also led the preparation of Integrated Resources Management Plans (IRMP), and collaborated technically with the USFS team for carbon inventory design, FD teams for conducting field inventories, and the soil division of the Bangladesh Forest Research Institute (BFRI) for conducting soil organic carbon analyses.

Forests in Bangladesh, which account for approximately seventeen percent of the country's land cover[1], harbor rich biodiversity as well as resources upon which millions of people rely for their livelihoods. Moreover, they are important sources of fuel[2], and other inputs needed for domestic, industrial, and commercial use, such as poles (e.g., for electrification purposes), pulpwood, and timber[3]. These factors, together with stressors such as population growth and urbanization, migration, and resulting changes in land use, have led to deforestation and forests degradation in many of the country's forest areas. According to the

[1] Bangladesh FD (2010: http://www.bforest.gov.bd/land.php).
[2] In 2010, the Food and Agriculture Organization (FAO) of the United Nations estimated that 70 percent of fuelwood use was for domestic purposes, 28 percent for industrial, and two percent for commercial. The same study reported that 100 and 70 percent of rural and urban households respectively use fuelwood for cooking (FAO 2000: 44).
[3] FAO (2000: 44-45).

Food and Agriculture Organization (FAO) of the United Nations, between 1986 and 1996 forest cover in Bangladesh decreased, with more than half of the medium to good density forests degraded to poor density forests, deforested, or encroached[4]. A recent report of the FAO (2011), however, national deforestation rate is estimated as only 0.2%, but this low figure indicates that good forests have already been degraded, resulting in low base.

In an effort to stem the deforestation and forests degradation, the Government of Bangladesh (GOB) has strengthened forests protection by revising the Forest Act of 1927, and placed 15 national parks[5], and 13 wildlife sanctuaries including 3 wildlife sanctuaries[6] in the Sundarbans under protected area status; these areas are legally protected under the Bangladesh Wildlife Preservation (Amendment) Act of 1974. Furthermore, in order to address the primary drivers of deforestation and forest degradation, and promote peoples' participation in the improved forest management of forest resources, the GOB has adopted a social forestry approach as laid out first in the Forestry Master Plan completed in 1993, followed by inclusion of social forestry in the revised Forest Act of 2000 and resulting Social Forestry Rules of 2004 and 2009.

This has facilitated collaboration between the GOB through the Forest Department and the local communities to enhance conservation, even while striving to meet the latter's consumption needs. A co-management approach has been institutionalized through the latest GOB order (No. Pa Ba Ma/Parisha-4/Nishorgo/105/Sting/2006/398 dated 23 November, 2009) whereby co-management councils and committees (CMCs) have been formed in the Sundarbans for co-managing the forests in partnerships with local community representatives.

Recently, in recognition of the risk that climate change poses to forests and the communities that rely on them as well as of their potential role in mitigation, the government has begun to explore means to access conservation and forest carbon financing opportunities by leveraging partnerships with key stakeholder groups through co-management organizations. The United States Agency for International Development (USAID) has supported these endeavors, first through the Nishorgo Support Program (NSP) and currently through the Integrated Protected Areas Co-management Project (IPAC). Part of USAID's support through IPAC has been a series of trainings offered to GOB (including FD; Department of Fisheries, DOF and Department of Environment, DOE) officials and NGO staff. While the first two in October 2009 and March 2010 focused on providing an overview of the international framework and introducing key concepts, the most recent writeshop in August 2010 was targeted at providing Assistant Conservators of Forests (ACFs) of FD and Assistant Directors of the DOF and DOE an understanding of the steps required to carry out a first approximation of forest carbon pools in their respective field areas and to develop draft profiles of the relevant social, economic, and environmental factors.

This concept note represents an important component in the broader context of Bangladesh's efforts to prepare for REDD by simultaneously beginning to identify the steps necessary to put in place an appropriate policy, and building local capacity to design, implement, and manage forest carbon activities.

The project concept note focuses on the Sundarbans Reserved Forests located in the southwestern part of Bangladesh. It is important to note that the development of this draft concept note into a project design document, and ultimately into a successful project will be contingent upon:

- Emergence of a real international market for REDD+IFM credits
- Development of a REDD policy framework including a strategy and a registry
- Approval by the local co-management entities, the Co-management Committees (CMCs) in the Sundarbans to be included in the project implementation and monitoring

[4] FAO (2000: 20-21).
[5] National parks are defined as "comparatively large areas of outstanding scenic and natural beauty with the primary object of protection and preservation of scenery, flora and fauna in the natural state to which access for public recreation and education and research may be allowed" (paragraph (p) of Article 2, the Bangladesh Wildlife (Preservation) Order (BWPO) 1973).
[6] Wildlife Sanctuary refers to "an area closed to hunting, shooting or trapping of wild animals and declared as such under Article 23 by the government as undisturbed breeding ground primarily for the protection of wildlife inclusive of all natural resources such as vegetation soil and water" (paragraph (p) of Article 2, BWPO 1973).

- Independent validation and verification of the project's baseline land use and carbon emission scenario as well as additionality generated under the with-project scenario
- Successful design and implementation of project activities, including the ability to work with local communities to stem the causes of deforestation and forests degradation that threaten the SRF and implement improved forest management practices
- Development of robust participatory monitoring and carbon accounting systems.

1.6 Project Aims and Objectives

The overall aims of the project are to achieve, through avoided deforestation and degradation, and improved forest management activities in the SRF, carbon sequestration with livelihoods improvements through community participation in forestry activities as well as conservation of flora and fauna species through measures including habitat protection and improvement.

The emissions reductions will be achieved through avoided deforestation along the frontier borders of the Sundarbans Reserve Forest and avoided forests degradation in selected forests areas subjected to mosaic deforestation and forest degradation. Improved forests management through conversion of logged forests including protecting logged or degraded forests from further logging will help reduce GHG emissions. CRISP has three objectives, which are to achieve the following:

1. **Climate:** to mitigate greenhouse gases through both emissions reductions and enhanced removals of carbon dioxide from the atmosphere. That is, to slow or reverse documented deforestation and forest degradation, and generating higher carbon intensities per hectare across more hectares through improved forests management.
2. **Community:** to assist the communities living within the 10 km zone of influence (hereafter referred to as the reference region or interface landscape zone) upon the project area by providing alternative livelihood options and conservation-linked value chain development to reduce forest dependency for daily needs and to ensure awareness raising and education facilities for adults and children to increase motivation about the importance of forests as well as carbon reserve for climate change mitigation and adaptation.
3. **Biodiversity:** to conserve the habitat for several Red List endangered species, including Royal Bengal tiger (*Panthera tigris tigris*), Irrawaddy river dolphin (*Orcaella brevirostris*), crab-eating macaque (*Macaca fascicularis*), and other important species of bird, fish, reptile, and other wildlife.

1.7 Project Activities

Carbon sequestration and emission reduction benefits, leading to improved forests management, will be attained through a suite of forests protection and conservation activities in the SRF. Main activities under IPAC include initial carbon inventory design (with US Forest Service) and field implementation (with FD), preparation of an Integrated Resources Management Plan; facilitation of the Sundarbans co-management platform including CMCs, Village Conservation Forums (VCFs), Peoples Forums (PFs) for forests protection; alternative livelihoods development for shifting biotic pressure away from the forests, climate change adaptation planning for building community and ecosystem resilience; and capacity building and training for improved biodiversity conservation, and forests protection and co-management. Main activities under the SEALS and GIZ Projects include forests protection, biodiversity conservation management as well as alternative livelihoods development for the communities dependent on the Sundarbans natural resources and climate change adaptation and mitigation.

1.8 Additionality Analysis

To demonstrate the additionality of the proposed project, the project test under the Clean Development Mechanism (CDM) and the Voluntary Carbon Standard is utilized. The proposed CRISP is not mandated by any enforced law, statute or other regulatory framework. Without interventions, the state of deforestation and degradation of the SRF is not expected to improve. However, due to resource constraints, there are not likely to be substantial initiatives on the part of the GOB to sustain and enhance the forest reserve. Moreover, in terms of investment barriers, the GOB currently lacks access to the international forest carbon markets, and with the exception of the IPAC and funding from SEALS and GIZ Projects, there are currently no donor funded initiatives in the SRF.

Given the status of the proposed project areas as reserve forests, the alternative to the proposed CRISP would be deforestation and forests degradation. In addition to overcoming investment barriers, the project would generate livelihoods benefits for the local communities through participation in forests conservation and monitoring activities, as well as enhance the biodiversity of the forest ecosystems by promoting the habitats of unique flora and fauna.

1.9 Project Participants

The Government has declared the co-management approach for managing protected areas through co-management councils and committees. The CMC is an authorized entity established from among nearby residents and other key stakeholders for the purpose of management including resource management planning and conservation responsibility of the Sundarbans. Members of the CMC are drawn from different strata of society, including local government, public representatives, concerned GOB departments, and others. The CMCs are working under a national network of protected areas known as "Nishorgo Network" with technical support from the Integrated Protected Area Co-management Project. Other donor projects are supporting the network in establishing co-management and scaling up natural resources co-management in the Sundarbans and other forests and wetlands. Thus the CMCs are going to have some resource conservation and local development rights.

Table 1.1: Project proponents

Proponent	Type of Organization	Nationality
Government of Bangladesh	Host government	Bangladesh
Four CMCs of the SRF	Local governance entity, representing community interests	Bangladesh

1.10 Project Boundaries

Project activities will take place in the SRF located in the southwestern portions of the country and its surrounding 10-km wide landscape (Figure 1.1). The Sundarbans is the world's largest mangrove forests, spanning a total of about one million hectares from the Ganges-Brahmaputra-Meghna estuary in Bangladesh to the South 24 Parganas area of West Bengal (India). It lies between latitudes 21°27'30" and 22°30'00" N and longitudes 89°02'00" and 89°55'00" E. The Sundarbans delta is the northern coast of the Bay of Bengal in the Indian Ocean. More than 60% of the Sundarbans ecosystem is within Bangladesh, consisting of about 600,386 ha, of which about 411,227 ha are land with 189,159 ha of water courses. The area's protected status dates back to 1875 when it was gazetted as Reserved Forests (with 55 compartments) under the Forest Act, 1875, with three Wildlife Sanctuaries established in 1977 and expanded in 1996 to 139,698 ha (Figures 1.2) under the Wildlife (Preservation) Amendment Act, 1974. The 4,112.27 km^2 of terrestrial forests legally classified as Reserved Forests form the project area (subdivided into the Satkhira, Khulna, Chandpai, and Sarankhola Forest Ranges) whereas the remainder wetlands and the identified interface landscape zone form the project reference region.

Figure 1.1: Project Area and Reference Region

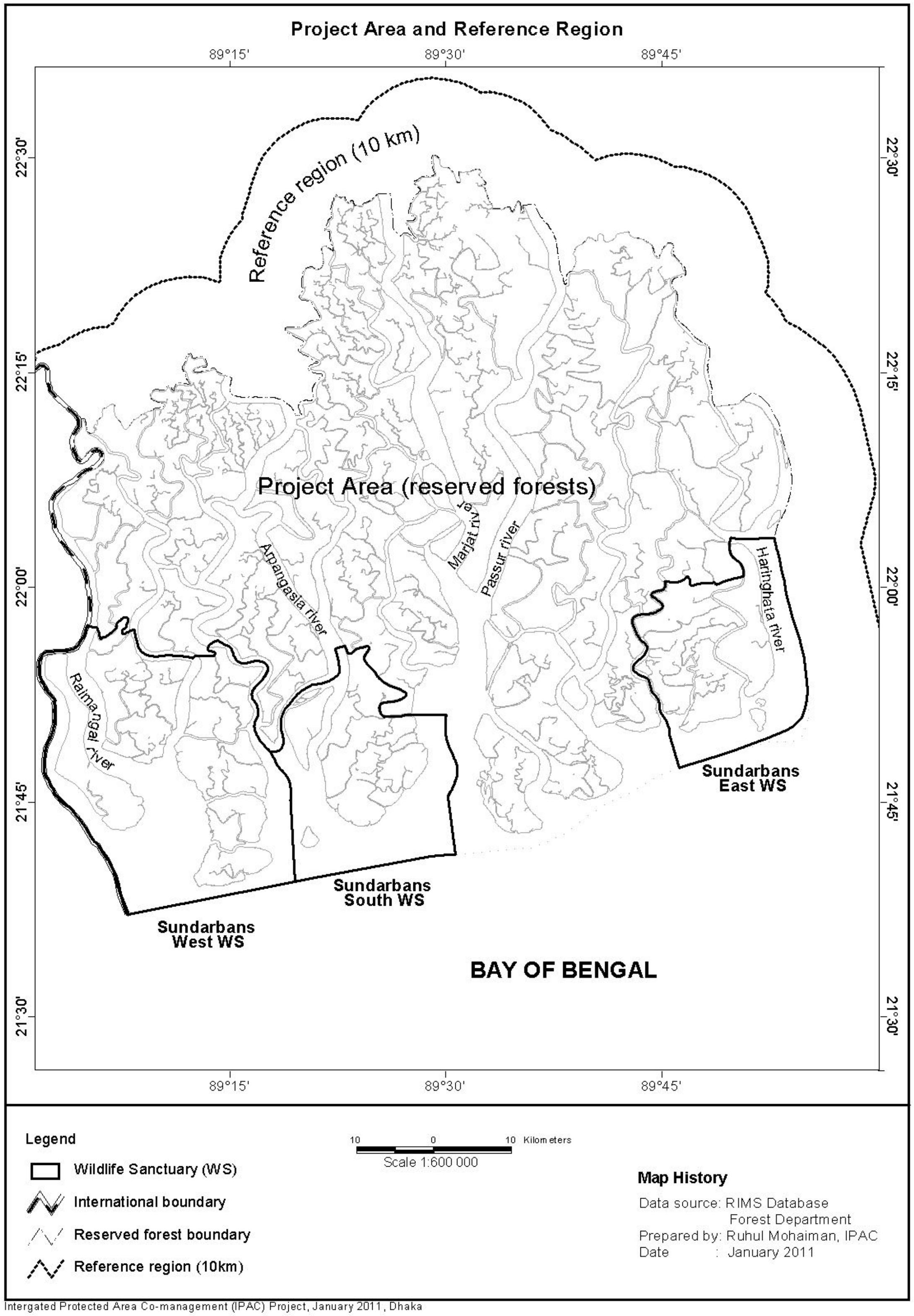
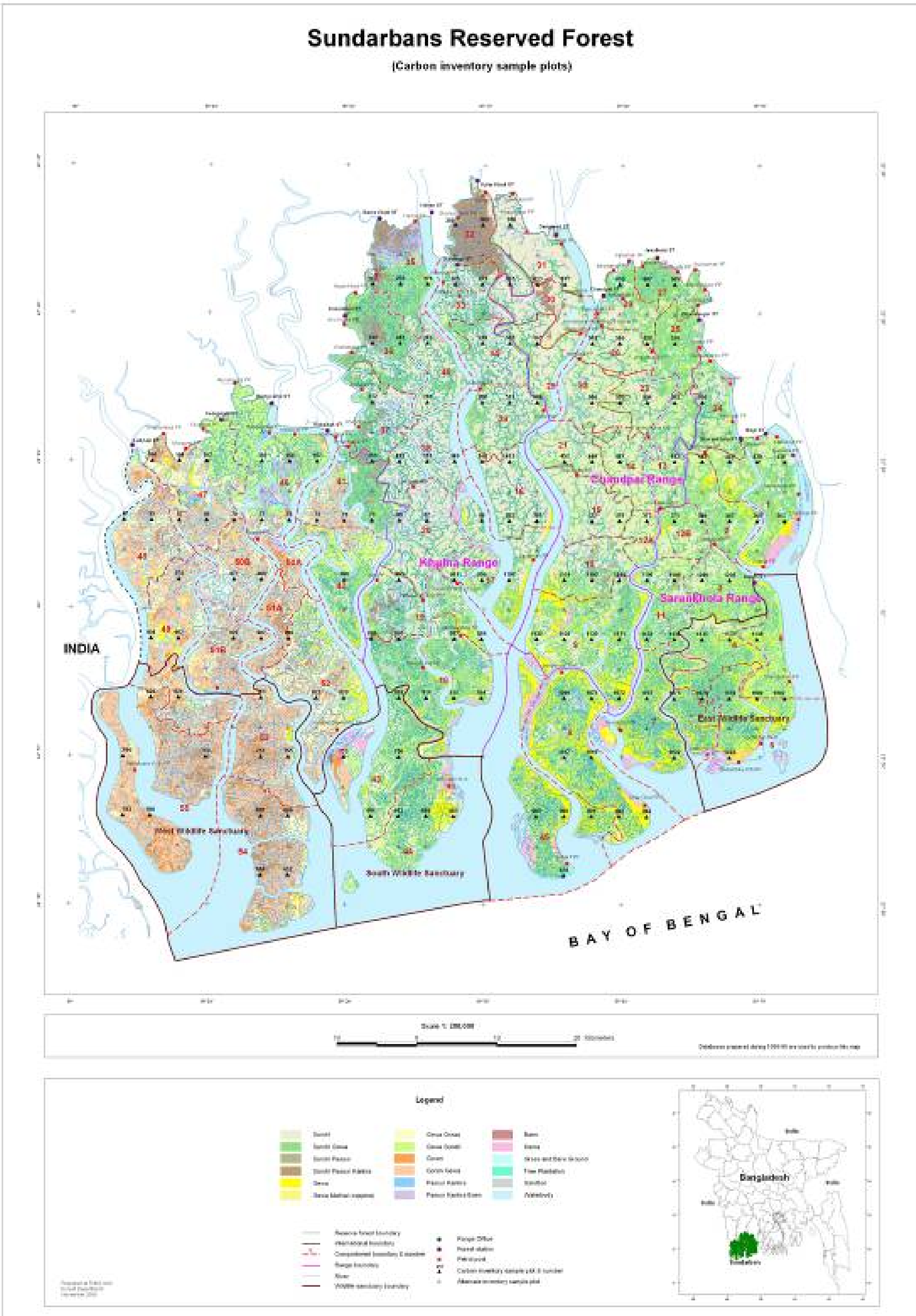


Figure 1.2: Compartments in the Sundarbans Reserved Forests



1.11 Project Objectives and Target Groups

1.11.1 Project Objectives

The primary aim of the project is to sequester carbon through forests protection and improved forests management as well as to generate alternative livelihoods options for local communities and conserve biodiversity in the project area and reference region. The proposed forests protection and improvement interventions will be implemented by the FD in conjunction with the CMCs, the later playing a particularly important role in joint patrolling, participatory monitoring, and conservation-linked value chains and alternative income generation activities. The involvement of the CMCs will not only help to strengthen local governance, but also promote empowerment of the surrounding communities and conservation of the biodiversity and natural resources harbored by the forests. The FD will be responsible for implementation and management, and an important focus will be on building their capacity by leveraging the training that has already been provided to a group of the ACFs in October 2009, and March and August, 2010 under the IPAC project. Moreover, the design and implementation of the project will contribute to the development of strategies and methodological tools that can be used to inform future REDD+ projects in Bangladesh.

Specifically, the objectives are to:

- Achieve emissions removals through avoiding deforestation and degradation, and improved forests management in the SRF
- Improve degraded habitat including forests and wetlands
- Provide income and empowerment opportunities to people from the surrounding villages, particularly members of co-management organizations (CMCs and community groups), by engaging them in forests protection, improved forest management, participatory monitoring and livelihood activities
- Conserve biodiversity by safeguarding the habitats of species such as the Royal Bengal tiger and dolphins
- Demonstrate a suitable methodology for REDD+IFM projects that can serve as a model for mangrove forests.

1.11.2 Participant Details

Although the project main proponents are the FD and the Co-Management Committees, local community including VCFs and PFs will be gainfully involved in the CRISP implementation. The population of the Sundarbans landscape is heterogeneous, with a history of immigration especially from the other areas (adjacent districts and Upazilas mainly), particularly after the independence in 1971. There are about 215 villages, 125,000 households and 500,000 people within the reference region.

1.11.3 Activity Locations

All of the proposed activities will be undertaken within Satkhira, Khulna, and Bagerhat Districts of Khulna Division, in southwestern Bangladesh. No villages are located within the project areas; however, 215 villages are within the 10-km wide reference region of the Sundarbans Reserve Forest (see Annexure 1 for details).

1.11.4 Acceptance of the Project by the Host Country

The Host Country has already approved (vide MOEF order no. PaBaMa/Environment-2/40/2011/421 dated 5 September 2011) a PIN document and the CRISP Project Concept Note : The Development Project Proformas (DPPs) for the IPAC and SEALS projects have been approved by the ECNEC, headed by the Prime Minister of Bangladesh.

1.12 Project Benefits

1.11.1 Environmental Benefits

I.II.I.I Local Benefits

CRISP supports maintenance and enhancement of interdependent climate change adaptation as well as socio-economic functions. In terms of climate change adaptation, the Sundarbans provide a buffer that absorbs the impact of increased incidence and intensity of cyclones, tidal surge and sea-level rise. These benefits are most profound for the 210 village communities located directly adjacent to the Sundarbans, and also accrue to the economically-important Mongla Port and the rapidly-growing city of Khulna. In terms of socio-economic benefits, the SRF provides a sustainable supply of a number of non-timber forests products (NTFPs) including honey and nypa palm (used locally as roofing material). More significantly, the Sundarbans wetlands harbor rich fisheries that contribute to food security and employment opportunities through sustainable and small-scale commercial fishing activities as well as provide breeding ground and nursery, key to the sustainability of large-scale commercial fishing in the Bay of Bengal. As home to the Royal Bengal tiger and other rich wildlife, the Sundarbans is an increasingly significant eco-tourism and recreation destination, providing conservation-oriented jobs and marketing opportunities to a growing number of people. Conservation of the Sundarbans through CRISP will amplify and sustain the local climate change adaptation and socio-economic services and opportunities.

I.II.I.I Global Benefits

Global environmental benefits from the CRISP include conservation of a population of 440 Royal Bengal tigers (or 10% of the world's tiger population living in the wild) as well as conservation of the only habitat where Asia's last two freshwater dolphin species, the Ganges River and Irrawaddy dolphins, co-occur. Conservation of the Sundarbans also contributes to the protection of many other terrestrial and aquatic fauna and flora unique to the mangrove ecosystem. The Sundarbans wetlands provide breeding and nursery grounds for commercially-significant fisheries in the Bay of Bengal, which provide employment to millions and contribute to regional food security. Moreover, conservation of the Sundarbans maintains a globally-significant carbon sink, mitigating impacts of climate change for the region and the world. Finally, the Sundarbans represents a barometer for the impacts of global climate change and the effectiveness of various adaptation and mitigation strategies.

1.11.II Socio-economic Benefits

CRISP will provide direct or indirect benefits to nearly 200,000 mostly poor and ultra-poor people living near to and dependent on the Sundarbans for their livelihoods and survival. For those living in any of the 210 villages participating in the Sundarbans co-management, direct benefits include alternative income generation activities, climate change adaptation support, and the opportunity to participate in robust local governance fora that will enable them to work together and leverage socio-economic support from the CRISP as well as other government programs. Importantly, co-management emphasizes the role of women and youth, thus empowering these significant and often marginalized constituencies in the local communities. Benefits for both direct and indirect beneficiaries include improved adaptive capacity to climate change, especially protection from cyclones, tidal surges and sea level rise, as well as more sustainable and resilient livelihoods opportunities founded on the effective conservation of the Sundarbans ecosystem services.

2. Current Conditions

2.1 Biodiversity Significance

The forests, wetlands, wildlife and aquatic resources of the Sundarbans are very rich biologically, located as they are in one of the most dynamic bio-geographic coastal zone. Accordingly, the Sundarbans attract both national and international attention whenever the status of forests and wetlands comes under scrutiny. For instance, the inclusion of the Sundarbans as UNESCO World Heritage Site and the three wildlife sanctuaries as Ramsar Site is testimony to the global realization about the Sundarbans ecosystem, comprising the world's largest mangroves and complex networks of tidal and fluvial waterways with rich terrestrial and aquatic biodiversity. The Sundarbans is a very popular recreation destination both for domestic and foreign tourists. Enormous amount of sediments and nutrients brought by the freshwaters from the Ganges and Brahmaputra into the Sundarbans and its adjacent landscapes is circulated by a seasonally reversing, wind-driven, basin-scale gyre, with adjacent meso-scale eddies rotating in the opposite direction, thereby producing highly stratified and productive coastal waters.

2.2 Biophysical Attributes

2.2.1 Topography

The Sundarbans forms the south most portion of the Ganges (Padma) and Brahmaputra (Jamuna) river deltas. Topographic variation within this low-lying physiography of the area compared to upland areas is negligible: The SRF floor rises from 0.9m to 2.11m above the mean sea level and the area undergoes a twice daily tidal inundation.

2.2.2 Geology and Soils

The Sundarbans is a delta composed primarily of depositions from the three major rivers flowing into the area: the Ganges, Brahmaputra, and Meghna. A submarine fan of the estuary continues for another 300 km into the Indian Ocean. The FAO found that these sediment deposits may reach to 15 km depth. The delta itself is Quaternary sediment of sand, silt, and clay flowing from the Himalayas and the Tibetan Plateau over the past 12,000 years since sea levels receded. Lacking geologic forces of uplift or compression, these sediments are uncompacted. According to the FAO, earthquakes in the 1700s may have shifted the Ganges to the east (into Bangladesh) away from the areas near Kolkata, to form the present-day confluence with the Brahmaputra-Meghna river complex. Elevations in the Sundarbans only reach 2 meters, creating an existential threat if sea levels rise as much as is predicted in most climate change models. Numerous south-flowing rivers and channels traversing the Sundarbans continually deposit sediments, sometimes forming island accretions (called *chars*). Floodwaters during rainy season carry silt downstream to form mudflats and ephemeral, shifting land that can be up to one km long and travel up to 600m per day.

The geology of the Sundarbans is of recent origin, raised by the deposition of sediments formed due to soil erosion in the Himalayas. The process has been accelerated by tides from the sea face. The substratum consists mainly of Quaternary Era sediments, sand and silt, mixed with marine salt deposits and clay. Geologists have detected a southeastern slope and tilting of the Bengal basin during the Tertiary. The work on the detailed geology of Pleistocene and post Pleistocene soils, including radiocarbon dating has been carried out by Umitsu (1991). Based on the variation in soil strength, grain size characteristics, etc., the depositional sediments can be divided into 5 categories, namely uppermost, upper, middle, lower and lowest. These categories are defined by a weathered surface and a sharp change in lithology, representing a period of marine regression. Umitsu correlated the boreholes at Khulna (Daulatpur) with those in Faridpur and Barisal. While the slope is consistence with present day ground elevations between Khulna and Barisal, the ground level is higher at Barisal, the uppermost layer is twice as thick as that at Khulna (12m compared with 6m). Thus Barisal appears to be an actively accreting area, while Khulna and Faridpur appear to be moribund. Studies from the boreholes indicate that apart from a regression at around 12000 BP before 1991, there was a rise in sea level as observed elsewhere in the world. The shell identified at Khulna borehole depths of 20m and 35m are of tidal brackish environment with a deposition estimated 7000 and 9000 BP. The evidence from these boreholes tends to confirm the impression that while the western side of the region is relatively stable, the south-eastern corner is an active sedimentary area that is subsidizing (Hossain and Acharya ,1994)

Mangrove soils have two main characteristics that are not found in most other forest soils: waterlogging and salinity. Inundation lowers oxygen levels and can lead to chemical effects such as higher concentration of hydrogen sulfides. Being deltaic systems, mangrove soils benefit from the large influxes of nutrients carried downstream by sediments. These counteract many of the effects of salinity and help account for the unique nature of mangrove ecosystems and their high productivity. In the Sundarbans, productivity is higher than many other mangrove ecosystems due to relatively lower salinity levels because of large volumes of freshwater input from the Ganges-Brahmaputra-Meghna river systems. The western portions – due to relatively lower volumes of freshwater throughput – are polyhaline (>10 ppt NaCl); the northeastern corner areas are miohaline (<5 ppt NaCl) and the remainder of the Sundarbans is mesohaline (5-10 ppt NaCl). Soil pH runs neutral to slightly alkaline (6.5-8) when wet, and slightly acidic (pH 5.3 to 6.4) when dried. Soil moisture is very high, with areas more inland showing inter-tidal variation. Micro-topography also of course affects soil moisture in specific locations. Forest Department studies have shown cation exchange capacity (CEC) in the range of 12-24 meq/100 g dried soil, generally following the sequence Mg>Ca>Na or K. The northeastern portion of the Sundarbans is reported to have slightly higher levels of calcium than magnesium. Organic matter averages 4-10%.

Soils of the SRF are derived from a mixture of deltaic floodplain deposits and tidal marine deposits (Figure 2.1). The surface soil is a silty clay loam, overlying alternating layers of clay and sand. In general, the soil fertility decreases from east to the west and from north to south. In the north and east portions of the Sundarbans, relatively high fertility is maintained by annual silting. These soils are slightly saline, silty clay loam and the sub-soil consists of alternate layers of clay and sand. Silt appears to be the most common textural class and grain size is larger in the eastern forests than in the west. Pyrite may occur on the localized depressions containing higher amount of organic matter. The presence of biotic, carbonate and feldspars protects the soil from becoming acid sulphate where drainage in not impeded. Hasan (1990) described the soil of the Sundarbans delta as unripened, slightly calcareous, tidally folded, grey, massive, alkaline, clay muds with low (<2%) organic matte content and saline, uncured or partly cured grey clayey deposits, and homogeneous in vertical and horizontal directions.

Organic Matter

The soil of the Sundarbans being formed entirely of fine silt and sediments carried by the Ganges and Brahmaputra, contain a high percentage of calcium carbonate and, therefore, fall essentially under the Pedocal group. The percentage of organic matter appears to be generally low. The highest percentage of organic matter is found in the top layer and the lowest percentage of organic matter was found in the bottom layer. The Bangladesh Forest Research Institutre (BFRI) has recently estimated the soil organic matter for the Sundarbans by using soil samples collected during forests carbon inventory.

Soil pH

The soil pH varies from 6.8 to 8.4, but throughout the SRF most of the soils fall on the alkaline pH range between 7.0 and 8.0.

Mineral Composition

The results obtained from a mechanical analysis of different samples showed that the silt fraction varies with depth. The clay fraction varies from 24 to 44%; sand fraction varies from 8 to 30%, and silt varies from 40 to 60%. It was found from the particle size analysis that different textures were readily discernible and could be used as a basis for classification into silt loam, silty clay and clay loam.

Chloride

Chloride is said to be the most common anion in the coastal soils of Bangladesh, ranging from 57mg/100g to 232mg/100g in oven dry soils, with significant gradation in proportion to distance from the sea perennial freshwater flushing, especially to east.

Sodium and Calcium

Content of Na and Ca were found to be highly variable in all studies, ranging between 57-98mg/100g of oven-dried soil with variations along north-south and east-west gradients. Experimental results for calcium ranged from 0.50mg/100g for subsurface soil to a maximum of 12.4 for surface soil in the compartments to the north-east; and for sodium, 1.8 to a maximum of 9.3mg/100g of oven dried soil in the compartments 6 and 8 in the south-west near sea.

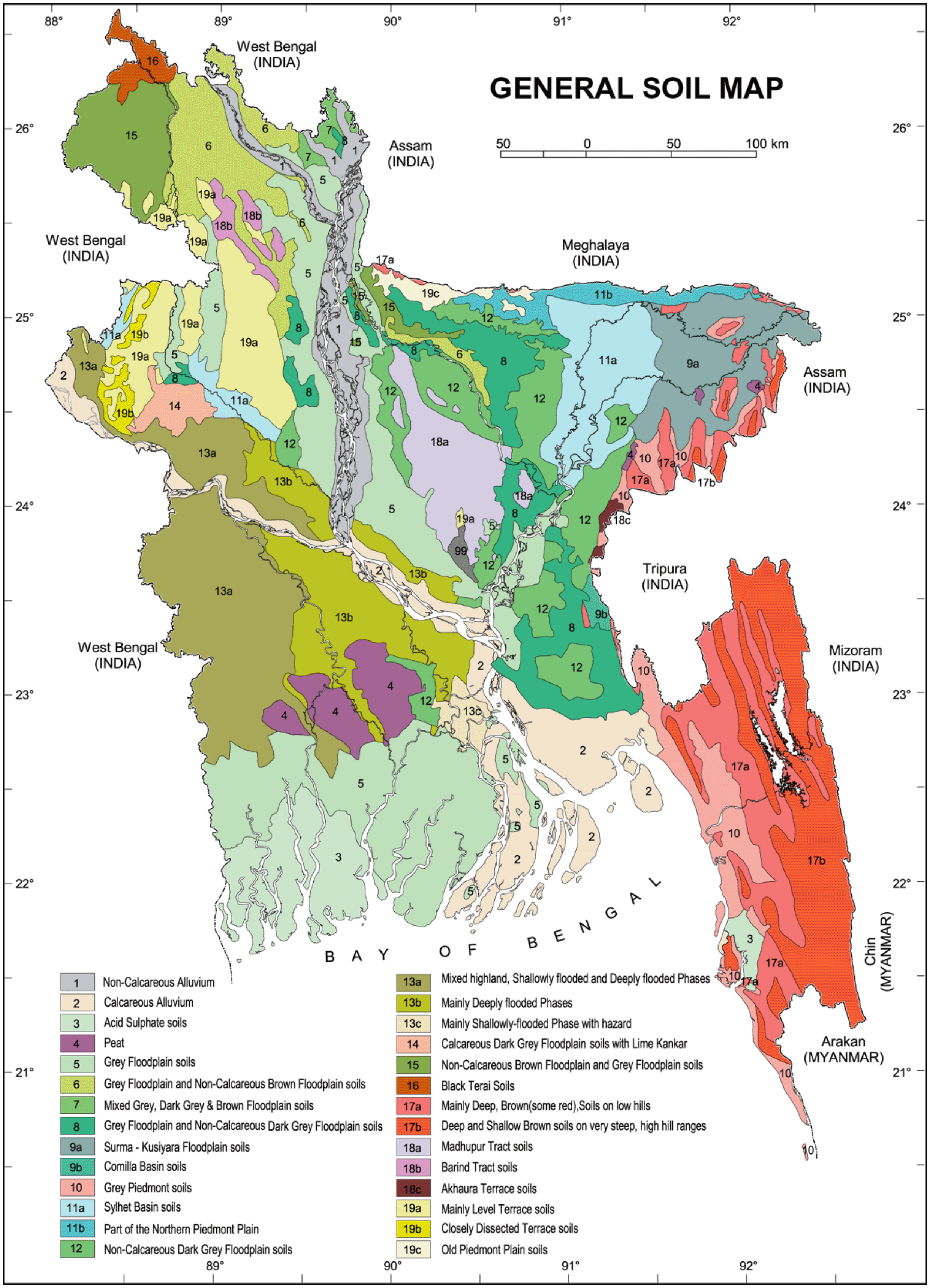
Sodium Absorption Ratio

This measure of the exchangeable sodium percentage shows considerable variation : 1.3 and 31.6% in surface soils and between 6.4 and 40.7 in subsurface soil.

Cation Exchange Capacity

The highest cation exchange capacity (CEC) of 22.87mg/100g was found in the permanent sample plot (PSP) 16 of the compartment number 1 and the lowest CEC of 9.94mg/100g was found in the compartment number 54. These figures are according to Karim (1988) who found the variation at their sites of 12-23mg/100g of soil with little difference between wet and dry season.

Figure 2.1: Soil Map of the Sundarbans



2.2.3 Climate

The Sundarbans, like most of Bangladesh, is classified as a tropical moist climatic regime. Rainfalls are monsoonal, with heavy rains from May or June through September or October carried by prevailing South-West winds. The monthly average precipitation in July and August is approximately 350 mm, with 25 or 26 wet days per month. Monsoon season temperatures average 29°, and may reach to 39° with relative humidity above 90%. Bangladesh is also subject to cyclones, with the Sundarbans affected by at least 16 storms since recording was initiated in the 1870s. In November 1988, a storm surge of 2.8 m and winds of 160 km per hour did significant damage to the Sundarbans, and Cyclone Sidr crossed the SRF in 2007 on its way inland, where it killed more than 2,000 people. The transition months of May and October experience the most storm activity from inland thunderstorms and Indian Ocean cyclonic storms. Temperatures are cooler during the winter months of December – February, falling as low as 12° and averaging 22° with relative humidity in the range of 45-60%. The Sundarbans is located south of the tropic of cancer and at the northern limits of the Bay of Bengal and may therefore be classified as Tropical Moist Forests. In absence of a meteorological station inside the Sundarbans, all data are collected from the nearby station in Khulna. The coolest average annual temperature (11.8°C) occurs during December-January, and the warmest (34.6°C) at the end of dry season, during May-June.

According to Bengali calender, there are six seasons in Bangladesh, namely: summer (*Boishakh-Jayistha*), rainy (*Ashar-Sharaban*), autumn (*Bhadra-Ashwin*), late autumn (*Kartic-Agrahayan*), winter (*Pous-Magh*) and the spring (*Falgoon-Chaitra*). However, at present the identification of the six seasons is difficult and so three main seasons are felt as a long summer, rainy season and winter. Another classification could be as pre-monsoon (March-May), monsoon (June- September), post-monsoon (October-November) and the dry-winter season (December-February). During pre-monsoon the average annual temperature at Khulna ranges from 20.4°C to 35.2°C, and during monsoon the temperature ranges from 23.6°C to 33.5°C and the monsoon winds bring high rainfall, humidity and cloud cover; sediment load and water levels of rivers also increase due to heavy rainfall in the upper catchment areas. The area inundated by tidal water increases and the salinity of river water reaches a maximum during this season. The post-monsoon season is hot and humid, sunny, with dewfall at night, sometimes quite heavy. There are occasional thunder storms, cyclones and strong surge. The dry winter season is characterized by cool, dry and sunny weather with low precipitation. Tide levels remain low and large areas of the Sundarbans experience a dry, exposed period with no tidal inundation.

2.2.4 Temperature

The annual average temperature during post-monsoon at Khulna is 31.75°C and the season is characterized by southerly winds, high temperatures and evapo-transpiration rates, with occasional heavy thunder storms. The annual mean (over a period of ten years: 2000-2009) maximum and minimum temperatures of the Sundarbans were 12.75°C and 28.44°C respectively. Highest and lowest monthly temperatures were recorded as 36.6°C in April 2009 and 11.9°C in January 2010.

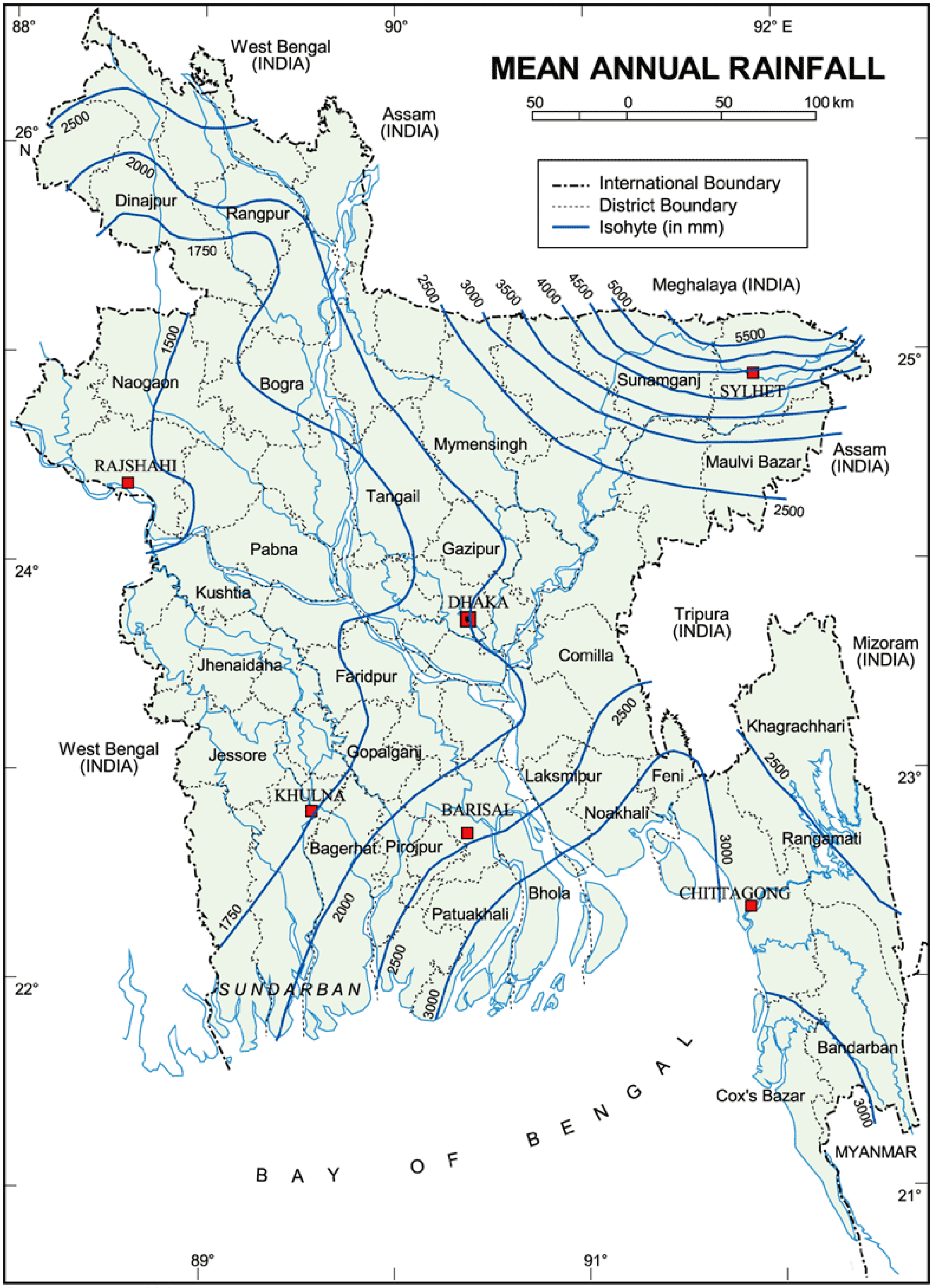
2.2.5 Rainfall

Winds from the North-East make November through April relatively dry months, with average precipitation below 20 mm. Rains may be less than 10 mm in December and January. The annual average (over 2000-2009) rainfall at Khulna was recorded as 1614mm : maximum annual average rainfall was 2040mm in 2000, whereas the minimum was 1,080mm in 2005. Figure 3.2 presents rainfall variations in the SRF.

2.2.6 Humidity

The region has relatively high humidity. The 10-year (2000-2009) annual average humidity was recorded as 81%. The highest and lowest humidity were recorded as 90% in April 2000 and as 65% in January 2005 respectively.

Figure 2.2: Mean Annual Rainfall in the Sundarbans



Source: *Brammer, 1996*

2.3 Hydrology and Salinity

As a tidal mangrove ecosystem, water dynamics of the Sundarbans are governed by upstream rainfall and tides. That, combined with the uncompacted geology described above, means that three types of water flows affect Sundarbans hydrology: surface flows, groundwater flows, and tides. At least nine main river channels traverse the Sundarbans Reserve Forest, with some of these joining and separating as they flow southward into the Bay of Bengal. The principal rivers among these are the Ganges-Padma, entering SRF as the Gorai-Madhumati; the lower Meghna River, entering as the Swarupkhati-Kocha; and the Bhadra, Chitra, Khulpetua, Kamarkhali, and Jikargacha rivers. These latter two form the eastern and western boundaries, respectively, of the Sundarbans. Monthly surface flow rates vary with season, from a low of 190 m^3/sec in March to as much as 7650 m^3/sec in August (FAO/UNDP). Flows in the eastern portions of SRF are generally higher than those in the west.

A single aquifer made up of interconnected zones of moderate permeability underlies the Sundarbans, capped by a lining of low permeability. Salinity levels tend to track fairly closely with those of surface waters, which percolate into the aquifer from rivers, ponds, and freshwater lakes as well as marine waters. Typical average salinity is in the range of 5-18 parts per thousand. As expected, the more northern inland portions of the Sundarbans have lower salinity levels than those of the southern areas closer to the coast. There is anecdotal evidence from communities near the Sundarbans that groundwater is becoming more saline, possibly as a result of increased draw or from rising sea levels linked to climate change. Tidal fluctuations along the coast are about 3 m between high and low tide on 12 hr, 20 min cycles. High tide reaches inland boundaries of SRF approximately 2½ later than along coastal areas. Seasonal variations in levels of high tide vary 600-800 mm, with the lowest occurring in February. Vegetation of the Sundarbans depends highly on hydrology, with salinity and oxygen levels determining which species thrive in lateral distributions or bands across the area.

The hydrology of the Sundarbans is quite complex and is dominated by the freshwater flows from the Ganga, Brahmaputra and Meghna rivers, which exhibit very high seasonal variation in their discharge, and the tides which range in height from 2 to 5.94 m. Tidal influence extends to more than 50 km inland from the shoreline and surges increase considerably during the cyclonic storms. The freshwater flows from the rivers and the tidal ingress result in a gradient of salinity that varies both spatially and temporally. In general, the salinity is higher nearer the coast and the water is nearly fresh on the inland side limit of the SRF. Similarly, the salinity decreases from west to east (Figure 2.3), and the eastern part of the Sundarban is oligohaline (<5% salinity). During the past few decades, however, the sources of all rivers in the western part of the Sundarban have progressively silted up, thereby disconnecting the inflow of fresh water into the mangrove delta. Freshwater flows are much larger from the Brahmaputra and Meghna rivers, particularly in the Baleshwar River on the eastern side of the Sundarbans. The reduced freshwater flows in western parts of the Sundarban have resulted in increased salinity of the river waters, and have made the rivers shallow over the years. At the same time, during ebb tides, the receding water level causes scouring of top soil and creates an innumerable number of small creeks, which normally originate from the centre of the islands. The ebb tide eroding action is stronger in some islands, and the receding water carries large volumes of silt, which is deposited along the banks of rivers and creeks during high tides, resulting in increase of the height of the banks as compared to the interiors of the islands.

Figure 2.3: Salinity Zones in the Sundarbans

2.4 Wind and Cyclones

Wind and Storms

The winds are generally light to moderate with a slight increase in force during the summer and monsoons, but in the southern Sundarbans, particularly near the coast, winds are stronger. At Khulna, the mean annual wind speed is 4.0 knots whereas this mean at Satkhira is 5.0 knots. The mean monthly distribution at Satkhira to the west has two peaks, in April and August. Winds blow mostly from directions between the south-east and south-west during May to September but in October, winds vary in direction. During the winter, winds blow mainly from the north-west but in March and April they blow from the south and south-west. Thunderstorms are common during summer afternoons. These may be in association with severe squalls and occasional hail. These are commonly known as nor'westers (because the associated squalls usually come from the north-west) or Kalbaisakhi (the disastrous winds of Baisakh, the first month of the Bengali calendar). Storms result in heavy rain and a sharp drop in temperature. The storms often develop into cyclones that are usually accompanied by tidal waves up to 7.5 m high.

Cyclones

The SRF is located at the apex of the Bay of Bengal and its geographical position places it in the immediate path of cyclonic storms generated over the sea or down from the Himalayas. These are accompanied by heavy tropical storms, floods, and tidal bores, which after combining in this part of the continental coast result in many natural disasters that frequently strike fast and unexpectedly. Major cyclones have been reported for centuries as cause of loss to human life and devastation of vegetation in the Sundarbans. During the last 135 years, more than 45 cyclones have crossed the coastal belt of Bangladesh, of which 13 are trekked through the Sundarbans.

The cyclonic winds rotate anti-clock wise, producing the highest winds and surge condition on their right side. Thus most of the Sundarbans can expect moderate damage compared to more severe effects in the lower Meghna estuary. Records available at the Surface Water Modeling Centre (SWMC) show that cyclone occurrences have averaged at 1 every 5 years in the coastal area since 1882. Although there is a gap in the records from 1926 to 1941, the frequency appears to be increasing this century from 1 in 3 years in 1950 to less than 1 in 2 years at present. Studies conducted by the Cyclone Protection Project-II (Flood Action Plan, FAP-7) commented on the role of the Sundarbans in dampening tidal surges and pointed out that 100m to 200m wide strips of dense mangrove vegetation can reduce wave energies by 20-25%. In addition, FAP-7 emphasized the need for disaster preparedness, to consider cyclone resistant housing; to give careful consideration to environmental impacts; and to undertake mangrove planting on a massive scale. Apart from coastal protection, mangrove plantations create employment opportunities for the poor, generate wood for many purposes and have many benefits for the mangrove ecosystem.

In last 10 years, several cyclones have crossed through the Sundarbans; the most devastating one was the cyclone Sidr which occurred on the night of November 15, 2007. The velocity of the wind was 220 to 240 kilometers/hour. It inflicted a huge loss to the Sundarbans and the coastal districts. More than 3,000 people were dead, thousands injured. Nearly 20 lakh families and 90 lakh people were affected by the Sidr and the damage to property, houses and crop was huge. There was huge damage to the SRF in terms of biodiversity and physical infrastructure. Many trees were uprooted and broke down and a large number of wild animals died. The freshwater ponds inside the Sundarbans were flushed with saline water, resulting in the scarcity of sweet water for the animals and people. The other important cyclone was Aila that occurred on May 25, 2009, mainly in the western part of the Sundarbans. Nearly 200 people died, and about 10 lakh families and 40 lakh people were affected. Many embankments and dams were washed out and people were in huge distress. The saline water entered into a big area, damaging crops and shrimp/fish farms.

2.5 Ecosystems Analysis

Major agro-ecological zones in the Sundarbans and its interface landscape are shown in Figures 2.4 and 2.5. In line with a biogeographical zoning approach, five habitat types are identified in the SRF, namely: shore, low mangrove forests, high mangrove forests, open land/grassland, and esturine-riverine areas. The shore habitat covers the open sandy to muddy areas along the edges of the Bay of Bengal which generally serves as the main habitat of a lot of shore bird species in the SRF. Mangrove forests, based on crop height, are divided into high and low forests. Intermittent grasslands, suitable for wildlife such as deer, are found in the SRF. Nearly one third of the SRF is under rivers and estuaries.

A system encompassing a community and the interacting environment is referred as an ecosystem. The project area and its reference region thus comprise both terrestrial ecosystems with mangrove forests and wildlife, and aquatic ecosystems of wetlands with important aquatic resources, on which the landscape population depends for coastal protection and also for meeting their subsistence food consumption and livelihoods needs. A variety of terrestrial and aquatic plants, animals and micro-organisms and associated ecological processes that make them function are present in the ecosystems. The influence of micro-climatic, hydrolic and edaphic factors including rainfall, freshwater flows, tidal flows, humidity, aspect, sunshine and soil is predominant on the Sunadrbans ecosystem. Conversely, the Sundarbans ecosystem has created its own micro-climate that is an integrated result of meteorological processes and the conditions present within the space occupied by the forests and wetlands ecosystems.

Of the four distinct biogeographic zones in Bangladesh, Sundarbans Forest Biogeographic Zone (SFBZ) encompassing the Sundarbans ecosystem is of immense importance. It encompasses the mouths, deltas, alluvial pans and coastal tributaries of the well-known rivers such as the Baleswar river on the east, and the Sela-Gang-Bangra rivers, the Pasur-Shibsa-Kunga rivers, the Arpangasia-Manalcha rivers, and the Jamuna-Raimongal-Harinbhanga rivers on the west. As the depository pan of these rivers, which drain with immeasurable amount of silt from the vast mountainous watersheds in the Himalayas and Meghalaya, this zone keeps on expanding in land area outward onto the Bay of Bengal due to land accumulation. It is generally characterised by thick vegetation dominated by well-known mangrove tree species such as sundari, gewa and keora, mixed with other species such as goran, pasur, kankra, baen, dhundal, and palms (e.g, golpata and hantal) and patches of grassland dominated by sungrass. This zone harbors the famous Royal Bengal tiger and many other important mammal species which include the Spotted Deer, Rhesus Monkey, Jackel and Civet, Reptile species such as the Estuarine Crocodile, and Monitor Lizard, bird species such as White-breasted Water Hen and Emerald Dove, and amphibians such as Bull Frog. In this zone abound also a good number of aquatic resources like fishes and crabs, and ceteaceans such as dolphins and porpoises.

Sustainable management of both forests and wetlands of the Sundarbans for producing products and generating services while maintaining their environmental roles and functions, is feasible but ecologically complex. Success of sustainably managing both mangrove forests and wetlands would, amongst others, depend upon adequate site information, understanding of plant and animal communities, co-management with local community, nutrient availability, natural regeneration, eco-restoration and ecological succession. An important process responsible for the sustainability of the Sundarbans is the biogeochemical cycling of nutrients both in forests and wetlands. The leaves, twigs, small branches and fruits make the litter falling on the forest floor and the decomposition of humus through micro-organisms (bacteria and fungi) helps in adding nutrients to forest soils for plant growth and also in storing soil carbon through organic matter.

Appropriate forests and wetlands management should thus be part of biodiversity and land management strategy so that perennial vegetative cover can be maintained in perpetuity. Such a management system should be perceived as husbandary of renewable forest and wetland resources with attention to the protection of conservation, food security, recreational and climate change values. As in the past, the Sundarbans ecosystem is expected to tolerate some level of disturbance including climate change due mainly to its in-built resilience (the disturbance the Sundarbans can tolerate before it shifts into a different state). However, anthropogenic climate change and human interventions may result in non-renewable state that may exacerbate biodiversity (exceeding critical thresholds and triggering non-linear response) loss. Adequate cycling of nutrients through flow of freshwaters and tidal ingress of saline waters is important for the sustainability of both wetlands and forests.

Figure 2.4: Agroecological Zones in the Project Area and Reference Region

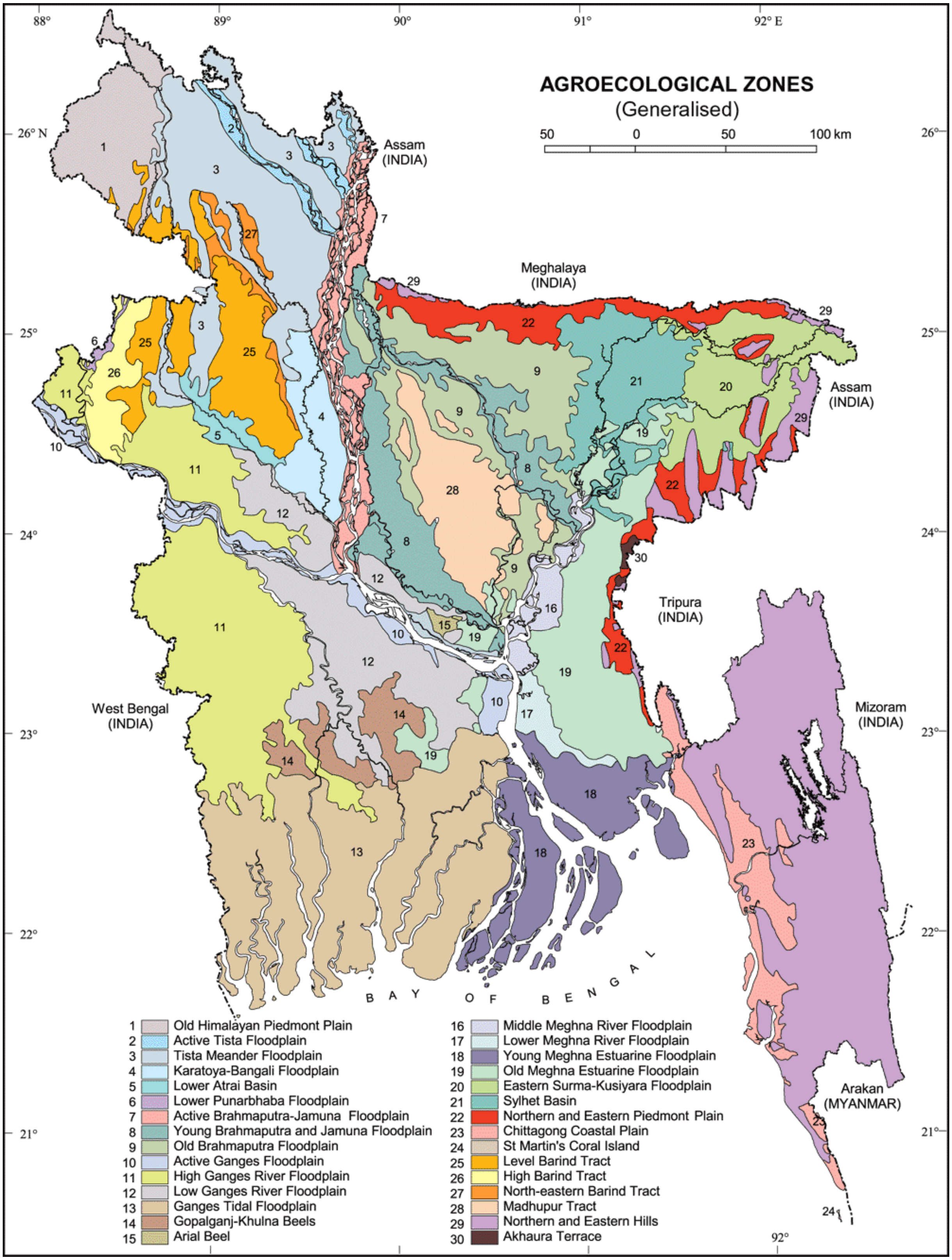
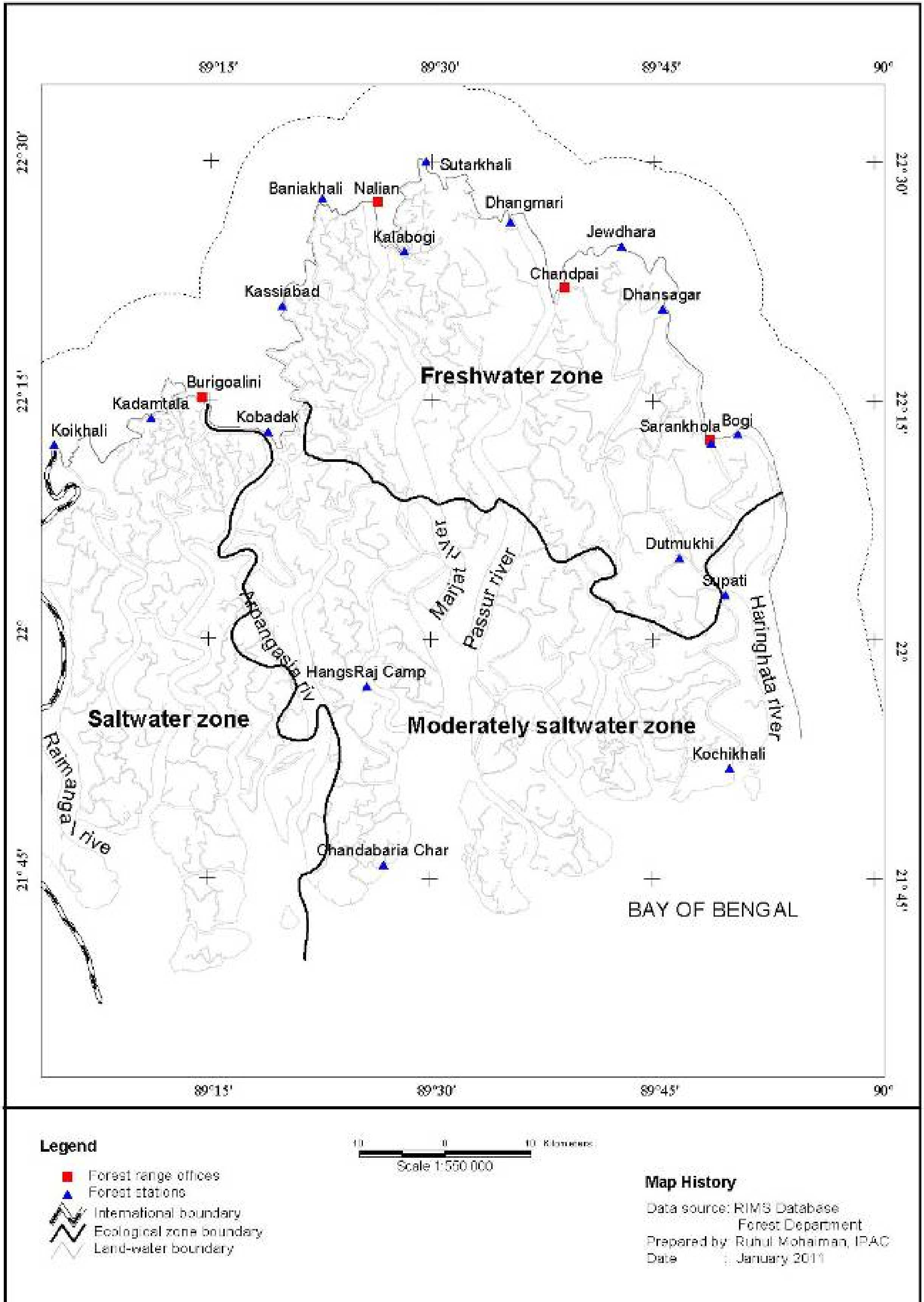


Figure 2.5: Ecological Zones in the Project Area and Reference Region



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

2.6 Mangrove Forests

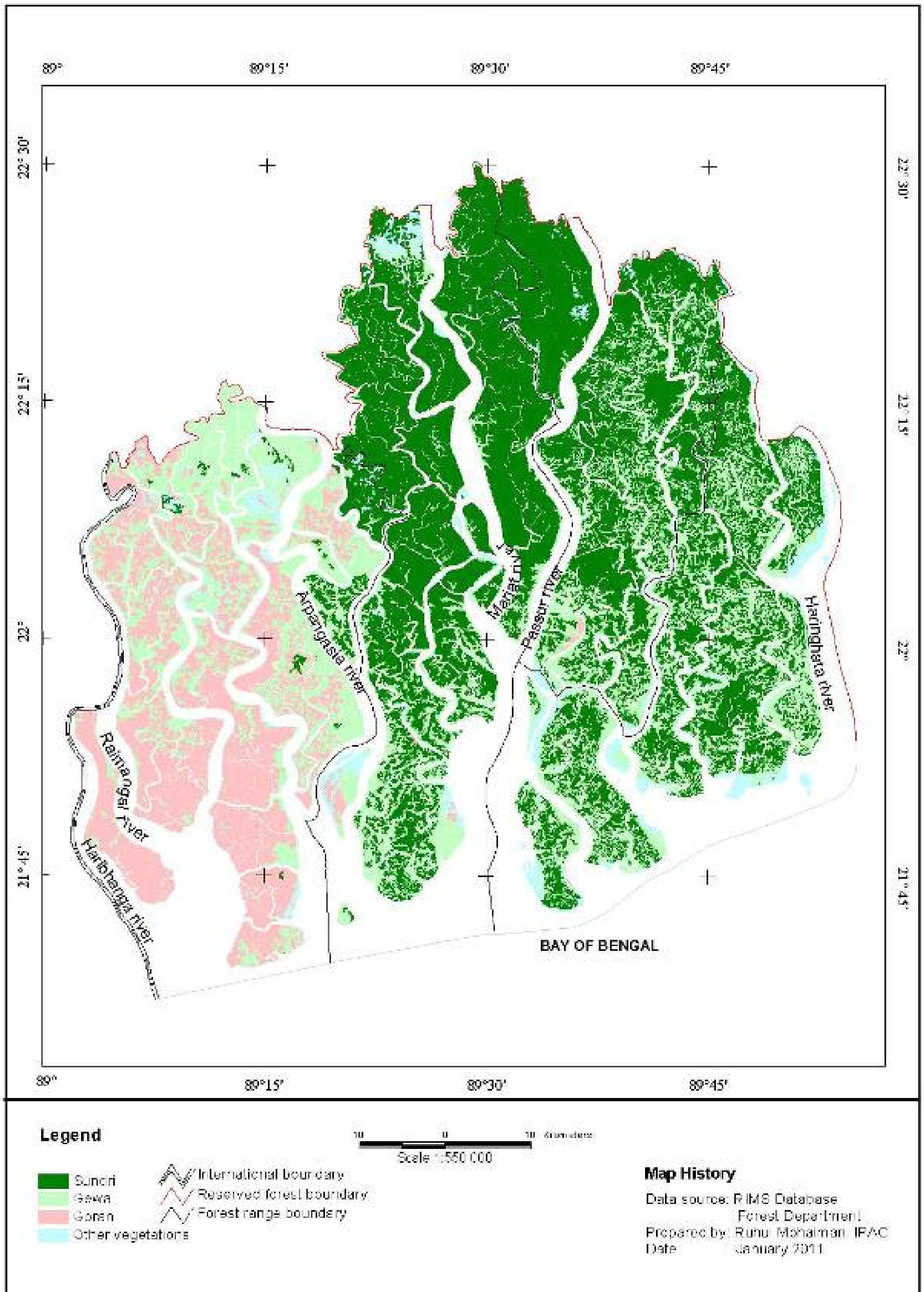
The mangrove vegetation of the Sundarbans differs a great deal from other non-deltaic coastal mangrove forests and upland forest associations. In the Sundarbans, mangrove plants occur in mono-dominant patches to a mix of species in various proportions. The forest patches are highly variable in size and combinations, and form a mosaic pattern of vegetation. The species that dominate the patches are not many. Unlike other mangrove areas, Rhizophoraceae species are of minor importance and dominant species are sundari, gewa, keora and goran. The forests occupy a flat deltaic swamp, extending over an area measuring more than 4,000 sq.km. Most of the area of the forest is washed by high spring tides during the rainy season. About 90% of trees are of brackish to saline tidal swamp type of littoral zone. Littoral forests, as the forests of the Sundarbans are ordinarily known, occur in the subtropical seas, especially on flat muddy shores where the water is relatively calm, as in lagoons, inlets and estuaries.

The land in the Sundarbans is rarely at a height of more than five feet above the mean high tide level. A high percentage of the trees growing in the Sundarbans produce profuse pneumatophores or breathing roots which overhang from the ground like spikes. Pneumatophores help in taking oxygen from the air to the roots of trees; the breathing roots may grow up to 1.5 meters, the average being about 30cm. The natural vegetation of the Sundarbans is halophytic which can loosely be termed as mangroves. The forest canopy is seldom more than 10m above the ground level and is typically more or less open, permitting at least some direct sunlight to reach the forest floor. Much of the forest is two storey, with scattered dominant trees attaining a diameter of up to about 20cm at breast height, although one or two species attain diameters up to 1m. Epiphytes are commonly found.

The Sundarbans flora is not very rich in species due to salinity: It is dominated by two species, sundari and gewa and there are about 25 other tree species which are common but considerably less frequent in their occurrence. In general, the forests in the northern and eastern parts of the Sundarbans, are better supplied with fresh water and are so floristically richer than those in the south and west. golpata palm, for example, which forms conspicuous fringes along the riversides in the north and east, becomes progressively less frequent towards the south and west. kewa kata, a prickly, succulent suffritex is similarly restricted in its distribution. Species such as jhanna, gurae and goran, which are members of the Rhizophoraceae and are frequent in the more saline areas, nonetheless occur in the north and east, although relatively less frequent. The other member of this family in the Sundrbans is kankra but the distribution of this species is widespread and does not appear to reflect salinity differences.

Apart from the family Sterculiaceae, to which belongs the dominant sundari, there are three plant families which can be regarded as key components of the mangroves, they are Avicenniaceae, Rhizophoraceae and Sonneratiaceae. The first of these is represented in the Sundarbans by baen and sadda baen, and possibly by others as yet unidentified species or varieties in the same genus. The second is represented by goran, gurae, jhanna and kankra, and the third, Sonnerratiaceae, by keora and ora. Six other families which are typically associated with dry land habitants include woody mangrove species and five of them are represented in the Sundarbans: Combretaceae, Euphobiaceae, Meliaceae, Myrsinaceae and Plumbaginaceae. Certain tree species which occur in places of lower salinity, usually on raised areas, are more commonly found as components of dry-land forest and are only marginally salt-tolerant; jir, jam and gab are examples. The trees of the Sundarbans exhibit various patterns of hydorphytic and halophytic adaptations, which facilitate survival in waterlogged and saline conditions. They have to compete not only with these factors but with their fluctuation, resulting from changes of tide and river flow.

Figure 2.6: Major Forest Types in the Project Area



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

The Sundarbans natural forests are characterised by the abundance of sundari, gewa, goran and keora. About 99% of the forest area is accounted for by 9 forest types and the areas of these are shown in Table 2.1 below:

Table 2.1: Major forest types according to the predominant species

Forest Type	Area (ha)
Sundari	74,992
Sundari-gewa	105,973
Sundari-pasur-kankra	9,556
Gewa	21,520
Gewa-sundari	75,703
Goran/Goran-gewa	34,604
Passur-kankra-baen	64,807
Keora	4,030
Others	8,286
Total Forest	**399,471**

Source: IRMP, 2010

Except for two forest types, the major types listed above are all characterised by the presence of one or both of the two species of sundari and gewa.

2.7 Wetlands

Nearly one-third of the Sundarbans is composed of a complex network of tidal and fluvial waterways ranging from a few meters to a few kilometers wide and carries substantial sediment load with a large amount of nutrients. Salinity levels in Sundarbans are determined by physical forcing from freshwater flows and to a lesser degree by diurnal tides. Freshwater discharge from Ganges-Brahmaputra-Meghna rivers, which are fed by snowmelts in Himalayas and monsoon rains, is maximum during monsoon season (June-September) which coincides with the formation of a counter-clockwise gyre in the Bay of Bengal. This gyre though responsible for the wide distribution of nutrients, their availability remains limited because coastal upwelling is suppressed by freshwater inputs along the coast, especially at the system mouth. The northeast monsoon during December-February drives a clockwise gyre which persists until May and reduced freshwater discharge during this time allows for upwelling of nutrients that were transported to the delta by counter-clockwise gyre formed during the previous months of the southwest monsoon. The high amount of nutrients, along with light winds, results in intensive coastal fisheries, which supply much needed protein to local community and beyond.

The process of accretion and erosion within the Sundarbans is highly complex due to the large number of interconnecting waterways. The sediments to both tidal and river water are distributed on the forest floors. The entire Sundarbans is in a dynamic state of erosion and accretion, constantly creating new environmental conditions. Tides affecting the Sundarbans originate from the Indian Ocean and travel past the deep Bay of Bengal reaching nearly 10 fathoms at Hiron Point. River flow and tidal currents play a major role in creating the environmental conditions of the estuaries around the Sundarbans.

2.8 Protected Areas

Within the SRF lie (see Figures 2.7 & 2.8) three wildlife sanctuaries (the Sundarbans, East, West and South, totaling 139,698 ha and gazette in 1996), the descriptions of which are provided in the Table 2.2. The unique array of natural mangrove forests, creeks, meandering streams, mighty rivers, estuaries and spectacular wildlife including royal Bengal tigers and dolphins make it a feast for all eyes.

Table 2.2: Wildlife Sanctuaries in the Project Area

Protected Areas	Water type	Description of the floral species
Sundarbans East H.Q. Katka Range: Sarankhola	Fresh or slightly saline	Predominant species Sundari is mixed with varying quantities of Gewa. The next important species is Passur frequently associated with kankra, beneath the Sundari stands. Singra is found on comparatively dry soils and Amur on moist soil. Goran is rare but Golpata is common.
Sundarbans West H.Q. Notabaki Range: Satkhira	Salt	Sparsely spaced, short-boled gewa is the main species over dense goran, interspersed with dense patch of Hental palm on the drier soils. Dhundal, Passur and Kankra occur sporadically throughout the area. Sundari does not thrive well and Golpata is very scarce.
Sundarbans South H.Q. Nilkamal Range: Khulna	Moderately salt	Gewa predonimates. It is also mixxed with Sundari in varying proportion, growing over a very dense jungle of Goran. Passur is associated with Kankra and baen. Golpata is abundant.

Figure 2.7: Sundarbans Reserve Forest showing the three Wildlife Sanctuaries and Forest Ranges

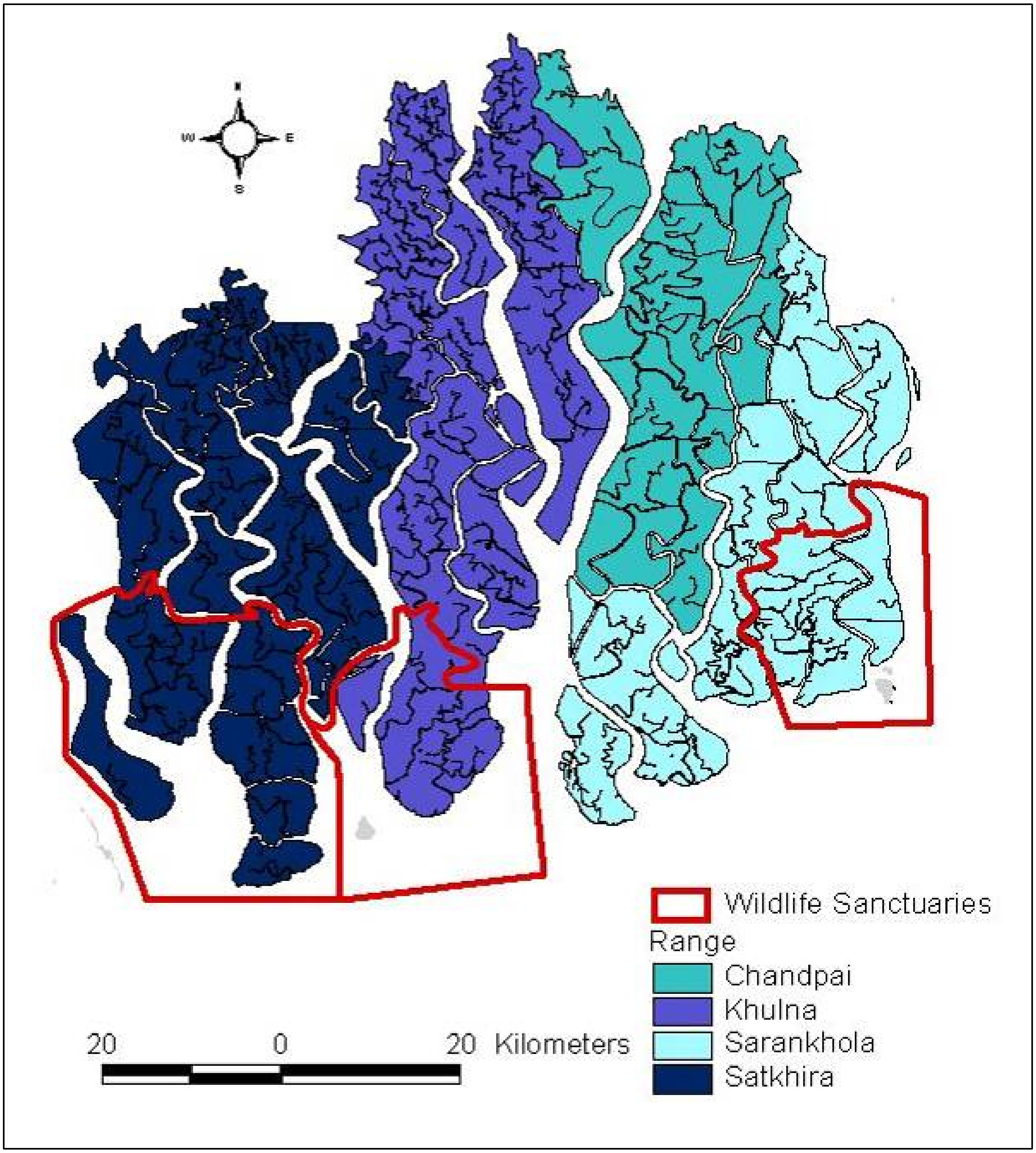
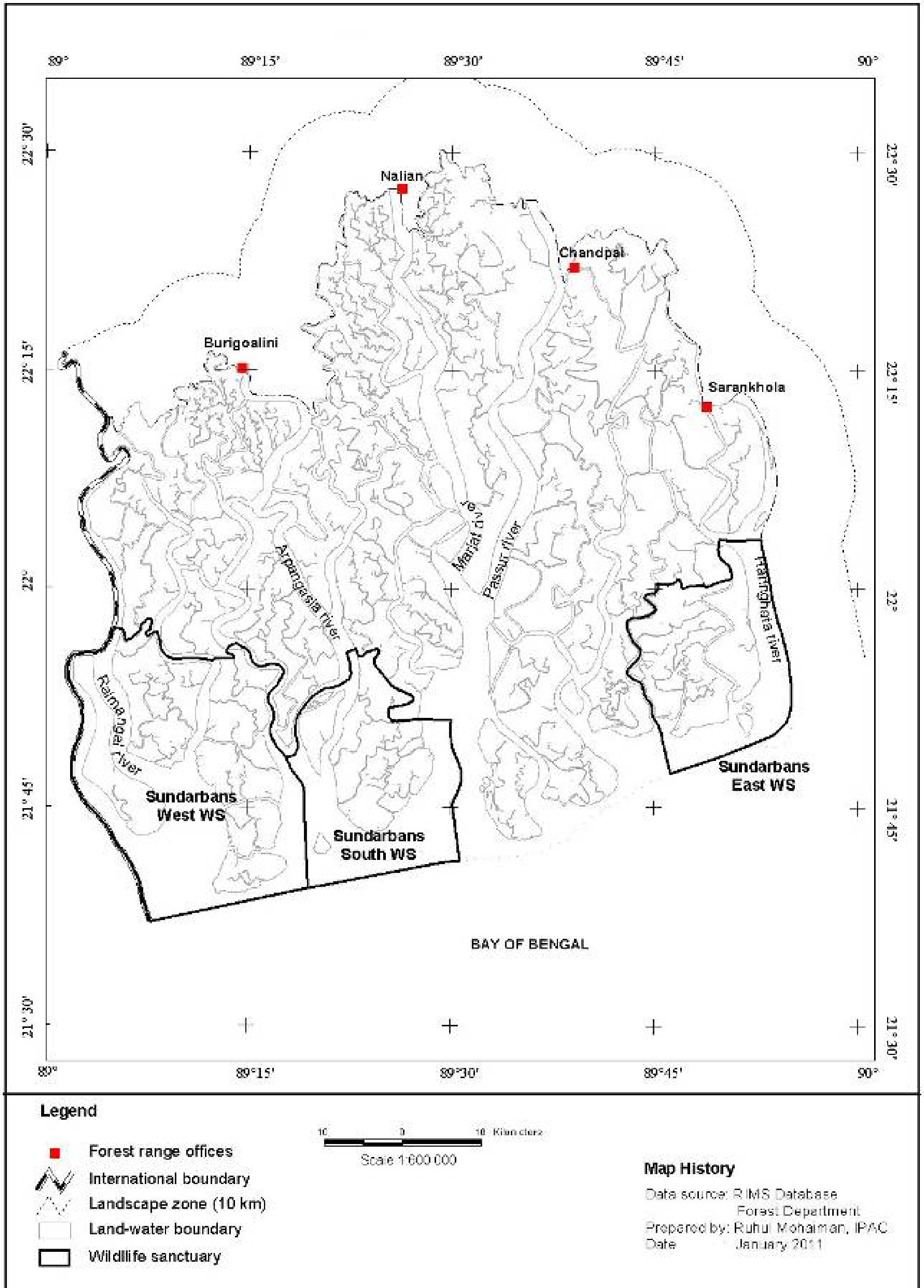


Figure 2.8: Wildlife Sanctuaries in the Sundarbans



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

2.9 Floral Biodiversity

Biodiversity analyses for major components of the Sundarbans are presented by reviewing relevant literature. The Sundarbans contains moderate floral diversity: The more prominent and important tree species found include sundari, gewa, keora, goran, singra, dhundal, amur, passur and kankra. Golpata palm, commonly found in the Sundarbans, is widely gathered for thatching material. Hental is another palm species which is used extensively in the construction of small huts as roof rafter and frame of walls. Sungrass or ullu is widely gathered for thatching, in addition to being the main fodder species for deer. Hogla, a bulrush is gathered and split for cheap fencing, and Nal is used expensively for making mats. Hargoza, a shrub, Hudo, another shrub, together with Ora are stream bank protection species that predominantly grow along riverbanks.

As many as 334 species of plants from 22 families and 30 genera are found in the Sundarbans. This includes six species representing all four genera of *Rhizopheraceae*, as well as three species of *Avicenniaceae*, three species of *Meliaceae*, and two species of *Sonneratiaceae*. Also represented are seven families of shrubs, comprising 12 species from 11 genera, six families (11 species) of climbers, 13 members of the *Orchidaceae* family, and seven species of epiphytic ferns. Other families represented include *Graminae*, *Palmae*, and *Pandanaceae*. None of the species are known to be endemic, and all are indigenous. There are no known endangered plant species in the Sundarbans, although the range of *Heritiera fomes* (sundri) is reported by the IUCN Red List to be in decline, making it endangered on a global level.

The northeastern portions of the Sundarbans are miohaline, characterized by high freshwater and silt inputs, and relatively higher topography leading to less frequent tidal inundation. These conditions create tall (15 m) forests of *Heritiera fomes* (sundri), often in pure stands or in association with *Excoecaria agallocha* (gewa). Where the sundri forests are mixed, they also may contain *Xylocarpus mekongensis* (passur), *Bruguiera* spp. (kankra), and *Avicennia officinalis* (baen). Understory growth typically consists of *Cynometra ramiflora* (singra), *Amoora cucullata* (amur), and *Ceriops decandra* (goran). Riverbanks tend to have high populations of the palm, *Nypa fruticans* (golpata), while new accretions are pioneered by *Sonneratia apetala* (keora). Gewa-dominant forests are more common in the moderately saline (mesohaline) areas occupying the inland middle portions of the Sundarbans. Sundri is increasingly less present toward the west and south. Overall canopy heights are lower (10 m) in the gewa forests that often also contain passur, kankra and baen mixed with *Xylocarpus granatum* (dhundul). Closer to the coast, *Lumnitzera racemosa* (kirpa) is more common. Other species prevalent in this zone include goran, golpata along water courses, and keora in greater abundance here than in other zones. The polyhaline areas in the western zone of the Sundarbans have dense stands of gewa and goran, with *Rhizophera mucronata* closer to the coast. Also found are keora, baen, kankra, passur, and dhundul. The palm *Phoenix paludosa* (hental) is common on lands of slightly higher elevation.

2.10 Faunal Biodiversity

About 289 terrestrial species of 185 and 219 aquatic faunal species of 146 genera (IRMP, 2010) have been reported as found living in the Sundarbans. Predominant and important mammal species include the Royal Bengal Tiger (Dora Bagh), Spotted Deer (Chital Harin), Macaque Monkey, wild Boar, Jackel, Jungle and Indian Fishing cats, small and large civets, small mongoose, common ottter, smooth coated otter, bats, Irrawady squirrel, crestless Malay porcupine, large bandicot rat and others. The principal reptiles species include the estuarine crocodile, python, common cobra, gecko, sea snakes, monitor lizard, turtles and others. Of the bird species, the aquatic ones include the Adjutants, Storks, Herons, Egrets, Little Cormorant and others. The semi aquatic ones include the Plovers, red-wattled Lapwing, Avocet, Stint, Curlew, Sandpiper, Common Greenshank, Gulls, Terns and others. A number of raptorial birds are also found which include the falcons, eagles, vultures, kites, harriers and others. The other terrestrial birds include the kingfishers, doves, pigeons, flycatchers, oriental magpie robin, red jungle fouls, woodpeckers, owls, rose-winged parakeet and others. The SRF and the surrounding landscape have a rich avifauna and the most recent list of species indicates that at least 315 species representing 48% of the birds known to occur in Bangladesh, have been recorded here (IRMP, 2010). Of these, 84 species are migratory, making the SRF a valuable location of passage of migrant and seasonal birds.

The inshore island of Tinkonia and offshore island of Putney, Nilbaria, Kachikhali and Dubla are valuable habitats for waders and resting points for migrating flocks. Some of the amphibians include the rana and mycroplyla species of frogs. Commercially important species of fin fish, shrimp and crabs in a provincial species list for the Sundarbans tallied a fisheries fauna of 8 species. Chondrichthyan fish, 168 species of Osteichthyan fish and 31 species of crustacean are identified from the SRF (IFMP, 1998). There are over 120 species of fish that are commonly caught in the SRF. Shellfish and mollusks such as univalves (gastropods) and bivalves (polycypods) are generally collected for lime production. There are at least seven species of bivalves in estuarine areas and the mangrove floor of the SRF. Dey (2001) reports 470 species of animals in the Sundarbans, while Siddiqi (2001) places the estimate at 635 species. As seen in Table2.1, the main difference between the two estimates is the avifauna.

Table 2.3: Estimates of faunal species diversity in the Sundarbans

Class	Estimated # species: Dey (2001)	Estimated # species: Siddiqi (2001)	Notes
Amphibians	8	8	Includes three toads and five frogs
Reptiles	35	53	Dey estimate does not include tortoises
Birds	186	300	Large disparity unexplained
Mammals	32	50	Siddiqi estimate not delineated by spp.
Fishes	177	177	53 pelagic species; 124 demersal species
Crustaceans/Mollusks	32	47	24 shrimps, 7 crabs, 8 lobsters, 8 mollusks
Insects	unknown	unknown	No systematic studies conducted to date
TOTAL SPECIES	**470**	**635**	

Of this large number of species in the Sundarbans, only few are considered to be Critically Endangered locally. This includes the Royal Bengal tiger (*Panthera tigris tigris*), Irrawaddy river dolphin (*Orcaella brevirostris*), crab-eating macaque (*Macaca fascicularis*), and estuarine crocodile (*Crocodylus porosus*). These four species, along with birds such as the Palla's fish eagle (*Haliaeetus leucoryphus*) have high conservation value for their place at higher trophic levels in the food chain and for their potential tourism attractiveness.

Table 2.5 lists some of the species in the Sundarbans which are considered to be Critically Endangered, Endangered, or Vulnerable.

A recent assessment by FD estimates 440 tigers in the SRF and being an umbrella species, effective conservation and management of tigers would require well protected habitat as part of REDD. Securing the protection and co-management of the SRF would automatically result in securing the conservation of tigers and hence of other lower pyramid wildlife including its prey, the deer and wild boar. The tigers are threatened due to a number of factors that in the SRF include habitat degradation and loss, poaching and prey depletion and climate change.

Table 2.4: Critically Endangered, Endangered, or Vulnerable Animals in the Sundarbans

Class Order Family	**Species**	**English common name**	**Local common name**	**Conservation status**
Mammals				
Primates				
Cercopithecidae	*Macaca fascicularis*	Crab-eating macaque	Lombaleji banor	Critically Endangered
	Macaca mulatta	Rhesus macaque / monkey	Banor	Vulnerable
Carnivores				
Canidae	*Canis aureus*	Golden jackal	Shial	Vulnerable
	Vulpes bengalensis	Bengal fox	Khek shial	Vulnerable
Mustelidae	*Aonyx cinerea*	Small-clawed otter	Ud biral	Endangered
	Lutra lutra	Eurasian otter	Ud biral	Critically Endangerd
Felidae	*Felis chaus*	Jungle cat	Ban biral	Endangered
	Felis viverrina	Fishing cat	Mecho bagh	Endangered
	Panthera tigirs tigris	Royal Bengal tiger	Bagh	Critically Endangered
Even-toed Ungulates				
Cervidae	*Muntiacas muntjak*	Barking deer	Maya harin	Endangered
Cetaceans				
Delphinidae	*Orcaella brevirostris*	Irrawaddy river dolphin	Shishu / Shushuk	Endangered
	Peponocephala electra	Melon-headed dolphin	Shishu / Shushuk	Critically Endangered
Phoceonidae	*Neophacaena phocaenoides*	Black finless porpoise	Shishu / Shushuk	Endangered
Platanistidae	*Platanista gangetica*	Ganges river dolphin	Shishu / Shushuk	Endangered
Reptiles				
Tortoises & Turtles				
Emydidae	*Batagur baska*	River terrapin	Barro kaita	Critically Endangered
Trionychidae	*Chitra indica*	Asian soft-shell turtle	Khalua kasim	Critically Endangered
Crocodiles				
Crocodylidae	*Crocodylus porosus*	Estuarine crocodile	Lonapanir kumir	Critically Endangered
Lizards & Snakes				
Elapidae	*Ophiophagus hannah*	King cobra	[unknown]	Endangered
Viperidae	*Daboia russelli*	Russell's viper	[unknown]	Critically Endangered
Birds				

Class Order Family	**Species**	**English common name**	**Local common name**	**Conservation status**
Kingfishers				
Alcedinidae	*Alcedo Hercules*	Blyth's kingfisher	Maachranga	Endangered
Coots, cranes, and rails				
Heliornithidae	*Heliopais personatus*	Masked finfoot	Goilo hans	Endangered
Falcons – diurnal birds of prey				
Accipitridae	*Haliaeetus leucoryphus*	Palla's fish eagle	Koral	Critically Endangered
Pelicans, cormorants, and relatives				
Ardeidae	*Gorsachius melanolophus*	Malayan night heron	Bagha bok	Critically Endangered
Pheasants, quials, and relatives				
Phasianidae	*Francolinus gularis*	Swamp partridge	[unknown]	Critically Endangered
Amphibians				
Frogs and toads				
Ranidae	*Euphlyctis hexadactylus*	Indian bullfrog	Sabuj bang	Endangered

Source: adapted from Dey 2001, Siddiqi, 2001

Of all of these species, and many others which are endangered, vulnerable, or threatened, perhaps the migratory birds and fishes are those about which little recent information is available. It is likely given the loss of habitat on the Indian side of the Sundarbans as well as along the coasts of the Bay of Bengal, that many of these bird and fish species are using the Sundarbans as refuge and nursery for maintaining stable populations. Although not quantified, this aspect of High Conservation Values from these species provides further justification for ensuring sufficient flows of financial, physical, human, and knowledge resources to provide for the long-term conservation of this globally important ecosystem. Carbon offset credits through a REDD+IFM mechanism can be one important contributor to that effort.

2.11 Cetaceans Biodiversity

Cetacean is a scientific grouping of dolphins, whales and porpoises. The wetlands in the SRF and coastal waters are suitable habitats for a large number of Ganges River dolphins (or Shushuks), Irrawady dolphins and finless porpoises. As in case of vegetation, the salinity gradient partitions Cetaceans' abundance in the SRF and the interface landscape: i) Shushuks found in mangrove channels with high freshwater inputs, ii) Irrwady dolphins in more saline mangrove and in open estuarine waters where freshwater inputs are reduced but still fairly high, and iii) Indo-Pacific humpback dolphins and finless porpoises in moderately saline, nearshore waters affected by freshwater inputs.

2.12 Ecosystems Biodiversity

A broad understanding of the importance of the inter-relationship of the flora, fauna, aquatic and water resources and the edaphic condition on which they occur, and that make up the mangrove ecosystem, has emerged in Bangladesh. These combinations of resources and conditions, occupying the special ecological niche where sea water meets freshwater, fertilized periodically by sediments from the land and the sea, are the foundation of its high biological productivity, uniqueness and diversity. These circumstances also provide the basis for the broad range of productive assets it contains and protective services it offers. The hydrological regimes and their characteristics are the primary determinants of the ecology of the SRF. Nutrient rich tidal waters and sediment laden stream flow from upstream watersheds and maintain the inherent productivity and build the land base. Three broadly defined ecological zones have been recognized based on the very complex correlation of varying degree of residual salinity, fresh water flushing physiography and their influence on the composition and character of species which inhibit the ecosystem.. The boundaries of these zones are far from static and affected by the natural temporal changes of a daily (tidal and run-off) and seasonal (rainy season versus dry season) nature and the long-term (alterations in the upstream watersheds) impacts of human interventions.

Mangroves over the world are not particularly diverse in terms of their floristic composition, specially compared with rainforest ecosystems. Only 50 to 75 species are recognised as genuine mangrove plants, and the SRF is no exception and its floristic composition is made up of nearly 60 species. What makes the flora of the SRF special, however, is the predominance of nearly the families of the Sterculiaceae and Euphorbiaceae in contrast to other mangrove associations which more typically are made up of Rhizophoraceae, Avicenniaceae and Laganculariaceae families. Similarly, the SRF is also floristically unique because of the dominance of sundari (*Heritiera fomes*), a high prized timber species. In addition to sundari, two other prominent species are gewa and goran.

2.13 Threatened and Endangered Species

All the plant species found in the SRF are indigenous and there is neither endemic nor exotic species and so far none is considered as rare. But sundari is considered threatened due to its top dying and selective removals due to commercial value. The SRF is the only remaining habitat within the lower Bengal basin where wildlife still finds refuge; at present, there are 42 species of mammals within the SRF and the adjacent areas, constituting 35% of the total fauna of Bangladesh. Historical records suggest the loss of at least six spectacular mammal species in recent times: Javanese rhinoceros (*Rhinoceros sondaicus*), one horned rhinoceros (*Rhinoceros unicornis*), wild buffalo (*Bulbulus bulbulus*), gaur (*Bos gaurus*), swamp deer (*Cervus duvaucali*) and the hog deer (*Axis porcinus*). Although the SRF in many respects has a high degree of uniformity, it has an interesting spectrum of faunal species, albeit reduced in numbers in recent times and difficult to observe in many instances. Of particular importance are the Royal Bengal Tiger (*Panthera tigirs*), spotted deer (*Axix axis*), wild boar (*Sus scrofa*), monkey (*Macaca mullata*), monitor lizard (*Varanus spp.),* turtles (both fresh and marine water), snakes, dolphins especially the gangetic dolphin (*Platanista gangetica*), otter (*Lutra perspicillata*), and the saltwater crocodile (*Crocodylus porosus*), which are diverse examples of rich wildlife spectrum requiring urgent management attention and intensive conservation action. The tiger is an inseparable legend attached to the Sundarbans and the species occurs throughout the SRF. Tidal mangrove forest is a rare habitat for the species where it has been pushed due to habitat shrinkage. In many ways, mangrove has proved to be an unusually secure abode for the tiger, in spite of the fact that the species is listed in CITES as endangered species as per the IUCN red data book.

Like the tiger, the other most visible mammal species, the spotted deer (*Axis axis*) lives on the edge of its natural range in the SRF. They are found throughout the SRF but are most abundant in the south where extensive grassland and scattered forests of keora occur; this type of habitat occurs in the three existing wildlife sanctuaries. The occurrence of barking deer (*Muntiacus muntjak*) appears to be limited to the north and the north-east in the SRF. Wild boar (*Sus scrofa*) occurs throughout the SRF including the off-shore islands. Monkey occurs throughout the SRF and is a common sight with greater incidence in the south. Some 35 species of reptiles has been recorded in the SRF. The marsh crocodiles (*Crocodylus porosus*), once abundant, is now quite rare. At least 30 species of snakes are reported to have found in the SRF but there has been a general decline in densities. The rock python (*Python morulus*) is listed as a vulnerable by IUCN and is another valuable species which is said to have declined over recent years and is rarely encountered.

2.14 Ecologically Critical Area

The 10-km wide area surrounding the northern and eastern boundaries of the SRF, with an approximate area of 175,000 hectares, was declared (by the Ministry of Environment and Forest, ref no. pa ba ma/ 4/7/87/99/263) as Ecologically Critical Area (ECA) on 30 August 1999, with the main objective of providing protection to the SRF and conservation of its biodiversity. This ECA has been included in the reference region for the project area comprising the mangrove forests. The ECA has some wetland resources which have over the period become degraded, thereby limiting the access of the poor people. There has been a great deal of change in the land use pattern and agricultural lands have been converted to *gher* for fish and shrimp culture. The fisheries production is going down in the ECA water bodies due to reduction of grazing ground and movement of spawn and hatchling. The area and the local people are characterized by poverty, natural calamities, poor education and health services, drinking water scarcity, and little income opportunities, all of which contribute to high biotic pressure on the natural resources of the SRF and the ECA. As the ECA area coincides with the identified reference region, a detailed analysis is presented in this section. A total of 5 districts, and 10 upazilas are within the ECA. Of the 47 Unions, only 27 unions are fully and the remainder are partially covered. Table 2.6 gives the list of district, sub-district (upazila) and unions with the coverage ratio and names. A list of ECA villages is given in Annexure 1.

Table 2.5: Districts, upazilas and unions in the Reference Region

Sl	District	Sl	Upazila Name	% coverage	Sl	Union Name	% coverage
1	Borguna	1	Patharghata	40%	1	Char Laldi	100%
					2	Hatempur	100%
					3	Char Duani	100%
2	Pirojpur	2	Mothbaria	30%	4	Sapleza	40%
					5	Gulishakhali	100%
					6	Amragachia	40%
					7	Baromachua	20%
3	Bagerhat	3	Sharankhola	95%	8	Dakhin Khali	100%
					9	Rayenda	100%
					10	Rajapur	100%
					11	Dhansagar	100%
					12	Khonkata	80%
		4	Morrelgonj	30%	13	Jeodhara	100%
					14	Nishanbaria	80%
					15	Khaolia	50%
					16	Baraikhali	50%
					17	Hoglabunia	20%
					18	Baharbunia	20%
		5	Mongla	80%	19	Chila	100%
					20	Sundarban	80%
					21	Chandpai	100%
					22	Mithakhali	80%
					23	Pourasava	100%
					24	Burirdanga	20%
4	Khulna	6	Dacope	60%	25	Laudobi	100%
					26	Banishanta	100%
					27	Bajua	100%
					28	Kailasgonj	100%
					29	Sutarkhali	100%

					30	Kamarkhola	50%
		7	Koyra	80%	31	Dakhin bedkashi	100%
					32	Uttar Bedkashi	100%
					33	Moharajpur	100%
					34	Baghali	80%
					35	Maheshwaripur	100%
					36	Amadi	90%
5	Satkhira	8	Paikgacha	5%	37	Goruikhali	50%
					38	Soldana	20%
		9	Shamnagar	70%	39	Kaikhali	100%
					40	Ramjan Nagar	100%
					41	Munshigonj	100%
					42	Burigoalini	100%
					43	Gabura	100%
					44	Nurnagar	20%
					45	Ishwaripur	10%
					46	Atulia	80%
					47	Padma Pukur	20%

Main wetlands in the ECA, distributed all over the area, cover canals and rivers which are connected with the rivers of the Sundarbans. Out of 16 unions, 4 unions have information on the wetland natural resources and it shows that are 29 water bodies of which 25 are canals and 4 are rivers. The length of 8 water bodies located in the eastern part is 52 km with perennial water retention and they are owned by the Government and so have open access as no fee is required for resource collection. On the other hand, in the west the canals (13 canals of this type under Shyamnagar Upazila) are closed as they are either leased out or illigeally occupied for fish culture, with no access to general people. Due to embankments many of the canals have been closed and it has affected the fisheries, thereby reducing the income of the poor.

Many canals are dead with no/little connection with the rivers. The canals are also getting silted up, making them seasonal with low water retention. The salinity is increasing in the area due to the reduction of sweet water flow as the rivers and canals in the upstream have become dead, silted up and blocked. The unemployment rate is high (20% to 90%) due to lack of income opportunities. As a result, a large number of local people depend on the SRF for livelihoods. The PRA/RRA information from 13 unions shows that the households' dependency for livelihoods on the SRF is minimum 10% and maximum 80%, whereas the forest resource dependency ranges between 2% and 60%, and the dependency on wetland (fisheries) resources is 5% and 70%. But as the ECA is endowed with low natural resources, the stakeholders' livelihood dependency on it is comparatively low as evident from the Table 2.7 as below:

Table 2.6: Stakeholders of the Reference Region

SL #	Stakeholder Name	Description of Stakeholders	Type of Stake	Level of Stake
A. Primary Stakeholders				
01	Occasional Fisher	Poor people: Mainly male; sometimes female and child	Fish and fisheries item	Minor
02	PL collector	Poor people: Male, female, children	PL of Golda and Bagda	Minor
03	Subsistence fisher	Poor people: Male & female	Fishes	Minor
04	Fish culturist	Rich and influential people	Fish culture in closed canals	Moderate
B. Secondary Stakeholders				
05	Small Mohajons (money lenders)	Local people, influential	Small funding, purchase product	Minor
06	Gher Owners	Influential and powerful persons e	Purchase shrimp PL, small investment to from PL collectors	Minor
C. Other /Institutional				
07	Department of Environment	Govt. body	In charge of resource management	Major
08	Depart of Fisheries	Govt. body	In charge of fisheries management	Major
09	Upazila administration	Govt. body	Management of Khas jalmohal and leasing	Major
10	Union Parishad	Local Govt.	Management of Khas jalmohal (small size) and leasing	Major
11	IPAC	GOB Project	Natural resource and biodiversity conservation, livelihood improvement and economic advantages for dependent people.	Major

In the 14 unions there are 83,314 households (HH) with a population of 425,685, of which male population is 221,436 and female as 204,249. This information, if extrapolated, results in the information for 40 unions as; Households 238,040, total population 1216,242 with male 632,675, female 583,568. Average HH size is 5.12 and male female ratio is 1.08: 1.00. It should be mentioned that all the 40 Unions are not within the ECA. Thus the actual number of households and population of ECA would be somewhat less than the calculated figure. Available data from 14 unions showed that the minimum and maximum literacy rates are 30% and 80% respectively; the percentage of educated people (SSC and above) is 5% as minimum and 60% as maximum. Most of the villages are in poor category and so the entire ECA area is poverty-prone with limited income opportunities, disaster prone, and conversion of agricultural land into ghers results in the benefits flowing to handful people who are already rich. The vulnerability to climate change is high in the entire ECA area. There are huge number of landless people and average rate is 29%. There are about 898 widows per union, and 565 separated / divorced women per union. The disable and beggar number per union is 335 and 217 per union respectively. The higher rate of widow is due to the death of males during the SRF resource collection by the attack of tiger, pirates and cyclones. The Muslim community is dominated all over the ECA with particular domination in Sarankhola, Morelgonj and Munshigonj Upazilas. The Hindu community prominent areas are Dacope, Koyra and Mongla Upazila, whereas the Christian community is mainly in Mongla Upazila.

Natural disasters such as cyclones, storms, water surge are very common and affect most of the resource poor people who are most vulnerable. Main disaster coping mechanisms available to local people include the embankment/dyke along the riverside, good houses, cyclone centers, etc. There are embankments around the periphery of the ECA in most of the areas except Mongla Upazila. However, the embankments in south and west regions are fragile and have been damaged due to cyclones such as Aila and Sidr. The present status of many cyclone centers is not very encouraging; the information collected from 14 unions shows that there is minimum 1 cyclone center in one Union Parishad (UP) with a maximum of 18, and with an average of 5 per UP. As most of the houses are non-bricked and unable to bear a cyclone, the whole area of ECA is under the threat of disasters and so subject to high level of vulnerability.

Although there are some health care service facilities in each union (in the form of “Family Health Care Center” and “Community Clinic”), there is no hospital in any of the unions. As a result, the local people rely on quacks and doctors with traditional practices. Drinking water is one of the major problems in the whole ECA due to salinity. Most of the ECA is with poor road and transport communication. Many outsiders have settled in the area permanently due mainly to easy access to natural resources of the SRF. They are competing with the local community over resources, thereby hastening resources depletion. In 11 unions there is 131,000 hectares of total land, of which only 48% is arable. Some land is used for fish and shrimp culture in ghers and ponds; in 10 union there are about 12,300 ghers, covering about 9,000 hectares area, and there are 30,663 fish ponds in 7 unions. The gher farming is done by the rich people, limiting the scope of income for the poor. It increases the salinity in the area, making land less fertile. The gher farming is believed to change the soil and water quality, causing degradation of the environment. The agriculture that would produce many by-products like fodder, cow-dung would help in fire wood and livestock rearing. The gher farming has created several social problems as it is capital intensive and requires less labour.

Within the south-west region, industrial activities are concentrated along the roads between Kushtia-Jessore-Khulna and along the rivers. In recent past there were about 165 industries in Khulna, located in Rupsha, Khalispur and Shiromony industrial zones. Some of them have closed in recent years, but approximately 150 exist presently. These industries discharge untreated waste into the Bhairab-Rupsha river system. In addition, several match factories, fish processing units in the Rupsha industrial area discharge effluent into the Rupsha river. Goalpara power station, some jute mills, match factories in the Khalispur industrial belt also discharge their untreated waste into Bhairab river. The pollutants find their way to the SRF wetlands through the Pasur-Sibsa river system to well below Mongla port which is the center of the country's maritime activities and also a significant source of water pollution. Presently in Bangladesh, the use of chemicals has an increasing trend and about 20 insecticides, 18 fungicides and 2 rodenticides are being used in the country. These chemicals eventually drain into the adjacent water bodies and are carried downstream in the SRF through the river waters. Their subsequent incorporation into the food chain, with biological magnifications at higher tropic level, risks the stability of the biota itself and result in disruption of biochemical cycles of the ecosystem.

Oil pollution is also affecting the environment of the SRF. Bilgewater and crude oil slicks derived from mechanized boats, fishing trawlers, goods carrying vessels and passenger launches travel along the Pasur river at a distance of about 100 km via the SRF to Mongla port. The number of sea going vessels handled by the Mongla port is less in recent years as the port activities have reduced substantially. However, there is potential of activating the port and the ship number will increase, if this happens. The number of other vessels (mechanized, passenger, fishing, etc.) has been reported to be on the increase in last 10 years. Oil from the fuel tanks spreads about 15 km downstream from the ship and affects a considerable part of the Sundarbans. There are reports about mortality of seedling of Heritiera and Excocaria from the oil spill and the mortality of fishes, shrimp and other aquatic animals. At present, the oil pollution is not a big threat for the SRF but there are increased potential risks in future.

Monitoring and surveillance facilities are not available to quantify the extent of the pollution. However, it is known that the fine grained anaerobic sediments, characteristic of mangrove forests, severely reduce the rate of microbial breakdown of oil. Burrowing activities of crustaceans, a characteristic of mangrove forest, can lead to persistence, high levels of oil contamination, not only on the soil surface but also deep in the sediments in the mangrove root zone. The light fraction of the oil, considered to be the most toxic, generally evaporates or degrades rapidly. Hence, the heavier fraction is the cause of most of the chronic impacts. Chronic exposure to oil residues results in damage to aerial roots, reduction in litter fall, and reduced survival and deformation of seeding. Coastal and marine fisheries are affected quantitatively and qualitatively with a reduction in the nutritional value of fish. The thin layer of oil on the water affects the multiplication of planktonic organisms and interferes with the growth and reproduction. Fish can also absorb oil directly with their feeding, resulting in the tainting of fish tissue. Also, the aromatic hydrocarbons present in the crude oil are persistent and carcinogenic. Since they have tendency to be biologically accumulated in fish tissue, they can pass it on into organisms of higher tropic levels in the food chain.

More than 125 polders have been constructed in the south-west region along the upper catchment area of the Sundarbans rivers. These polders were constructed mainly to control the saline intrusion into the agricultural fields. The impact of polderization has also been felt in the Sundarbans rivers. A large number of rivers have been silted up. It is feared that the Bhadra river, which passes through the Sundarbans to meet the Pasur, is undergoing rapid siltation and may cease to connect this part of the SRF with upstream catchment area of the river in near future. Another boundary river, the Kharma Khal, which used to connect eastern fresh water carrying rivers with Pasur system, no longer connects these rivers and has silted up completely. Major interventions including excavation are needed to re-connect some of these streams and rivers. Some of these embankments can be brought under co-management through benefit sharing by involving local community in raising embankments plantations that will stabilize the polders and also provide usufructury benefits to local community.

2.15 Assessment of Forests Management

A detailed review of various management systems and practices employed for scientifically managing the Sundarbans is necessary for drawing relevant lessons that can be taken on board while designing and implementing forests protection and improved management strategies. The management of the Sundarbans is several hundreds year old and the history of changes in legal status boasts a number of unique features including the distinction of being the first mangrove forest in the world to be brought under scientific management. However, the early management of the Sundarbans was confined to revenue generation from the export of timbers, and in the middle of the 16th century, the local king used to impose levy on the export of the wood from the forests. During the early British rule, the forests were leased out to settlers, which resulted in the conversion of large track of forests into farm-lands and human settlement areas: At the beginning of the British rule, the Sundarbans was twice from its current size and the local landlords, whose properties extended up to the boundary of the forest, cleared and reclaimed forestland regularly.

Systematic management of the Sundarbans forest tract started in the 1860s after the establishment of a Forest Department in Bengal. The Sundarbans was declared a Reserved Forest in 1875-76, under the Forest Act, 1865 and was transferred from the civil district administration to the newly created Forest Management Division in 1879 with the headquarters at Khulna. The first survey of the Sundarbans was carried out during 1769-1773. In 1821-23 the boundaries of forests were surveyed. A number of inspections of the Sundarbans by prominent British Foresters between 1863 and 1874 raised the awareness about the value of the Sundarbans as significant forest resource base. The recommendations of these foresters resulted in the formulation of the first set of guidelines for regulation and exploitation of the trees, and thereby, promoting the conservation of the forests. The export of timber from the forest was regulated through the establishment of Forest Stations on the main routes of timber export from the forests.

Between 1905 and 1908, the Sundarbans was again surveyed in detail by the Survey Department of the province of Bengal and map sheets (Scale: 1 inch = 1 mile) were published in 1909. Subsequently, local surveys have been undertaken to incorporate accretion as well as loss of areas through erosion. The latest sheet of these maps was published in 1924, which was updated during working plan preparations. A set of maps based on both aerial photographs and field surveys was prepared during the 1959 inventory by Forestal. A new set of maps became available in 1985 after the ODA (UK) inventoried the forests. The Forest Resource Management Project (FRMP) conducted forest inventory in 1996/97, and prepared maps based on the base-maps derived from 1:50,000 SPOT satellite imagery of 1989 and amended by using 1:15,000 aerial photographs in 1995. The latest version of the Sundarbans maps was produced by the RIMS-GIS Unit of the Sundarbans Biodiversity Conservation Project of the Forest Department in 2002. It modified slightly the map produced under the Forest Resource Management Project. The maps are at a scale 1: 20,000 and show the area and boundaries of the ranges and compartments, wildlife sanctuaries, the locations of all station and camp offices and a distinct classification of each forest type. These updated maps have been used in the IRMP and CRISP.

The first 10-year management plan came into operation in 1893-94 wherein the forests of Khulna and Bagerhat subdivisions were divided into two felling series and 10 annual coupes. The felling of sundari was limited to these coupes and minimum felling girth of 91 cm was prescribed. In the plan, sundari and to a limited extent *Sonnetatia apetala*, *Xylocarpus mekonggensis*, *Bruguiera gymnorhiza* and *Amoora cucullata* were dealt for conservation and exploitation. Felling of other species remained practically unregulated. A revised working scheme was prepared for the period of 1903-08 in which the same felling series were maintained but the annual coupes were reduced to one-fourth of the former size, thus increasing the felling cycle to 40 years. Simple silvicultural rules were prescribed for the felling of sundari. During this period the introduction of transit permits and felling hammer marks helped reduced the incidence of timber theft. In the working scheme for the period 1906-07 to 1929-30, the felling series and the cutting cycle for sundari were the same as in the former scheme but the exploitable girth was raised to 106.6 cm. All mature trees were hammar-marked before felling and thinning was prescribed in overcrowded younger stands.

The first regular working plan for the SRF was prepared by S.J. Curtis for the period of 1931-1951. The Curtis' plan focused on scientific harvesting and was in effect when the subcontinent's partition divided the administration of the Sundarbans between Bangladesh and India. The Curtis plan was updated for the period 1937 to 1947 to enable the execution of certain prescriptions which were found to be too elaborate. Several interim plans were prepared based on the Curtis' prescriptions until the Forestal Inventory was completed in 1959. Based on this inventory, a comprehensive management plan for the period 1960-1980 was prepared. But the plan continued beyond 1980 and was still in effect when the ODA inventory was conducted in 1983. From the results of ODA inventory, Balmforth prepared his interim prescriptions which were followed until the government declared a moratorium on the felling of timber from the natural forests in 1989. The felling of gewa, goran and other fuel wood species, however, were exempted from this ban. Similarly the golpatta and species of plam continued to be harvested. After 1990, the felling of sundari was restricted to salvage felling of top-dying sundari trees.

A draft management plan for the Sundarbans for the period 1990-2000 was prepared based on the Management Plan manual developed by Balmforth (in 1985) but the proposed plan was not implemented as it was not approved by the Government. In 1998, an Integrated Forests Management Plan (IFMP) for the SRF was prepared for 12 years period (1998-2010) under the World Bank supported FRMP. In the IFMP, for sundari the cutting cycle was for 20 years, minimum felling diameter 27.6 cm for sundari production areas and 22.6 (for compartments of 7,18,19,20, 38 and 40), annual allowable cut (AAC) prescribed 21,500 cu. m. for interim period and around 54,000 cu. m. in regular period. The keora harvest plan was 28,200 cu. m. for 2000-2005 and 26,700 cu. m for 2005-2010. The other timber species felling suggestion was 14,124 cu. m. for 2000-2005 and 15,067 cu. m for 2005-2010. The FRMP inventory of 1996/97 and the analysis carried out by the FRMP showed that the increased AAC by the Balmforth Interim Felling Prescription for gewa was way above the sustainable capacity for the forest, resulting in further degradation of the growing stock.

The IFMP was elaborative and explanative, and also had a forecast on the harvest plan for another 10-years (2011-2020). Though it gave the details of harvest plans for all major timber species, the prescriptions could not be carried out due to ban on commercial timber felling. While the IFMP was in operation by the Forest Department, there were couple of natural incidences that damaged the Sundarbans to great deal; the most devastating one was the cyclone Sidr of November 2007 which made a huge damage to the forests, wildlife and fisheries. To compensate the loss and early recovery of the Sundarbans, the IFMP prescriptions were put on hold; all the forest products harvest were banned except few minor products like fish, honey and bee wax, and only in 2009, when the forests came back to a reasonable situation, the golpata harvest was permitted.

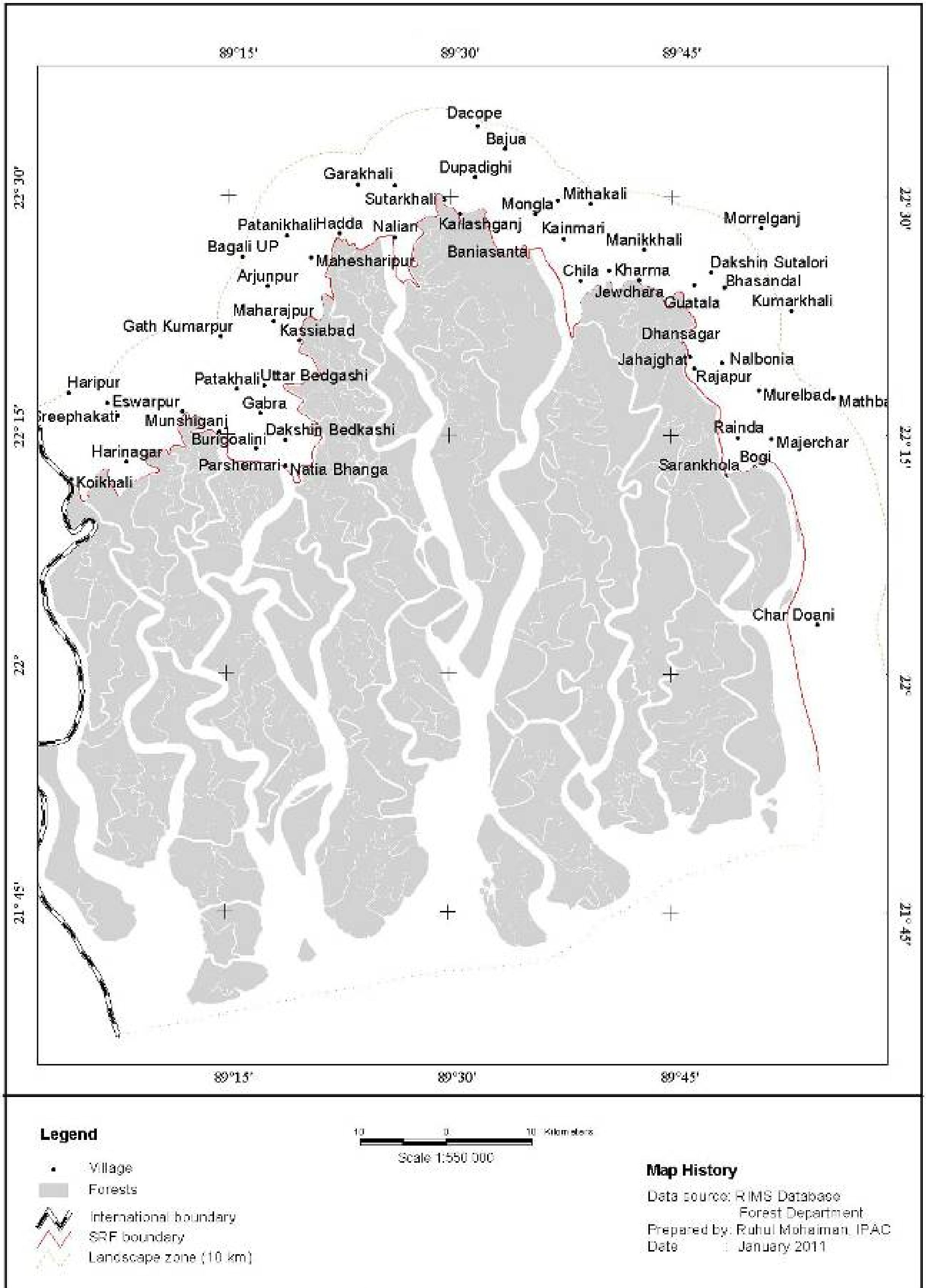
For the aquatic resources, the traditional approach, which was carried out through the previous plans did not set any limit to the levels of extraction. These resources together with fuel wood and golpata extraction, gathering of honey bee's wax, and collection of other minor forest products, were a major source of revenue to make up for the lost timber revenues during the moratorium period. Minimal harvests of sundari from top-dying salvage operations were made available to the market through departmental extraction and public auctions. However, the fishermen continued using of tender sundari poles, and the sundari top-dying continued. The erosion of river embankments and siltation continued and the reduction in water depth and freshwater inflow from the upstream had negative impacts. The impact of climate change (temperature increase, salinity increase, reduction in fresh water flow, cyclones, etc.) is believed to have some changes in the overall environment of the Sundarbans.

2.16 Reference Region

As improved forests management of the Sundarbans can not be achieved in isolation from the surrounding socio-economic realities and development priorities, it calls for a sustainable landscape approach which focuses on a broader spatial scale in order to integrate relevant forests/wetlands and ecosystems with socio-economic and institutional systems. It is a holistic approach that takes in to account relevant factors that impinge on improved forests management of the Sundarbans in the context of a mosaic of different land-use patterns and socio-economic attributes. The identified landscape zone (IRMP, 2010) is taken as a reference region for improved forests management of the Sundarbans in order to address co-management issues in the context of a broader socio-economic, natural resource governance, institutional and environmental perspective. It provides a suitable framework to manage the Sundarbans for multiple uses by addressing interactions between local economy, local stakeholders and natural resource base. It entails biodiversity conservation by establishing suitable linkages between the forests ecosystem with the interacting local community. It will help restore socio-ecological processes both within the project area but also in the reference region by accounting the presence and needs of local community. It promotes gainful partnerships with local stakeholders, which will help integrate the management of the SRF with community development.

The project area comprising the SRF and its reference region covers full or partial areas of five administrative districts (Khulna, Bagerhat, Satkhira, Pirojpur and Borguna), of which the first three are of great importance. As the Ministry of Environment and Forests have declared a 10 km band as ECA as per the provisions of Environmental Conservation Act, 1995, the periphery of the SRF thus includes the legally declared ECA within a 10-km band boundaries surrounding the SRF in north and east. This is what is designated as interface landscape zone as reference region in the context of the modalities of the livelihood interventions and support for environmental and biodiversity consideration. The project area and the reference region comprise 5 districts, 10 Upazilas, 151 unions and 1302 villages (2.8). The location of select villages in the reference region is shown in Figure 2.8.

Figure 2.9: Location of Select Villages in the Reference Region



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

Table 2.7: Details of the Reference Region

District	Upazila	No. of Union Councils	No. of villages
Bagerhat	Sadar, Mongla, Morrengonj, Sarankhola	65	486
Khulna	Dacope, Koira, Paikgacha	37	440
Satkhira	Shymnagar	13	216
Pirojpur	Mathbaria	20	94
Barguna	Patharghata	16	66
Total	**10 (UZ)**	**151**	**1,302**

Source: BIDS, 2010

2.16.1 Socio-economic Assessment

The Southern Delta of Bangladesh has been known in the past as Bangladesh's breadbasket and its potential remains significant even today, especially for increased production of agriculture including aquaculture, rice and horticultural crops. The region, however, has been marked by a number of transformational changes such as an increased salinity from natural and man-made causes including climate change, large embankments, and reduction in fresh water flows. The climatic events, most recently Cyclones *Sidr* followed by *Aila*, have had particularly adverse impacts on salinity of agricultural lands and waters due to numerous polders which have over the period not been maintained properly. Salinity levels have both stimulated and followed the financially attractive but capital-intensive production of shrimps in lands that were hitherto cultivated with rice and other agricultural crops. Along with the shift in land use has gone a decreased demand for agricultural labor, reduced locally produced farm products, and increased farm prices. At the micro level, salinity in neighboring fields is now increasingly leeching into ponds and remaining cropped areas, and fish that once thrived in the region in fresh water ponds are now much less productive, and saline tolerant species are becoming the norm. Along with these changes in salinity has come an increased concentration of land ownership in the Sundarbans Landscape Zone (SLZ, a 10-km wide band surrounding the northern and eastern periphery of the Sundarbans Reserved Forests, SRF comprising 600 km^2 of mangrove forests and wetlands, adjoining to the Bay of Bengal in south and India in west), where an increasing number of landless poor and ultra-poor populate into homesteads that become smaller each year. Community people mostly depend on forest resources and work as day labor in different sectors of the local economy that is characterized by severe poverty, dense population due to in-migration, rich natural resource base, high incidence of natural disasters, high salinity of water and land, absence of capital and agricultural facilities, and geographical remoteness.

Integrated Protected Area Co-Management project's co-management socio-environmental governing platform provides a unique opportunity to implement CRISP, taking advantage of technical innovation, the best scientific knowledge and strong linkages to sustainable landscapes. Throughout the SLZ, and in gainful partnerships with the government recognized Co-Management Organizations (CMO), IPAC is already supporting forests protection and equitable benefits sharing from the SRF. IPAC thus provides a solid but dispersed platform with field presence in remotely located project villages that is being leveraged for CRISP implementation. IPAC's ability to reach-out to more people will transform their livelihoods to more productive livelihoods thereby reducing their dependence on the SRF resources, thus strengthening conservation management and sustainable lands and waters productivity as well as climate change mitigation by reducing pressure on forest degradation.

IPAC is currently working in the SRF and its surrounding SLZ comprising 20 Union Parishads in 6 Upzillas (Shoronkhola, Morolgong and Mongla in the Sundarbans East Forest Division, Shyam Nagar, Dacope and Koira in the Sundarbans West Division) of Khulna, Bagerhat and Satkhira districts, with main objectives of conserving biodiversity and improving the livelihoods of the local community by following a co-management approach. The IPAC co-management platform in the Sundarbans includes 4 co-management committees (CMCs) comprised of government agencies as well as community organization, 209 Village Conservation Forums (VCF) representing more than 140 villages with a total population of 160,000 in 32,000 households, and 340 Nishorgo Shahayak, volunteer community facilitators. By employing the co-management platform that is already in operation, the project intends to promote ultra poor and poor households (HHs) by improving environmental governance and developing their capacity to increase land-based production and equitably share ensuing enhanced benefits.

There are no communities or human settlements within the boundaries of the project area. However, in the reference region adjacent to the Sundarbans, there are populated villages in the eastern and northern periphery of the SRF. In the south of the Sundarbans, there is the Bay of Bengal and to the west, the Indian Sundarbans. The Sundarbans landscape has a rich history of local people and new migrants pushing into a harsh environment to access land and natural resources. The people in the identified reference region of the Sundarbans and the society they form are as complex and dynamic as the ecological systems on which they depend. History informs that society has passed through many phases when society was conquering the natural environment and overcoming vulnerabilities encountered. Equally, history highlights that there have been phases of leaving and loss as the forces of nature and economies prevail. The majority of communities in the villages located in the reference region are Bengali, mostly Muslim with a smaller number of Hindus and Buddhists, and the Muslim Bengalis tend to be the most affluent. There are some religious and ethnic minorities which differ from area to area. The status and role of women differs depending on the area. In the reference region, women are less conservative, despite the fact that most wear veils outside their home, they benefit from a high degree of mobility, and participate in social activities and events. However, some groups are more conservative than others, with middle-class women having the latter tendency. Some evidence of empowering factors exist, with a higher percentage of women having access to credit than men, the former from NGOs such as BRAC, ASA, Proshika, Coast, and Digonta, and the latter from banks such as Grameen and Krishi. Some 60 percent of women claim that their opinions are considered by the head of the family or other male equivalent.

Village society is divided into a few small *samaj* (community groups) with its informal (e.g. Imams) and formal (elected representatives of Union *Parishads*) leaders. They play an important role in the motivation of local people as well as in conflict resolution; consultation with them is often required before the introduction of a forest activity. Most of the local communities are poor, and landless, with majority of the households falling into the extremely poor category. Illiteracy rates are high, with women experiencing higher rates than their male counterparts. Government facilities for education and non-formal education, and awareness raising initiatives by NGOs have led to reductions in illiteracy. However, many households cannot afford to educate their children beyond the primary level, due to lack of resources. Most villagers are dependent on forests and wetlands resources not only for their employment and livelihoods, but also for protein integral to their diets; household materials; and fuel wood for domestic use. Illegal harvesting, motivated by lack of alternative sources of fuel, disturbed the natural regeneration of the forests, contributed to their considerable degradation, and negatively affected wildlife habitats. In terms of the movement of fuel wood, the first entry point is usually a small market, although the final destination may be a much larger market.

The site appraisal reports show that the people of the reference region are heavily dependent (about 70% of the total households) on the natural resources of Sundarbans. The second high employment opportunity is from aquaculture mainly in the form of shrimp, prawn and white fish culture and is about 10%. The remaining 20% are of from day labor, agriculture, business and service. There is limited scope of diversification of income sources because of geographic location, remoteness, natural calamities, education, social and religious barriers, change in land use pattern, impacts of climate change and other aspects. The employment opportunities have been reduced from the past and a reasonable number of people are out of work or the work availability is seasonal. There has been a great deal of occupational shifting among the local people from agriculture to natural resource harvesting and shrimp farming. The literacy rate is about 80% in the reference region. Remarkable is that the higher education (S.S.C and above) rate is very limited. This is due to lack of education facilities and poverty. The poor families can not afford education to their children due to lack of money and invest them into income activities at early stage of life. The religion of the area follows the national trend of Muslim majority. The second category is Hindu and the third is Christian. There is an indigenous group namely "Munda" in the south.

2.16.2 Land Use

The current land-use of the project area is forestry and fisheries. The entire project area is a mangrove forest with wetland (in the form of river, canal, *chatal, chara*) inside. There is limited harvesting of the resource. The traditional land use patterns in the reference region have seen rapid changes in last 20 years, especially since 2000; according to information from the community people, 80% of the land was under agriculture 30 years ago. Because of the construction of flood control embankments, natural tidal flow has been affected and many areas have become waterlogged. The increase of salinity and less opportunity of sweet water entrance during the monsoon has resulted in dramatic reductions in agricultural productivity. This situation has encouraged the expansion of shrimp farming. The process of uncontrolled population growth has reduced the per capita cultivable land. It has also created overcrowding and high rates of unemployment in agriculture as well as over-expansion of aquaculture and brackish water shrimp farming. This has created a range of ecological and socio-economic problems in the reference region, leading to crisis in the livelihoods of the poor and marginalized people. There are some differences in the land use pattern within the reference region. The eastern part has some more agriculture, the southern part with mixture of agriculture & shrimp farming while the western part is with exclusive domination of shrimp farming.

2.16.3 Land Ownership and Tenure

The sole owner and manager of the project area is the Forest Department of the Government of Bangladesh (GOB). The department is empowered by the GOB through relevant Forest Acts and Rules. So the access right to the project area and resource collection is controlled by the FD and requires their permission. There are no current, ongoing, or recent disputes over the project area, which has been under protected status by the government since 1875. The land category of the project areas is Reserved Forest land, with the legal title of land ownership held by the Government of Bangladesh through the FD. Although formal ownership of the project area rests with the FD, the management has been vested with the recently established co-management councils and committees (CMCs). Thus, land tenure is clear, and rather than land disputes being the greatest source of these conflicts, forest resources and the FD’s attempts at preventing their exploitation through poaching and illegal harvesting are. While most disagreements are resolved by the CMCs or the FD, in the case of serious conflicts, the police and local MP may be asked to intervene. If the conflicts arise from forest land disputes, people often go to the forest office to resolve the conflict.

2.16.4 Legal Title to the Land

Legal title to all of the project area rests with the State. There are no tenure disputes due mainly to the long-standing history of government ownership going back to British colonial times in the 19th century. No legal framework yet exists in Bangladesh for tenure rights over carbon or any Voluntary Emissions Reductions (VERs) or Certified Emissions Reductions (CERs) that may be generated as a result of project activities.

2.16.5 Community and Poverty Analysis

As human settlement inside the project area is restricted due to its enhanced protection status as per the Forest Act and Wildlife Act, neither villages nor cultivated fields are found inside it. Only some floating dwellers engaged in harvesting NTFPs including fish temporarily reside inside the SRF. But the total population living in the identified reference region is estimated to be as high as 8.55 lac (about 6.0% of the country’s total population) living in about 15,352 sq. km. (10.4% of the country's area); the density of population is 557 which is below the national average of 966.

Approximately half of the total area of five districts lie in the reference region : Khulna has the highest area as 72%, followed by Satkhira as 51%, Bagerhat as 41%, Pirojpur as 27% and the lowest in Borguna as 21%. In terms of population more than a quarter (28%) of the total population of the five districts live in the interface landscape zone : The highest percentage of population live in Bagerhat (56.4%), followed by Khulna (24.1%), Pirojpur (23.6%), Borguna (20.7%) and the lowest in Satkhira (17.0%). Almost similar is the distribution of the 1,302 villages across the landscape districts. Important demographic and area details are presented in Tables 2.9 and 2.10 as below:

Table 2.8: Population and demographic status in the reference region

District	Area (km^2)	Population ('000)			# HH ('000)	Size of HH	Sex ratio (M/F)	Population (2009) density (per sq.km)
		Total	Male	Female				
Bagerhat	3,959	1,646	854	791	343	4.8	108	416
Khulna	4,395	2,728	1427	1301	568	4.8	110	621
Satkhira	3,858	2,115	1083	1031	441	4.8	105	548
Pirojpur	1,308	1,151	582	569	240	4.8	102	880
Barguna	1,832	912	463	450	194	4.7	103	498
Total	**15352**	**8551**	**4408**	**4144**	**1781**	**4.8**	**106**	**557**

Source: (BIDS, 2010)

Table 2.9: Proportion of area and population in the reference region

District	% reference region area in respective district	% of reference region population (2009) in respective district	% reference region villages in respective district
Bagerhat	41.4	56.4	47.1
Khulna	72.3	24.1	40.0
Satkhira	51.0	17.0	15.1
Pirojpur	27.0	23.6	14.6
Barguna	21.1	20.7	11.8
Average reference region district	**49.0**	**28.1**	**27.2**

Source: (BIDS, 2010)

Nearly one-quarter of the total household in the reference region enjoys the electricity connection which is below that in coastal zone (31%) or the country as a whole (31%) (Table 2.11). Similarly, the number of active tube wells per Km^2 in the reference region is 5 compared to 7 in both coastal and as national average. The percentage of households enjoying sanitation in the reference region is 44.5, which compares favorably with national average (36.9%). In terms of literacy or child mortality rates, the landscape enjoys a slighty better position than that of coastal zone or the nation as a whole. Child mortality for every thousand is estimated at 93, compared to 103 for coastal district and 90 for Bangladesh as a whole.

Table 2.10: Selected socio-economic indicators by the reference region districts

Districts	Agricultural HH as % total rural HH	Literacy Rate (7+ years)	Child Mortality (less than 5 years)	Sanitation (%)	# active tube wells (km^2)	Electricity Connection (%)
Bagerhat	76	58.7	87	33.2	4	27
Khulna	69	57.8	90	37.0	6	26
Satkhira	60	45.5	96	59.2	4	42
Pirojpur	18	64.3	94	47.6	10	10
Barguna	79	55.3	94	36.7	4	9
landscape districts	58	55.7	93	44.5	5	25
Coastal Zone	N/A	51.0	103	45.6	7	31
Bangladesh	**N/A**	**46.2**	**90**	**36.9**	**7**	**31**

Source: (BIDS, 2010)

Both the reference region and the coastal region of the Sundarbans contribute significantly to the economy of Bangladesh. However, agriculture still remains the mainstay of the economy of the reference region. In FY 1999-2000, the share of agriculture to GDP in the reference region was 29% against the national average of 26%. The contribution of industries sector was 22%, which was the same as that of coastal zone but less than that of national average (25%). The reference region shares nearly 50% to service sector on par with the national average in general and the coastal area in particular. Most of the reference region districts have miserably low level of GDP per unit area, indicating a low level of regional development (Table 6.5). An average reference region district has GDP per sq. km of only Tk. 8.5 million, compared to Tk. 14.4 million in coastal zone and Tk. 21.8 million in an average district in Bangladesh (see Table 2.12). The district Bagerhat has the highest level of GDP (Tk. 10.4 m), which is nearly 2 times higher than that of Satkhira (Tk. 5.6m).

Table 2.11: Per capita and per sq. km GDP

Districts	GDP (2000 constant price)		Per sq. km. GDP (Million Tk.)
	District GDP (million Tk.0	Per Capita	
Bagerhat	27,717	16839	10.39
Khulna	63,112	23135	10.20
Satkhira	27,360	12936	5.61
Pirojpur	16040	13936	7.01
Barguna	15414	16901	6.16
landscape districts	27642	15929	8.5
Coastal Zone	35726	18198	14.38
Bangladesh	40706	18269	21.8

Source: (BIDS, 2010)

The main characteristics of the reference region, which differentiates it from other areas, is its complexity as manifested in the diversity and dynamic nature of the livelihoods of the local people, especially the poor. Although agriculture is still the mainstay of the economy, the reference region provides varied sources of livelihood, which are not commonly available in other parts of Bangladesh. More than half a million people live on the collection of fuelwood and NTFPs such as fish, honey, wax, and leaves of trees from the Sundarbans. In the reference region, nearly 30%of the people or nearly four times that of the share of national figure earns their living by fishing (Table 2.13). The people of the reference region, in general, are just surviving at subsistence level. Since soil condition varies considerably because of various hydrological conditions, the cropping intensity also varies accordingly. Generally, the reference region is with low cropping intensity, 134% as a whole, but non-saline tidal water flood plain has a good agricultural land than that of saline tidal flood plain. Pirojpur has the highest cropping intensity (171%) and the lowest in Bagerhat (107%0 (Table 2.13)

Table 2.12: Selected indicators for livelihoods in the reference region

Districts	Land-less	Agri-labor (%)	Per capita land (ha)	Per capita agri-land (ha)	Fisher-men (%)	One crop land	Two crop land	Three crop land	Cropping intensity (%)
Bagerhat	49.3	36	0.24	0.09	12	95	3	2	107
Khulna	49.0	40	0.16	0.05	40	NA	NA	NA	-
Satkhira	47.3	31	0.18	0.07	31	50	28	-	156
Pirojpur	53.2	32	0.11	0.09	32	36	57	7	171
Barguna	49.0	32	0.20	0.11	38	56	37	7	151
landscape districts	49.1	33	0.18	0.08	30	59	30	5	134
Coastal Zone	53.5	33	0.06	0.06	14	NA	NA	NA	-
Bangladesh	**52.6**	**36**	**0.10**	**0.07**	**8**	**31**	**42**	**13**	**154**

Source: (BIDS, 2010)

The local populations in the reference region are suffering from marginalization and inequality in income. Poverty status can be considered as a proxy to the extent of marginalization. BIDS (2010) conducted Head Count Ratio (HCR) between the reference region and non- reference region districts, which shows a dismal picture (Table 6.7). The extreme poverty levels of the landscape districts and upazilas are at considerably higher level in almost of all the districts and upazilas, compared to respective non- reference region areas. Although the coast as a whole and the reference region in particular, is endowed with natural resources and environment resources the landscape upazilas have much higher extreme poverty compared to non- reference region upazilas in Bangladesh. Thus the poverty situations in the reference region appear to be extremely severe.

Table 2.13: Poverty mapping in the reference region and non- reference region Upazilas

Reference Region Districts	Non-reference RegionUpazila	Head Count Ratio (%) (HCR)
Bagerhat	Bagerhat Sadar	0.306
	Mongla	0.415
	Morrelgonj	0.503
	Sarankhola	0.487
	Reference Region Bagerhat	0.430
	Non- reference region Bagerhat	0.238
Khulna	Dacope	0.604
	Koyra	0.348
	Paikgacha	0.344
	Reference Region Khulna	0.414
	Non-Reference Region Khulna	0.318
Satkhira	Reference Region Satkhira (Shyamnagar)	0.652
	Non-Reference Region Satkhira	0.451
Pirojpur	Reference Region Pirojour (Mathbaria)	0.179
	Non- Reference Region Pirojpur	0.185
Barguna	Reference Region Borguna (Patharghata)	0.361
	Non- Reference Region Borguna	0.432
Bangladesh	**Reference Region Upazilas**	**0.423**
	Non- Reference Region Upazilas (Bangladesh)	**0.262**

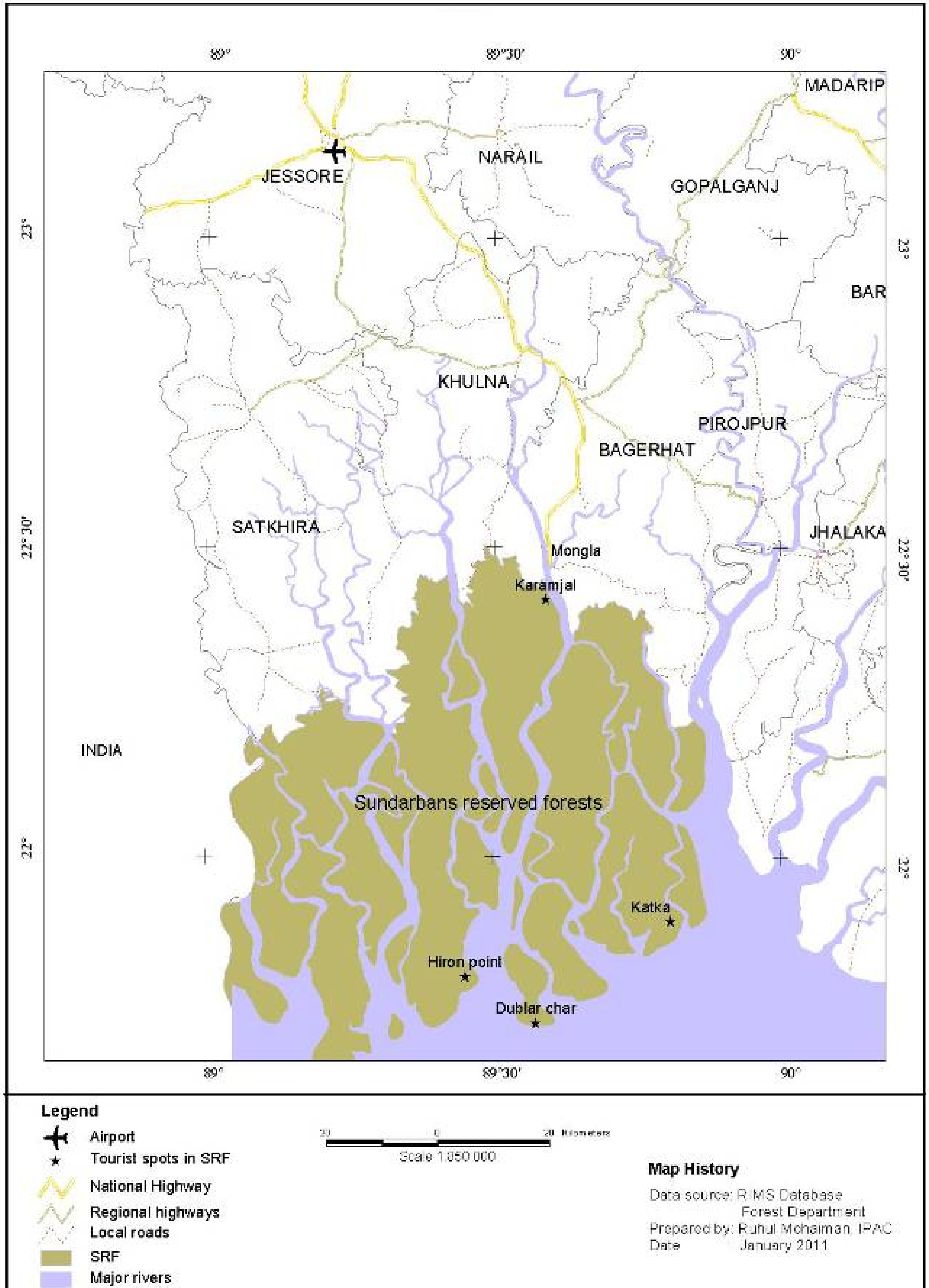
Source: (BIDS, 2010)

The Sundarbans plays an important role in the economy of the southwestern region of Bangladesh as well as in the national economy. It is the single largest source of forest and provides raw material for wood based industries. The harvest of non-wood forest products such as thatching materials, honey, bees-wax, fish, crustacean and mollusk resources of the forest takes place regularly. The vegetated tidal lands of the Sundarbans also function as an essential habitat, nutrient producer, water purifier, nutrient and sediment trap, storm barrier, shore stabilizer, energy storage unit and aesthetic attraction. The direct dependency on the project area of surrounding living people is quite high: BIDS (2010) reported that more than 28% of the reference region population are dependent on the SRF. More than one million people are involved in various resources collection from the Sundarbans, a large majority of which are fishers including about 2 lacs of shrimp fry fishers. If it is assumed that on an average, a collector harvests 1.8 products over the year, the number of SRF collectors is estimated as about 0.59 million. As indirect values to local populations, the forests have immense protective and productive functions, which enhance the resilience of local community for facing adverse impacts of climate change. Various non-timber forest products help generate considerable employment and income generation opportunities for at least half a million poor coastal population. Besides production functions of the forest, it provides natural protection to life and properties of the coastal population in cyclone prone Bangladesh

2.17 Main Drivers of deforestation and forests degradation

A number of activities contributing to forest degradation continue to adversely affect forest land and forest cover. Main factors that have contributed to the deforestation and degradation of these lands include population growth and migration. These increases in population have resulted in or contributed to fuelwood collection for personal use as well as for sale and illicit felling for constructions and fish harvesting. These anthropogenic pressures have contributed to the degradation of the forests, and poverty and limited livelihoods options are important factors in local community members' willingness to participate in these illegal activities. These stressors are further exacerbated by the weak law-enforcement capacity of the FD, as well as high demand for the forest products by sawmill owners and illegal timber traders. The need for timber for boat making and fishing by local community and floating populations is substantial and most of it is met through unauthorized removals by using maritime access routes (Figure 2.9), sometimes in connivance with local FD field staff. Poor facilities and salaries of the FD field staff exacerbate the illegal harvesting due to high temptation for gratification. Peripheral deforestation is threat due mainly to highly commercial shrimp industry that has developed of late as the third largest foreign earning sector (after garment sector and remittances).

Figure 2.10: Maritime routes for transport of illegal forests produce



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

3 Project Baseline

A field inventory was conducted between December 2009-April 2010 in the project area to collect data on, growing stock, biomass, dead organic matter, litter, and soil required for establishing the carbon baseline. In order to estimate benchmark carbon stock in the project area, a regorous forest inventory was designed by the USFS and IPAC team, and implemented by FD field staff. Field-based carbon (C) stock estimates for the project area are discussed in this section. It presents an estimate of current C stocks, obtained from the 2009-2010 field-based forest inventory. Methods are briefly summarized here where relevant, but comprehensive methodological information can be found in the separate protocol and meta-data documents (hereafter 'the protocol'; see "Protocols for Measuring & Reporting Carbon Stocks in Mangrove Forests" by USFS (2009). For this carbon inventory, a Tier 3 approach (per IPCC sourcebooks) was considered most appropriate as the project area represents a key terrestrial carbon stock or sink/source for the country. The measurements required for a typical forest resource inventory and a Tier 3 carbon inventory are generally quite similar. An existing forest inventory plot grid in the Sundarbans provided an opportunity to leverage past data to compare historic and future carbon stocks and emissions.

3.1 Inventory Design

Boundary

The inventory area is defined as the project area (the SRF), the boundaries of which are well defined by relevant legislation and are well mapped. Aquatic portions of SRF—the rivers and sea channels—are not considered with respect to carbon storage as carbon accounting and markets are currently focused on terrestrial carbon stores only, particularly forests. This means that, although the total area within SRF is ~600,017 hectares, only the ~412,000 hectares of actual land area are included for carbon accounting. This means that total carbon stocks in the SRF were computed over the 412,000 hectares of land, not by the 600,017 hectares of total area.

Stratification

In some cases it may be desirable to stratify the project area into subpopulations, or 'strata,' that form relatively homogenous units. Because each stratum should have lower variation within it, fewer plots may be needed to achieve the same level of precision. Stratification could be based on, for example, land use or vegetation type, but should be carried out using criteria that are directly related to the variables to be measured—for example, the carbon pools in trees. For Sundarbans, it was recommended not to *a priori* stratify the project area. This recommendation was for several reasons. First, an existing systematic sampling grid is already in place, with historic data available from those ground points. This will allow past, current, and future data to be evaluated in a consistent manner. Second, as long as a systematic sampling grid was started from a random point (which the SRF inventory grid was), that sample layout is considered the most rigorous and intuitive. Third, the Sundarbans is a dynamic region, with short- and long-term changes in forest cover and biomass occurring due to changes in hydrology, sedimentation, disease, and human factors. Thus, a stratification employed today may not make sense in the future as vegetation communities and lands shift spatially. For information purposes, in addition to presenting reserve-wide estimates (non-stratified), summaries by vegetation type and management unit are also presented.

Carbon Pools

Most international standards divide forests into roughly five carbon pools: 1) aboveground and belowground biomass of live trees, 2) non-tree vegetation, 3) dead wood, 4) forest floor (litter), and 5) soil. Not all pools are required to be measured in every project; decisions can be made at the project level to streamline the effort involved in carbon assessment. A pool should be measured if it is large, if it is likely to be affected by land use, or if the land-use effects or size of the pool are uncertain. Small pools or those unlikely to be affected by land use may be excluded. For the SRF carbon assessment, consultation with FD personnel suggested a recommendation to measure trees, non-tree vegetation, dead wood, and soil. Trees are the most susceptible to land use activities, and soil may be the largest and most uncertain carbon pool in mangroves. Dead wood and non-tree vegetation may be a significant biomass component in SRF and may change significantly with logging activities. Forest floor is usually a minor or even negligible biomass component in Asian-Pacific mangroves; as SRF is similar, this pool was excluded.

Methods for measuring trees, non-tree vegetation, and dead wood were adapted from relevant IPCC-associated sourcebooks (see the protocol for full descriptions of measurements for each C pool). In brief, trees were quantified by stem surveys for large and small trees, non-tree vegetation was quantified by counts combined with allometric destructive harvests, and dead wood was quantified by line-intercept transects. Because mangrove soils are often C-rich and vulnerable to land-use change to deeper layers, soils were measured to 1-meter depth rather than only 30 cm as commonly recommended. To reduce the amount of material to be processed, subsampling was employed, taking advantage of the fact that mangrove soils are typically non-differentiated over the top meter of soil. Thus, rather than taking a core of the entire top meter, manageable subsamples of 5 cm were taken representing 0-30 cm depth and 30-100 cm depth, respectively.

Determining Type, Number, and Location of Measurement Plots

Type— Permanent or Temporary:

Sourcebooks describe options for 'permanent' sample plots, in which all trees within plots are tagged and tracked through time, or 'temporary' sample plots, in which trees are not tagged. In the latter method, trees are treated like other C pools and are tracked at the plot level over time, rather than as individuals. For the time and logistical constraints imposed by mangrove field work, it was recommended here that trees are not tagged.

Plot shape and clustering:

The shape and size of sample plots is a trade-off between accuracy, precision, time, and cost for measurement. Plots can either be one fixed size or 'nested,' meaning that they contain smaller sub-units for various C pools. Nested plots are generally more practical and efficient in forests with a range of stem diameters and densities, and were used in this inventory.

Clustered plot designs (using multiple 'subplots') tend to capture more microsite variation in vegetation, soils, etc., thereby reducing among-plot variation (increasing overall precision). For the SRF carbon assessment, a clustered plot composed of five circular subplots was employed, thus taking advantage of the increased precision of clustered sampling, and the fact that this plot design was employed during the previous forest inventory for the SRF.

Number and location of plots:

Plot locations can be selected randomly or systematically (plot grid with random origin). However if some parts of the project area have higher carbon content than others, systematic selection usually results in greater precision than random selection. Systematic sampling is also easily recognized as credible. The last SRF inventory, conducted in the 1990s, sampled 1204 plots situated on a systematic grid at 1-minute intervals of latitude/longitude. Based on logistical constraints communicated by the Forest Department, approximately 150-300 plots is the maximum number that can be sampled in a given census effort (300 would take two field working seasons). Although 300 is the desired and recommended number, 150 may be adequate to achieve reasonable precision. The lower number is still likely adequate for the C assessment given local circumstances, and is similar to plot densities in difficult-access roadless areas that has been used by the United States' Forest Inventory and Analysis program.

To facilitate these options, the original plot grid was subsampled by selecting every second plot in both the x and y directions. This yielded 295 plots (the full option). To attain a lower plot density, every second row of this new grid was sampled; this yielded 155 plots. To determine that plots are representative of the entire project area, periodic checks were made to ensure that the overall activity is performing in the same way as the plots. Field indicators of carbon stock changes were used to accomplish this task.

3.2 Field Inventory

The field inventory started with four days of *in-situ* field training, during which the first plots were surveyed. Officials from the USFS, Bangladesh Forest Department, and IPAC accompanied the participants. Participants learned the field protocols, practiced the use of instruments, and discussed probable questions regarding the inventory process. The actual inventory started in December, 2009, led by two Assistant Conservator of Forests (ACFs). IPAC organized the logistics including the hiring of vessels, labor for the team, medical support, and purchasing miscellaneous supplies. Of the 155 inventory plots (originally established in 1996-97) targeted for re-sampling, 5 were found under water due to erosion, subsidence, or canal migration (and possibly sea-level rise). At least two of these five losses were apparently due to recent cyclone damage. Thus, a total of 150 plots were sampled in the 2009-10 inventory. Plots which were partially under large canals were recorded as such, with an estimate of the percent of the plot area under water and measurements taken as normal in above-water portions.

Two field inventory groups, each led by an ACF, were formed for the SRF inventory team. Each group consisted of one ACF, one Forest Ranger/Deputy Ranger, two foresters, two students, two laborers, and two armed guards. Each group was assigned a small engine boat with boatman. The team leaders and some of the crew had participated in the training. The students were from the Forestry Program at Khulna University, which is located near the SRF. The team leaders and the Forest Ranger/Deputy Ranger worked mostly as recorders and reviewers of data. The foresters and students worked as enumerators. Each trip was seven to ten days long depending on stored food and availability of fresh water. Before starting each journey, both groups sat together with detailed maps and GPS units to plan for the next plots. Local knowledge of laborers, guards, FD district staff, and even fisherman aided the crews' efforts to find suitable routes to plots and minimize hiking time. Generally each group completed one plot per day, but often this pre-planning activity helped the groups to complete more than one plot a day.

3.3 Data and Sample Management

Field data were entered into computerized spreadsheets periodically and backed up electronically in multiple physical locations. Strict precautionary measures were taken in the process of data collection and data entry to minimize error (see QA/QC section below). Completed data forms were checked and reviewed in the field and data entry was also reviewed. At the end of the inventory, completed data forms were photo-copied and stored in two physically separate secure locations (Forest Department and IPAC offices). The final electronic data files, including one version with only field-collected numbers and one version with C computations, are stored with FD personnel, IPAC offices, and USFS personnel. Soil samples were air-dried in the field, oven-dried to constant mass at 60 °C at the Khulna IPAC cluster office, then sent to Chittagong for carbon analysis. Soil carbon analyses were conducted in the laboratory of the soil sciences division of the BFRI.

3.4 Data Analysis

Aboveground and root C pools were computed using both locally derived allometries (via destructive harvests of various shrub species outside the plots) and international standard common mangrove tree allometries (see protocol and references therein) combined with local tables of wood density by tree species. Soil C storage was calculated as the product of soil C concentration (% of dry mass determined by wet oxidation techniques by BFRI), soil bulk density, and soil depth range. All plot-level computations were corrected for the portion of the plot falling on a canal >30 m width, so as not to bias the land-based C density estimates with areas that are officially considered water.

3.5 Current Carbon Stocks

3.5.1 Carbon Density

Estimated current carbon pools are shown in Table 3.1. Mean total C density (excluding soil) was 136 Mg/ha (95%CI: ±16 Mg/ha), or moderate to high compared to other mangroves around the world. Total C density of non-soil pools ranged from a low of 20 Mg/ha in one Gewa-dominated stand to a high of 446 Mg/ha in one Sundri-dominated stand. Trees constituted the bulk of the C density across the forest reserve, with a mean of 82 Mg/ha aboveground and 36 Mg/ha belowground, which combines to account for 87% of all non-soil C.

Table 3.1: Mean carbon pools in the SRF, 2009-2010 inventory

C pool	C density (Mg/ha)	95% CI
Trees aboveground (stems + foliage)	82	± 11
Trees belowground (roots)	36	± 4.2
Saplings + seedlings aboveground	1.4	± 0.1
Saplings + seedlings belowground	1.0	± 0.1
Non-tree vegetation	2.8	± 1.1
Goran	7.9	± 2.0
Down wood	4.3	± 0.9
Soil 0-30 cm	TBD	± TBD
Soil 30-100 cm	TBD	± TBD
TOTAL (not incl. soil)	136	± 16

Uncertainty estimates (95% confidence intervals, or 95% CIs) were computed using standard techniques outlined in the protocol. The 95% CI for the total C density was derived through basic error propagation (square root of the summed squares of component pools), as outlined in the protocol. As some pools were highly correlated, pools were aggregated in an ecologically sensible way for error propagation (e.g., tree aboveground and belowground pools were obviously correlated and were combined into a single 'tree' pool for the uncertainty propagation step).

Although the plot sampling was not strictly stratified a priori, the grid-based sample covered all major land types and allowed post adhoc analysis of different strata (e.g., vegetation types, management units). With respect to vegetation type, plots classified as Sundri-dominated forest contained by far the highest C density at 169 Mg/ha, followed by Gewa-dominated classifications which contained 102 Mg/ha (Table 3.2). Low-stature Goran-dominated vegetation contained the lowest C density at 64 Mg/ha, with Goran shrubs comprising 41% of C pools in that vegetation type (Table 3.2).

Table 3.2: Mean carbon pools (Mg/ha) in SRF from 2009-2010 inventory, by major forest type

C pool	SUNDRI dominated		GEWA dominated		GORAN dominated	
	C density	95% CI	C density	95% CI	C density	95% CI
Trees aboveground (stems + foliage)	109	± 15	56	± 15	20	± 4.1
Trees belowground (roots)	47	± 5.5	25	± 5.9	11	± 2.3
Saplings + seedlings aboveground	1.5	± 0.2	1.4	± 0.2	1.0	± 0.3
Saplings + seedlings belowground	1.1	± 0.1	1.0	± 0.1	0.7	± 0.2
Non-tree vegetation	2.1	± 0.8	4.0	± 3.1	2.8	± 3.8
Goran	2.6	± 0.9	11	± 3.6	26	± 7.8
Down wood	5.4	± 1.4	3.5	± 0.9	1.7	± 0.8
Soil 0-30 cm	TBD	TBD	TBD	TBD	TBD	TBD
Soil 30-100 cm	TBD	TBD	TBD	TBD	TBD	TBD
TOTAL (not incl. soil)	169	± 21	102	± 21	64	± 11

Note: Forest type was determined by cross-referencing the inventory plot grid with the vegetation map layer created by FD RIMS office in 1990s, supplemented with cross-checking a subset of plots to verify that stand composition corresponded with mapped classification. Future in-depth analyses of stand composition in 2009-10 may shift the designation of some plots in the new inventory.

Separated by management unit (Range; see Table 3.3), the Chandpai Range contained the most C-rich forests at 193 Mg/ha; the Satkhira Range contained the lowest C density at 57 Mg/ha.

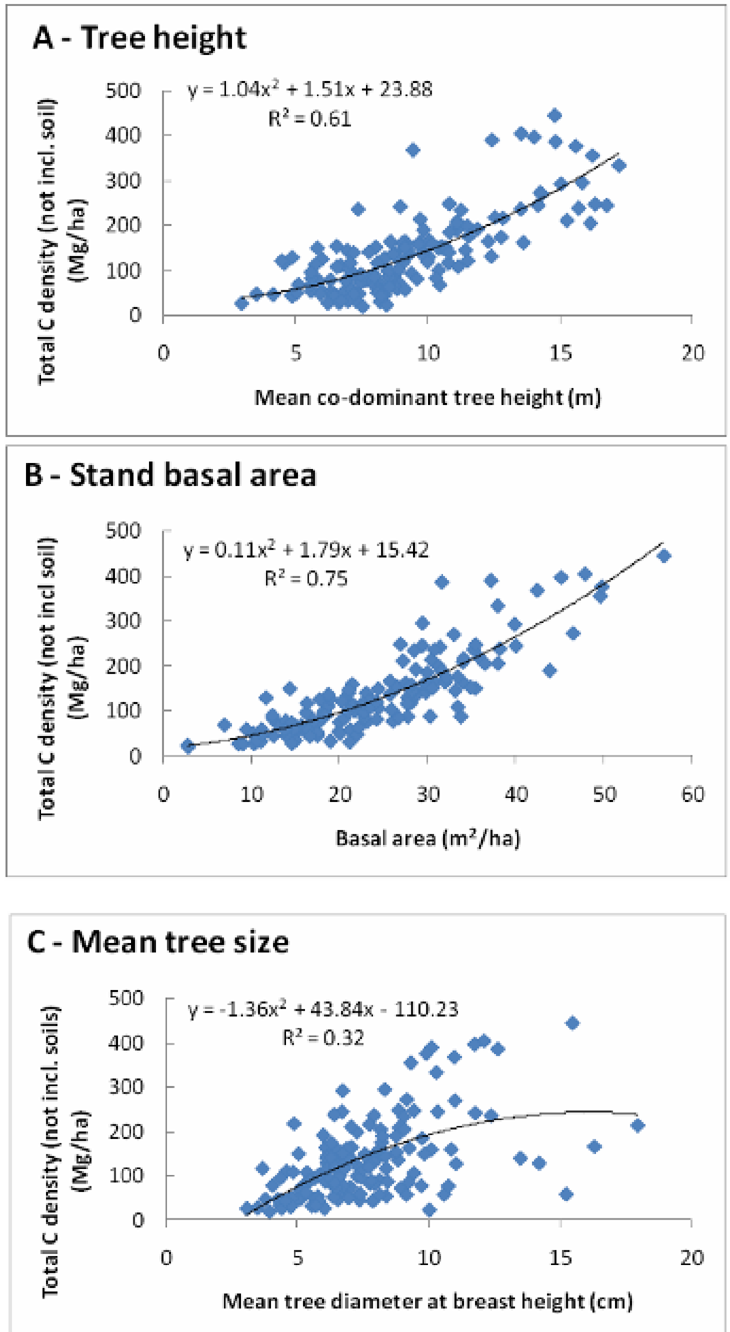
Table 3.3: Mean carbon pools (Mg/ha) in SRF from 2009-2010 inventory, by management range

C pool	CHANDPAI		KHULNA		SATKHIRA		SHARANKHOLA	
	C density	95% CI	C density	95% CI	C density	95% CI	C density	95% CI
Trees aboveground (stems + foliage)	127	*± 36*	93	*± 14*	20	*± 3.1*	101	*± 19*
Trees belowground (roots)	52	*± 13*	43	*± 5.5*	11	*± 1.7*	41	*± 6.7*
Saplings + seedlings aboveground	1.5	*± 0.3*	1.4	*± 0.2*	1.0	*± 0.2*	1.7	*± 0.2*
Saplings + seedlings belowground	1.1	*± 0.2*	1.0	*± 0.1*	0.8	*± 0.1*	1.2	*± 0.2*
Non-tree vegetation	2.7	*± 2.0*	3.2	*± 1.8*	2.5	*± 2.3*	2.6	*± 3.0*
Goran	1.2	*± 1.2*	4.6	*± 2.4*	19	*± 4.7*	4.7	*± 3.1*
Down wood	7.2	*± 3.0*	3.0	*± 0.7*	1.9	*± 0.5*	6.4	*± 2.0*
Soil 0-30 cm	TBD	*TBD*	TBD	*TBD*	TBD	*TBD*	TBD	*TBD*
Soil 30-100 cm	TBD	*TBD*	TBD	*TBD*	TBD	*TBD*	TBD	*TBD*
TOTAL (not incl. soil)	193	*± 48*	150	*± 20*	57	*± 7.1*	158	*± 26*

Several measures of stand structure were also assessed for their relationship to C density (Figures 3.1 and 3.2). The two attributes most strongly related to C density were height of co-dominant trees and stand basal area (Figure 3.1). Mean tree diameter (at breast height; dbh) was also correlated to C density, although not as strongly as height and basal area (Figure 3.1). This latter relationship included all trees including small saplings; future analyses may improve the correlation by including only medium to large trees. The strong relationship between tree height and C density suggests good potential for using LiDAR, which can measure forest height remotely, to track changes in C stocks in the future.

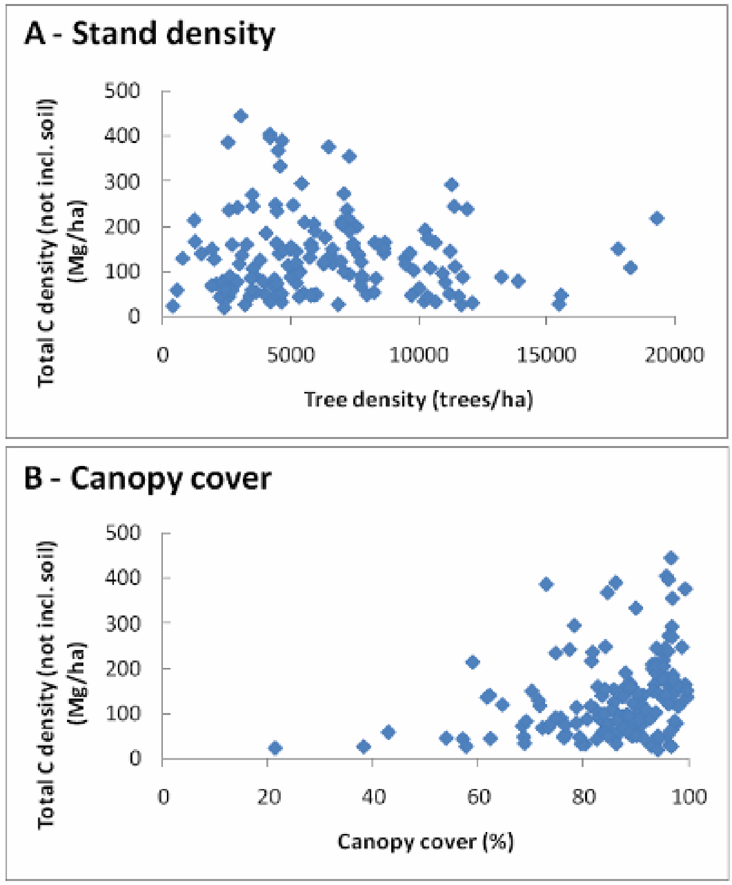
Stand density (trees per hectare) and canopy cover were not strongly related to total C density (Figure 3.2). These attributes can be high even when overall forest stature is low, for example when dominated by low shrubs.

Figure 3.1: Relationship between total carbon density (sum of all non-soil pools) and plot-level estimates of (A) co-dominant tree height, (B) stand basal area, and (C) mean tree size.



Total carbon density is fairly well correlated with these measures of stand structure. The relationship between tree height and C density suggests good potential for using LiDAR imagery to predict C density.

Figure 3.2: Relationship between total C density (sum of all non-soil pools) and plot-level estimates of (A) tree stem density and (B) canopy cover.



These measures of stand structure are poor predictors of C density ($R^2 < 0.15$).

3.5.2 Forests Carbon Stock

The total C stock of the SRF (see Table 3.4), which is obtained by multiplying the mean per-hectare C density by the land area, is estimated to be 55.8 Megatonnes (Mt, or 55.8 x 10^6 Megagrams). The 95% CI for the total C stock is 49.4 to 62.5 Mt. These values do not include C storage in soils. The amount of carbon dioxide (CO_2) equivalents contained in the SRF, obtained by multiplying by a molecular conversion ratio of 3.67, is estimated at 205 Mt (± 24.5 Mt), or over 4 times the annual CO_2 emission rate of Bangladesh from fossil fuel consumption.

Table 3.4: Total C stock CO_2 equivalents across the SRF, 2009-2010

Mean total C density (Mg/ha)	Land area (ha)	Total C stock over whole SRF (Mt)	95% CI for total C stock (Mt)	CO_2 equivalents (Mt)	95% CI for CO_2 equivalents (Mt)
136 (± 16)	411,693	55.8	49.4 - 62.5	205	181 - 230

Notes: - 1 Mt = 10^6 Mg.

- Land area is from RIMS office GIS data.

- 95% confidence limits for total C stock and CO_2 equivalents are simple propagation of lower and upper confidence limits of C density multiplied by the land area. No uncertainty estimate was available for land area, precluding full error propagation incorporating uncertainties in both parameters.

3.5.3 Soil Carbon Stock

Forest soils of the Sundarbans occur under the Agro-Ecological Zone-3 and are characterized by the twin effects of salinity and water logging. Biological factors contribute in the rapid breakdown of litter falling on the forest floor. Organic matter, a carbonaceous substance, is the remains of plants, animals and micro-organisms, which are continuously assimilated/decomposed into the soil by other micro-organisms. Organic matter acts as depository of plant nutrients and increases water holding capacity of soils, thereby enhancing water availability to plants. Sequestrated CO2 in plants tissues eventually becomes part of soil organic matter.

Three parameters (soil depth, bulk density and organic carbon concentration) must be estimated for quantifying soil carbon pool. A core sample was taken near the centre of each subplot with a 1-m long open faced peat auger. Two sets of 5cm soil samples (cylindrical) were taken from the core sample at the mid points of 0-30cm and 30-100cm soil profile. The 5 subplot samples (separately for 0-30cm and 30-100cm) were aggregated for each plot and air-dried by placing under sun. The aggregated samples were oven dried in IPAC office. The bulk density was estimated (by dividing the mass of the oven-dry soil sample by the volume of the sample) at the office whereas %OC carbon was estimated by the BFRI based on wet oxidation method. The following formula was employed for calculating soil carbon per ha :

Soil C (Mg/ha) = bulk density (g/m3) x soil depth interval (m) x %OC x 0.01

The per ha soil carbon, estimated based on the soil samples collected from 150 plots, comes to be as 59.77236 Mg/ha. If multiplied by the total forest area, the total soil carbon stock is estimated as 24.63 Mtons per ha.

3.6 Quality Assurance / Quality Control

Quality assurance / quality control activities were emphasized from the outset of the 2009-10 inventory. Field procedures were subject to strict oversight and review by the project leaders. The crew carried the protocol at all times in the field, and any confusion could be solved by referring to the protocols as well as the local knowledge of team members. Before starting the journey, the plot location and access route were thoroughly studied using GPS units and detailed maps. The latitude/longitude points in the GPS were duly checked by the team leaders. An important quality control activity was re-arrangement of team composition. Every week the team leader was changed; thus each team had the experience of working with both leaders. In this way, any gaps or methodological differences were minimized. The team composition itself was also changed occasionally during the field season. This shuffling helped in reducing observer/team biases and also improved efficiency.

Each completed data sheet was reviewed in the field. The bottom of every data sheet provided room to document quality control activities. At the end of every field outing, all data sheets were reviewed by a crew member for completeness, legibility and accuracy. Once satisfied by the quality of data recorded, the data reviewer recorded their name and the date of the review, along with any notes on issues that were noticed during the check so that they can be prevented in the future. The soil samples were re-packed from the plastic sample containers to whirl packs/zip bags after air drying. This re-packing was done by the crew on the main vessel. The team leaders monitored these processes to minimize mistakes. Completed data sheets were filed separately by plot and stored in a safe location in the vessel. Upon return from a 7-10 day sampling trip, a copy of each data sheet was made and kept in the Khulna IPAC office. At the end of the inventory, completed data sheets were photo-copied and stored in two physically separate secure locations (Forest Department and IPAC offices).

Field data collection procedures were also observed and checked by higher officials of the Forest Department and IPAC. The officials accompanied the inventory team to a subset of plots to observe the data collection procedure. They also visited a subset of plots from where data had already been collected two months earlier, to check for actual visitation and accuracy of measurements (the plots were re-sampled by the crew with the officials present). It was found correct with the previous data, and the marking tape was found precisely at the center of the plot. The officials were satisfied with the quality of inventory work.

The data entry process was also conducted very carefully, with close oversight by the team leaders. Entered data were also checked and reviewed. After completion of data entry, a randomly selected 10% of plots were cross-checked for data entry errors, plus spot-checking of others. The observed error rate was less than 1%, which was deemed acceptable and highly unlikely to affect overall estimates significantly. The database was also checked for extreme outlier values (e.g., trees larger than 200 cm) to eliminate potentially influential errors. The final electronic data files, including one version with only field-collected numbers and one version with C computations, are stored with FD personnel, IPAC offices, and USFS personnel. For data analysis, all data steps were recorded in understandable fashion in spreadsheet files, with separate meta-data documenting how various decisions and approaches were arrived upon during the computations.

4. Project Impacts

4.1 Environmental Impacts

By targeting the protection of the SRF, the CRISP is expected to have numerous positive environmental impacts, including an increase in forest cover; forests and wetlands restoration; improvements in natural regeneration; decreased siltation; improved control of illicit felling and poaching; conservation of unique ecosystems and biodiversity, including the habitats and breeding grounds of endemic, rare and endangered species, such as the Royal Bengal Tiger, dolphins and indigenous fishes; and enhanced aesthetic value for eco-tourism.

The project will have the following beneficial environmental impacts related to planning and design:

- Multi-story natural forests with enriched vegetation
- Regeneration of vegetation stemming from prevention of illicit removal of mother trees and root stock
- Control of poaching and tiger conservation
- Restoration of forests, promotion of aesthetic and recreational values, environmental improvement, and pollution abatement
- Poverty alleviation, improved governance, community empowerment, and enhancements in women's welfare.
- Nature tourism and conservation awareness about biodiversity conservation

The following beneficial environmental impacts will result from the operation of the project:

- Improved forests and constituent biodiversity
- Enhanced forest land productivity
- Enhanced soil fertility and efficient nutrient cycling
- Effective community protection of forests, wildlife and wetlands
- Wetlands restoration and aquatic biodiversity conservation
- Improved drainage, protected coasts and embankments with less siltation
- Livelihood support for local people
- Improved environmental governance and environmental amelioration
- Enhanced community participation in the protected area management
- Enhanced resilience and reduced vulnerability of local community to climate change.

No significant adverse environmental impacts are foreseen, due to appropriate preventive and mitigation measures to be incorporated into the design of the project. For example, poison will not be used by fishers for catching fish. As no commercial harvesting is planned in the SRF, and so no felling related adverse impacts and damages are envisaged. Appropriate conflict resolution mechanisms will be put in place to enable the CMCs to manage conflicts. As restoration and enhancement of the forests and wetlands is expected to lead to a rise in tourism to the SRF, efforts will be made to build CMC's capacity and involve them to a greater extent in visitor management to ensure that eco-tourism needs are met and biodiversity conserved.

4.2 Socio-economic Impacts

This project seeks to use existing co-management mechanisms to implement CRISP activities that mitigate greenhouse gases through avoided deforestation and forests degradation, and improved forests management. By managing and implementing activities in conjunction with the co-management committees in the SRF included in this project, several direct and indirect positive, and no negative, socio-economic impacts are anticipated. In terms of direct effects, the involvement of local communities through CMCs and CPGs in the implementation and monitoring of project activities will provide alternative income streams, and offer a disincentive for engaging in illegal exploitation of forests and wetlands resources. Protection and enhancement of the forested areas will enhance their attractiveness to tourists and promote the development of eco-tourism, which will also provide members of local communities with alternative employment options. With more reliable incomes, the local communities will be able to reduce their reliance on forest resources. Moreover, any proceeds from carbon sales will be reinvested in the communities to address key needs identified by the CMCs, which will further advance poverty alleviation goals.

Regarding indirect impacts, leveraging the existing co-management committees will facilitate the engagement of different user groups, including marginalized segments of the population such as women, and ethnic, religious, and cultural minorities. Their engagement in project activities will serve the dual purpose of reducing their reliance on forest resources, thereby mitigating an important cause of deforestation and forests degradation, and empowering them to give them a more active voice in community decision-making. Furthermore, forest enhancement will decrease siltation, and act as a buffer from climate change impacts such as storms, enabling improvements in the health and security of the communities in the surrounding landscape.

5. Project Design

5.1 Project Management Units

The CRISP is proposed to cover 411,227 hectares of mangrove forests in four project management units of the Sundarbans Reserve Forest. Table 5.1 shows the number of hectares within each of these units.

Table 5.1: Area and general location of the four project management units

Management unit	Approximate size (ha)	General location
Satkhira Range, Sundarbans Reserve Forest	121,477	From Andamanik petrol post South along the eastern boundary of compartments 41 and 42, then West along northern boundaries of South and West Wildlife Sanctuaries to international border with India, then North to Koikhali station, then East along Sundarbans Reserve Forest boundary to Andamanik.
Khulna Range, Sundarbans Reserve Forest	114,444	From Sutar Khali forest station South along the eastern edge of compartments 32, 33, 34, and 39 to the Bhadra River, then West along the northern boundary of South Wildlife Sanctuary to Satkhira Range boundary, then East to Sutar khali station.
Chandpai Range, Sundarbans Reserve Forest	82,993	From Sutar Khali forest station South along the western edge of compartments 31, 30, and 29 to the Bhadra River, South to Kokilmoni petrol post, North to Mora Bhola petrol post then Northeast to Nangli petrol post, then northwest to Sutar khali station.
Sarankhola Range, Sundarbans Reserve Forest	92,313	Areas bounded on the east by the Baleswar River, and falling to the south and east of a line from the Nangli petrol post going south-southwest to the Bay of Bengal, except those areas in East Wildlife Sanctuary.
Total area	**411,227**	

5.2 Problem Statement

Heavy biotic pressure brought by manifold increase in human population and consequent demand for agriculture and settlements have in past resulted in the loss and degradation of the country's forests in general and the SRF in particular. Effective protection of the SRF is necessary for ensuring the country's ecological security, conserving biological diversity and controlling adverse impacts of climate change. The ecological security of the Sundarbans needs to be ensured as habitat degradation and loss of wildlife have over the period taken place in the Sundarbans as elsewhere in Bangladesh. As noted earlier, the Sundarbans Reserve Forest was first established in 1875, during British colonial rule over India and what are now Pakistan and Bangladesh. The results of the carbon inventory conducted in 2009-2010 show that the overall carbon stocks of the entire Sundarbans have increased since the previous inventory conducted in 1996-97. However, parts of the Reserve Forest have been subjected to frontier deforestation and mosaic forest degradation over the past couple of decades. It is this frontier deforestation and mosaic forest degradation that motivated the Forest Department to undertake the CRISP to reduce biotic pressures on the mangrove forest ecosystem, increase the ability of the Forest Department to achieve higher levels of protection and conservation, and to restore the areas which have experienced declining forest quality by implementing improved forests management practices.

As one of the world's most impoverished countries, facing a wide range of development challenges and budgetary pressures, the Government of Bangladesh lacks the resources to accomplish these goals using standard mechanisms of financing. A low level of value-added production both in the agricultural and industrial sectors combined with a difficult environment for tax collection limits the generation of revenues to internally fund these activities. International donors concentrate their efforts on assisting Bangladesh in a range of initiatives from health and education to food security, and mitigation and adaptation to climate change.

The international carbon markets – whether voluntary markets in either the pre-compliance or social responsibility segments, or compliance markets searching for offset credits from non-traditional sources – provide potential means for Bangladesh to finance protection and restoration of the largest mangrove ecosystem in the world while also alleviating poverty among the communities in the reference region. The possibility exists to create a virtuous cycle of improving forests habitats, leading to improving livelihoods, leading to greater school enrollment, leading to smaller portions of the population relying on the forests, and leading to even more improvement in the habitats. Absent the revenue stream from sales of carbon offsets, the Sundarbans is likely to experience accelerating forests degradation and deforestation. This scenario could produce a greater challenge for Bangladesh in adapting to the impacts of climate change, as declining stocks of NTFPs including fish and other animal protein sources from the mangrove nurseries force people to cut more of the forest in a downward cycle of worsening poverty.

5.3 Proposed Solution to Problem

In order to accentuate the virtuous cycle of habitat and livelihood improvement, and to avoid the negative cycle of increasing degradation and worsening poverty, the Forest Department on behalf of the Government of Bangladesh proposes a set of activities that will reduce deforestation through effective community patrolling, restore degraded forest areas through improved forests management, improve livelihoods through conservation-linked value chains and alternative income generation activities, and increase biodiversity conservation both in the project area and reference region. These activities include the following:

1. Improved environmental governance of the Sundarbans Reserve Forest through:
    a. Improved enforcement of existing laws and policies related to forests protection and improved forests management;
    b. Strengthened capacity of Forest Department and CMC personnel responsible for managing the SRF, including human resource skills, financial and communication resources, physical assets, and scientific knowledge; and
    c. Broader community involvement in the overall governance of the SRF for climate, community and biodiversity objectives.
2. Socio-economic growth options for communities living within the reference region, primarily through the following:
    a. Implementing identified conservation-linked value chains and livelihood activities including fisheries and eco-tourism; and
    b. Equitable benefits sharing with local communities from the government revenues accruing through forests produce and non-timber forest products (NTFPs) such as fish, eco-tourism, honey, wax, golpatta and grass
3. Improved functionality and delivery of tangible and intangible ecosystem services through:
    a. GHG removals and carbon enhancement through habitat restoration from improved conservation by gainfully involving local communities in strengthened forests and other biodiversity protection; and
    b. Biodiversity protection and conservation with specific actions linked to key Red List species.
4. Improved forests management through:
    a. Designing and implementing sustainable management zoning in and around the SRF; and
    b. Bringing the forest in the project area under permanent ban on commercial harvesting of both forests and NTFPs, and effectively enforcing this ban in gainful partnerships of CMSs and CPGs.

5.4 Land Ownership

The entire Sundarbans Reserve Forest is owned by the State, represented by the Forest Department as the authorized agency acting on behalf of the Government of Bangladesh in management and operation of the SRF under the Forest Act, 1927 and its amendments. Permanence of emission reductions and removal enhancements will follow from increased enforcement of existing laws and policies, as well as reduced pressures by involving local community through livelihood interventions to be implemented by the CMCs. Leakage is a relatively minor issue in the Sundarbans since almost all of the mangrove ecosystem falls within the SRF, and there are no sizeable Government forests in the reference region.

5.5 Monitoring Activities

The proposed activities will be implemented by the Project Proponent, the Forest Department, collaborating with the co-management committees (CMCs), representing the communities in the reference region. Increased enforcement will include joint community patrolling along vulnerable boundaries by FD field staff in collaboration with the members of community patrolling groups and the CMCs, with the co-benefits of contributing to emissions removals through carbon sequestration and enhancement, and providing skill development and grants in kind for conservation-linked livelihood enterprises for the community members. To the extent possible, members of the communities within the reference region will be engaged in the project activities, including undergoing training and provided with equipment necessary for ongoing monitoring of carbon stocks, populations of at-risk species, and violations of law enforcement.

5.6 Community Benefits

Majority of the people in the reference region are primarily poor and ultra-poor households engaged in subsistence agriculture, artisanal fishing, and non-commercial extraction of natural resources. A list of identified villages in this 10-km reference region is given as Annexure 1. The livelihood enhancement component will generate greater household revenues for many of the villages, with the target being to have a critical mass of households earning tangibly greater revenues from livelihood activities that they are less inclined to engage in natural resource extraction from the SRF that might result in the degradation of the forest. Non-destructive extraction of NTFPs in the SRF will be among the options to be pursued during the project implementation period for the benefits of local community based on an equitable benefits sharing mechanism, which is being developed under IPAC.

5.7 Biodiversity Benefits

The principal biodiversity benefits from the CRISP will be conservation of habitat for several keystone species that are Red Listed as Critically Endangered, including the Royal Bengal tiger, Irrawaddy river dolphin, and crab-eating macaque. Main biological values of the Sundarbans include providing suitable habitat to the biodiversity of global significance, comprising both terrestrial and aquatic flora and fauna; habitat connectivity; and sustenance of threatened and endemic species. Important ecological functions of the Sundarbans include climate change mitigation through carbon sequestration, enhancement and storage, conservation of waterbodies, coastal protection and climate change adaptation, inland and coastal fisheries, amelioration of environment, food security, etc. The Sundarbans provide significant scope for outdoor recreation, nature interpretation, conservation awareness, and wildlife education and research. The Sundarbans is also a good source of eco-tourism, aesthetic values, dense mangroves, tiger habitat, historical and cultural values, and scenic beauty. The Sundarbans ecosystem is, however, fragile with a very rich biodiversity, which if not conserved timely, may be lost for future generations. Many conservation values of the Sundarbans are characterized as global and regional public good but also have significant national and local conservation values.

5.8 Global and National Benefits

As the SRF is an ecosystem of national and global significance, its conservation under CRISP will result in the flow of benefits that will mitigate climate change far and wide. The conservation of the Sundarbans and its reference region is critical for ensuring the country's ecological, climate and food security. The mangroves and wetlands of the Sundarbans are significant carbon sinks, necessary for addressing climate change both globally and locally. The Sundarbans is not only the last remaining habitat of the Royal Bengal tiger but also important breeding ground of indigenous fishes including hilsha, and ceteaceans such as the Ganges and Irrawady dolphins. Intense forests-water interactions result in high productivity, making the ecosystem very dynamic and useful both ecologically and socio-economically. Nearly one million people from the interface landscape depend directly or indirectly on the Sundarbans for earning their livelihoods. Transnational biodiversity values ensue from the fact that the mangrove forests in the Indian state of West Bengal are in contiguity with similar ecosystem values and significance.

5.9 Project Organizational Structure and Governance

The following management structures will be in place:

- As important platforms for local community participation recognized by the Ministry of Environment and Forests, the project will be implemented through the relevant CMCs; and
- As owners of the forest land in the protected areas, the FD will be responsible for the management of the forest lands and assets under the proposed project.

While the CMCs will largely be responsible for the implementation, management, and monitoring of project activities, they will be supported by the FD, who will lead and/or guide the technical aspects of implementation of forestry related activities as well as provide necessary training to members of the CMCs, villagers, and other local communities involved in project activities. Partner organizations may also be involved in discrete implementation and monitoring activities as needed. One potential partner is the Community Development Centre (CODEC) which has an established presence in coastal Bangladesh including the Sundarbans and has under IPAC been interacting with the CMCs since their inception. It has extensive experience in transparent project management on behalf of poor communities in the country, and has the potential to play an important role supporting the CMCs and the FD.

In terms of financial management, in recognition of the CMCs still limited, but increasing, experience in this area, the FD and/or a partner organization with an experience of interaction with the CMCs as well as relevant grants management experience, may help with coordination of investor related activities. Assistance may include receipt and allocation of funding received from investors; monitoring of carbon prices; and financial transaction reporting. However, identification and selection of the beneficiaries would be done by the CMCs. Several layers of participatory monitoring will take place under the project. While the CMCs, with support from the FD, will be responsible for regular monitoring of project activities, including those in place to minimize leakage and the drivers of forest degradation, partner organizations will periodically assess impact, administration, and management as well as provide monitoring reports as per agreement with the FD and the CMCs, and based on approval from investor(s)/donor(s). In terms of financial management, there will be strict adherence to the transparency guidelines as required by the investor(s)/donor(s), and the Committees accounts will be audited as per the regulations of the Government Gazette establishing them. During meetings with the FD field staff and co-management committees (CMC) and other local stakeholders in the Sundarbans, they expressed general support for the idea of a carbon project, which they saw as a way of improving their livelihoods, increasing enforcement to exclude outsiders, and increasing ecotourism.

6 Project Interventions

Main purpose of the project interventions, i) is to provide effective protection to the SRF including forests and wetlands and their constituent flora and fauna by following a co-management approach that will focus on establishing gainful partnerships with key stakeholders but also simultaneously strengthening FD protection and communication mechanisms and facilities, and improving environmental governance; and ii) to design and implement improved forests management practices including management zoning and making the current temporary ban on commercial harvesting as a permanent one. The main factors responsible for deforestation and forests degradation will be identified through stakeholder consultations. Mitigation measures against the identified contributors to degradation, including illicit felling and poaching, will be implemented by collaborating with local stakeholders. The management zoning as proposed under the CRISP will be implemented. The current temporary ban on commercial harvesting of timber and fuelwood will be made permanent by implementing the prescriptions as made in the recently approved Integrated Resources Management Plan (IRMP). Improved participatory forests management practices will be designed and implemented. Equitable benefit sharing mechanism will be put in place for sharing benefits both from the NTFPs and carbon credits. Successful implementation of this project would result in forests and wetlands conservation. With protection by the CMCs through employment of the existing CPGs, over the maturity period the forest cover would be enhanced by the development of mangrove forests of indigenous species, resulting in a rich assemblage of multistory vegetation. Detailed project interventions are discussed in the next Chapter.

6.1 Improved Forests Management

6.1.1 Management Zoning for Improved Forest Management

A management zone is an area of specific management category, distinguishable on account of its management objectives. Management zonation helps achieve different management objectives by applying appropriate management strategies and operations in each identified zone. The forests and wetlands within the SRF and its surrounding landscape will be managed based on sound co-management practices that will conserve biodiversity and benefit local community. The existing levels of land-use will be managed by means of suitable zoning in ways that do not result in major adverse environmental or irreversible ecological impacts. This includes co-managing sustainably the existing and expected land-uses with some controls on location and use-intensity.

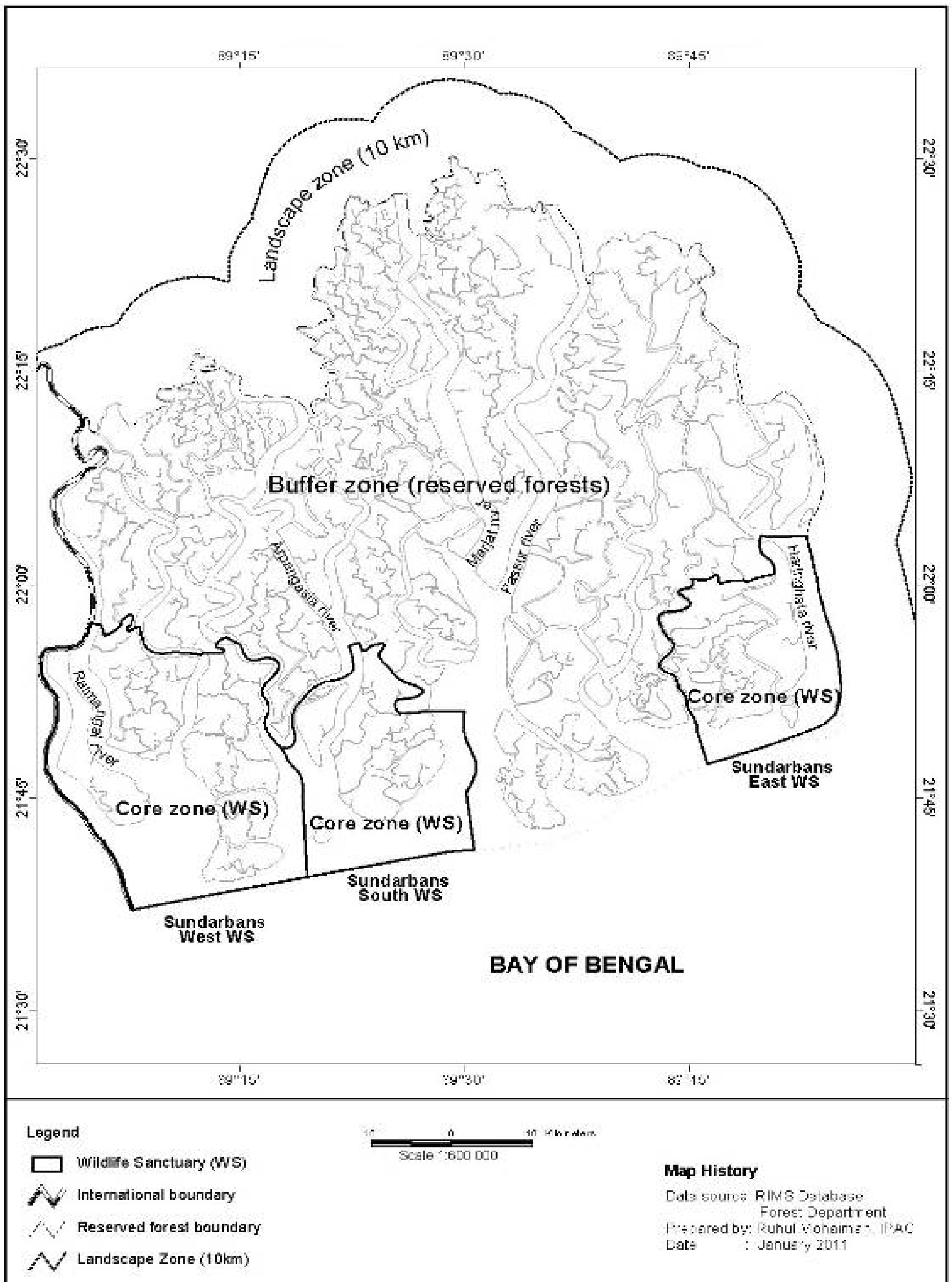
Sustainable management zoning is done to implement improved forests management practices in identified areas of the SRF spatially. In order to provide a basic spatial framework for protecting the areas of highest conservation value and maintaining the maximum possible area under natural forest cover, the SRF is categorized into two main zones, core zone and buffer zone, based on existing biodiversity and management objectives. Additionally, the identification of an interface landscape zone influencing the designated core and buffer zones is necessary for sustainable development of both neighboring forests/wetlands and local community. The core zone will have the highest conservation value followed by buffer zone, which would adjoin the identified interface landscape zone comprising local stakeholders and impacting land-uses. This interface landscape zone is the reference region under the CRISP.

All the notified area of the three wildlife sanctuaries is the core zone, which has the highest conservation value. The entire SRF, except the three Sanctuaries, is the buffer zone to the designated core zone (Figure 6.1). The 10-km wide ECA spread along the northern and eastern boundaries of the SRF will function as an interface landscape zone. The project reference region is coterminous with this interface landscape zone. No commercial harvesting of timber, fuelwood and non-timber forest products will be allowed in the core and buffer zones. This major policy decision will greatly contribute in improving the growing stock and in restoring the degraded forests and wetlands ecosystems.

6.1.2 Permanent Ban on Commercial Harvesting

With the Government approval of the IRMP the present temporary ban (in vogue until 2015) on commercial harvesting from the SRF has now been made permanent one and the commercial harvesting of aquatic resources including fish and shrimp is also be included in this ban. However, limited harvesting of forests and non-forests produce including fish will be allowed for local stakeholders including members of CPGs. The proposed benefits sharing guidelines under IPAC will be approved and implemented for sharing such benefits with local community.

Figure 6.1: Management Zoning in the Sundarbans



Intergated Protected Area Co-management (IPAC) Project, January 2011, Dhaka

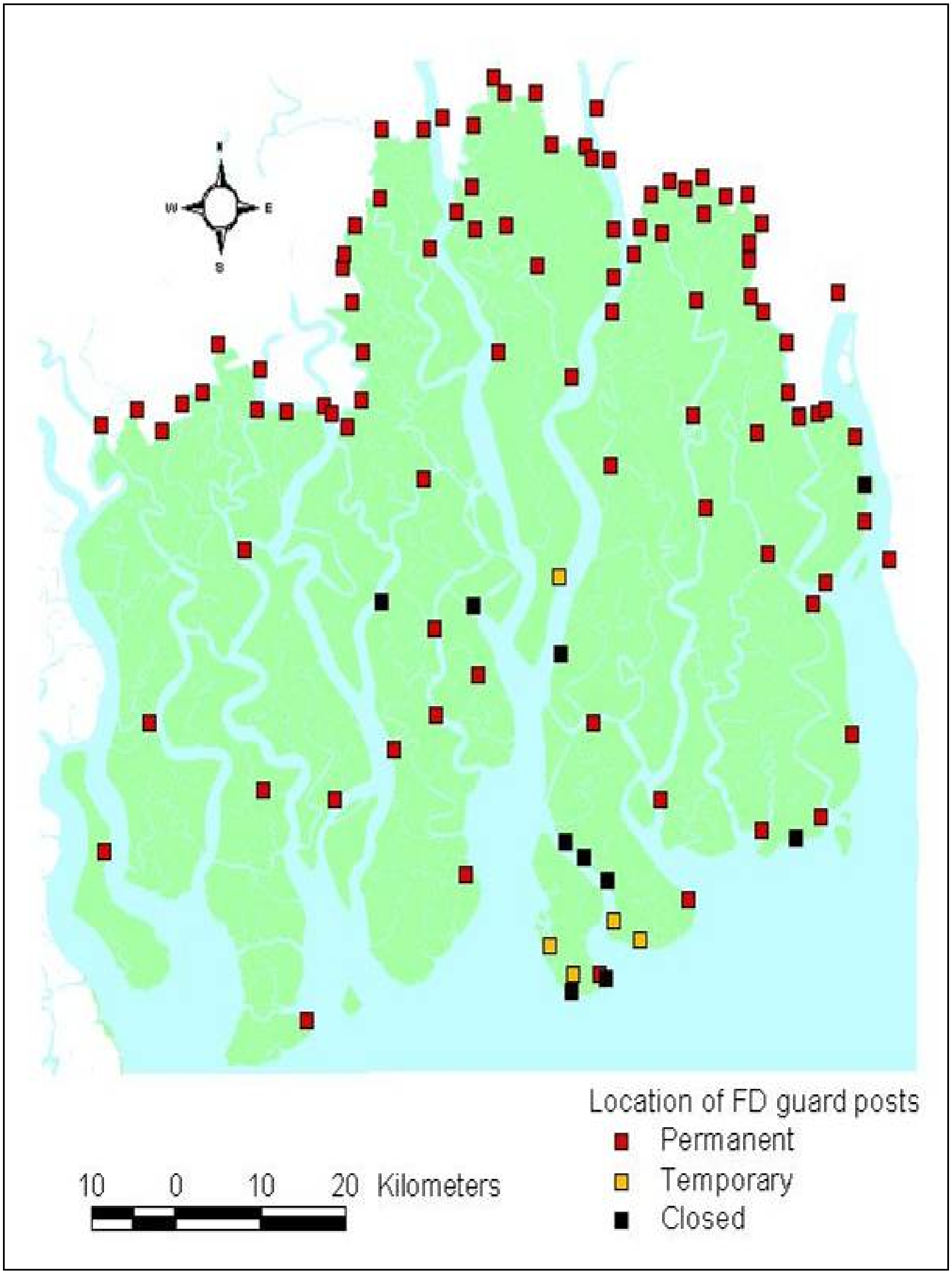
6.2 Controlling Deforestation and Forests Degradation

Natural features demarcate the Sundarbans particularly in southern and eastern borders whereas the international boundary on western borders is delineated by the common international rivers. The northern and eastern boundaries of the SRF, not covered by the natural features, will be surveyed, delineated and marked on the ground with concrete pillars (see NSP and FSP Guidelines) at all important and/or turning points and will be labeled. The boundaries of the core and buffer zones will be defined, mapped and marked on the ground by associating local stakeholders, preferably with wooden posts having legible inscriptions in Bangla for easy differentiation. While carrying out the demarcation, an advantage of natural features (i.e. rivers, streams/creeks/khals, ridge, roads, etc.) will be taken, wherever possible. All the locations where primary access routes cross the three sanctuaries' outer boundaries will be clearly marked with signs indicating the name and summarizing key regulations in written text and symbols. Two types of signboards will be used, i) a well designed, large wooden signboard at Range and Sanctuary HQs, and ii) concrete signboard at other identified locations. A regular maintenance program by associating CMCs will be necessary for boundary and pillar renovation as the area is vulnerable to natural calamities such as storms and cyclones.

Effective conservation of the Sundarbans requires protection of forests and wetlands of the entire SRF against illegal removal of trees and other biodiversity including fisheries resources by employing local community and FD field staff. The FD posts responsible for protection are categorized as Range Offices, Forest Stations and Forest Camps. Forest Camps are exclusively tasked with patrolling whereas Range Offices and Forest Stations (Figure 6.2), in addition to patrolling and patrol monitoring, collect revenue and carry out general administration. A total of 104 posts, including permanent, temporary and mobile (special boats), were recorded and it was concluded that due to more post locations, northern forest areas came under high patrolling coverage when compared to southern forests. But the existing posts are not adequate to provide effective protection to the forests and there is no formal delineation of the jurisdiction of these posts.

Only 58 boats including 44 motorized boats are in operation in 69 posts and the remainder 159 boats need repairing. Similarly of the total 95 jetties, mostly wooden, only 57 jetties are in operation. Only 61 posts have arms (total 397 guns with 53,354 bullets) and other navigation equipments including telecommunication system are largely lacking. A total of 582 FD field staff (Chandpai-158, Sarankhola-120, Khulna-196 and Satkhira-108) and 56 non-governmental personnel were found on field duty. The posts are, therefore, understaffed and not adequately equipped with required equipments and tools for efficient protection. Patrolling frequency is limited by the availability of diesel, which in most cases is not adequately provided in the formal FD budget. For instance, a total of 24,451 patrols (22,693 by boat and 1,758 by foot) were (April 2008 to May 2009) recorded in the Sundarbans.

Figure 6.2: Existing Locations of Forest Posts

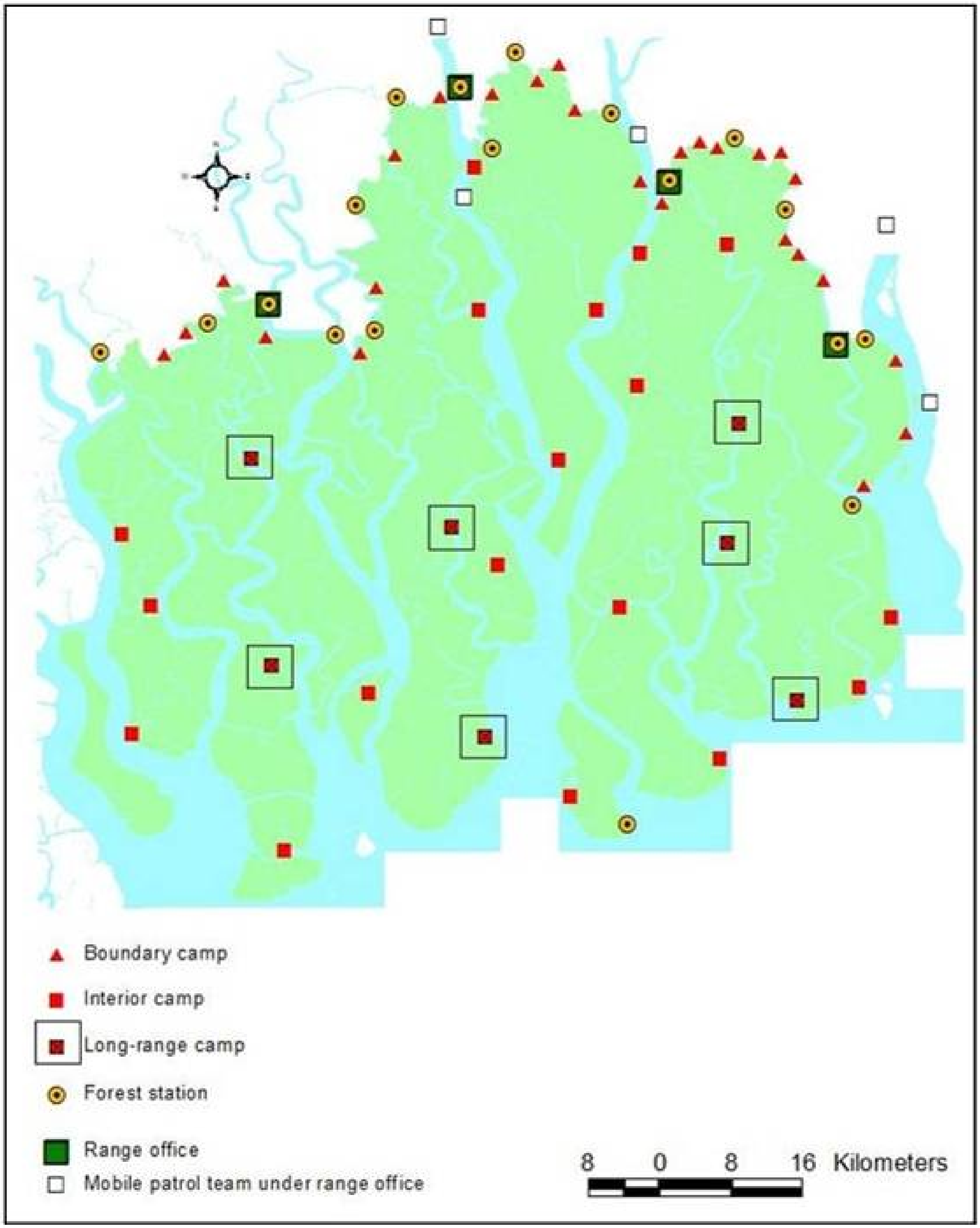


Main forests patrolling recommendations focus on, i) updating roles of teams and posts, and ii) updating numbers and locations of FD posts and their patrolling jurisdictions. Three types of recommended patrolling posts as are boundary patrol camps, interior patrol camps and long-range patrol camps. Range Offices will continue to be operational forests/wetlands/wildlife management/administration unit but will be better equipped (improved communication and a striking force with arms) to deal with organized smuggling of timber and poaching of tigers. Forest Stations will continue to be responsible with revenue collection but will increasingly shoulder patrolling duties with better equipment and manpower. Boundary camps will be established near designated stretch of forest boundary neighboring villages with responsibility of checking boats at entry and exit levels. Interior and long-range camps will continue to be responsible for normal and mobile patrol by employing FD boats and improved communication equipment. The overall number of posts are recommended to be reduced by 25% (from 97 to 73) and 32 Forest Camps are to be closed down but 8 new Camps are to be set up at strategic locations and 2 Camps are to be upgraded as Forest Stations. Overall there will be existing 4 field Range Offices (two additional Ranges are at Divisional HQs), 18 Station Offices, 26 Boundary Camps, 18 Interior Camps and 7 Long-range Camps (Figure 1.3).

Field monitoring will be employed as a tool for effective protection by employing selected indicators and taking corrective actions. Main monitoring interventions focus on, i) improving monitoring of field staff patrolling activities for controlling illicit felling and fishing, poaching of predators (tiger) and prey (deer), and ii) establishing monitoring units in the identified canals in selected compartments. Monitoring by senior FD staff such as DFO and ACF will be strengthened by providing adequate motorized boats and equipment including GPS, life saving devices and arms. Suitable monitoring indicators would include patrolling frequency, patrolling coverage and distance from the posts, quantity and quality of seizures, and the number of offence cases booked and offenders prosecuted.

A number of existing posts are either lying vacant due to frozen recruitment or the posted staff are reluctant to join from their duties due mainly to inhospitable living conditions. Main staffing recommendations focus on, i) updating the existing SRF organogram by reposting existing staff in line with redistributed posts, ii) recruiting field staff to fill all the existing vacancies, iii) and promoting all the Boatman. Under physical work, main recommendations focus on, i) to establish adequate number of FD boat fleet and jetties, and provide for their regular maintenance and running costs in annual budget, and ii) to improve infrastructure including drinking water facilities, and patrolling equipment such as GPS, flashlight, uniform, footwear, map and stationary, first aid box, and arms for defense. Main telecommunication recommendations focus on, i) strengthening existing walkie-talkie system, and ii) providing GPS and laptops for internet access wherever feasible.

Figure 6.3: Proposed Locations of Forest Stations and Camps



The GOB has agreed to implement a co-management approach for managing the Sundarbans by involving key stakeholders. Accordingly, four CMCs have been functioning to manage the Sundarbans comprising Chandpai and Sarankhola Forest Ranges of the Sundarbans East Division, and Khulna and Burigualoni Forest Ranges of the Sundarbans West Division. An equitable sharing of benefits and costs of the Sundarbans protection and management among the stakeholders is an important part of a co-management approach. Establishing effective linkages of socio-economic and ecological incentives and biodiversity conservation is instrumental in eliciting stakeholders' participation in protecting, rehabilitating, conserving and sustainably managing the Sundarbans by building gainful partnerships based on shared rights and responsibilities.

Enhanced protection by FD is needed particularly for combating organized smuggling by outsiders and dacoits. The strengthening of protection infrastructure and redistribution of posts (Figure 6.3) with enhanced presence of field staff as described above will help control organized smuggling. However, the protection of the Sundarbans cannot be ensured without gainfully involving key stakeholders including local community in the reference region and floating forests/fisheries dependent community. CPGs will be formed particularly on the northern and eastern side of the SRF including eastern wildlife sanctuary by following the approved joint patrolling guidelines (IPAC, 2011). Conservation-oriented management of the Sundarbans with restrictions on the informal harvesting of forests and fisheries through enhanced protection will result in high opportunity costs to local poor in terms of foregone benefits, which they were deriving from the forests and wetlands before the implementation of strict protection/enforcements practices. Sustainable use of identified NTFPs including grasses, golpata, honey, wax and fish will be, therefore, be allowed for bonafide consumption *in lieu* of their protection efforts and increased opportunity costs. The protection efforts will be augmented through communication and outreach activities, public awareness, stakeholders' access to livelihood and value chain activities in the interface landscape zone.

7 Estimating Additionality

Additionality is estimated for REDD and IFM separately as below, though these two mechanisms complement each other in the forests protection and the ecosystem conservation for the Sundarbans.

7.1 Additionality due to REDD

The current inventory re-sampled a subset of a previous field inventory, which was conducted in 1996-97. This allows a direct comparison between C stocks at the different time points, and an assessment of associated C emissions or uptake during the interim. The two main approaches to estimating land-use emissions are the stock-change approach and the gain-loss approach. The stock-change approach estimates the difference in carbon stocks at two points in time, while the gain-loss approach estimates the net balance of additions to and removals from a carbon stock. The stock-change approach is used when carbon stocks in relevant pools have been measured and estimated over time (such as in forest inventories), and is the approach used here.

Tracking of plot-level data is currently the primary way to assess forest degradation, the reduction in forest carbon density in lands remaining technically as forest cover as is the case for the Sundarbans. Deforestation, the loss of forest cover, is best assessed using remote sensing data ("activity data") but is not relevant in the case of the Sundarbans. The activity data can be combined with the plot-level ground data to complete a comprehensive baseline assessment. All effort was made to conduct the change assessment using consistent methodologies. Computations of C density and C stocks in the 1996-97 inventory followed the exact same procedures as that for the 2009-10 inventory. For consistency, only the 155 plots in common between both surveys were included in the change assessment (rather than using all 1204 from the 1996-97 inventory). It should be noted that the re-sampled plots were in the same locations in both inventories, but some spatial error likely existed. In some cases the crews noticed markings of old plots; however, these were inconsistent and not reliable overall (durable plot markings are especially challenging in mangroves). This error is difficult to avoid but, over the course of >150 plots, any associated sampling error should balance out (i.e., not result in directional bias).

Certain differences existed in the 1997 dataset, requiring some adjustment of method and limiting what could actually be compared between time points. Mainly, the 1996-97 inventory was largely a timber resource inventory rather than a carbon inventory, so effectively only trees were measured. Non-tree pools were largely ignored in the previous survey. Therefore, only tree pools (aboveground and belowground) could be tracked over time. Trees are the most ready indicator of forest change and degradation, so this change assessment should still yield quite valuable insight. This assessment also evaluates whether there are strong enough correlations between tree and other pools to estimate changes in non-tree C pools between inventories (i.e. by knowing tree pools, it may be possible to predict/estimate other pools, allowing a comparison of total C density between surveys). The five inventory plots that were surveyed in 1996-97 but were under water in 2009-10 due to land subsidence, erosion, channel migration, sea-level rise, or cyclone damage, were included in the change assessment. The loss of standing C stock in these sites (reduction to zero tree biomass) was factored into the estimate of change. Because these five plots were included, this necessarily used an adjusted estimate of mean C density for the 2009-10 dataset compared to the estimate presented above, which excluded areas now under large canals. This difference was relatively minor.

7.1.1 Carbon Density and Carbon Stocks

Estimated 1996-97 carbon pools and comparisons with 2010 pools are shown in Table 7.1. Mean C density in 1996-97 (trees and sapling/seedlings only) was 76 Mg/ha (95%CI: ±6.6 Mg/ha). Carbon density ranged from a low of 15 Mg/ha to a high of 188 Mg/ha. Multiplying by land area to obtain total C stock, the 1996-97 inventory indicates a C stock of 31.4 Mt at that time (95% CI: 28.6 - 34.0 Mt). Molecular conversion to CO_2 (by multiplying by the conversion factor of 3.67) yields an estimate of 115 Mt CO_2 equivalents (95% CI: 105 – 124.8 Mt) stored in SRF in 1996-97.

Table 7.1: Comparison of mean C pools in SRF between 1996-1997 and 2009-2010 inventories

C pool	1997 inventory		2010 inventory		Change (2010 minus 1997)	
	C density (Mg/ha)	95% CI	C density (Mg/ha)	95% CI	Δ C density (Mg/ha)	95% CI
Trees aboveground (stems + foliage)	46	± 4.3	80	± 11	(+) 34	± 12
Trees belowground (roots)	27	± 2.3	35	± 4.2	(+) 7.2	± 4.8
Saplings + seedlings aboveground	1.6	± 0.2	1.3	± 0.1	(-) 0.3	± 0.2
Saplings + seedlings belowground	1.0	± 0.1	1.0	± 0.1	0.0	± 0.1
TOTAL (tree + sapl/seed only)	76	± 6.6	117	± 15	(+) 41	± 17

Notes: Only tree and sapling/seedling pools could be compared because these were the only pools measured in the 1996-97 inventory.

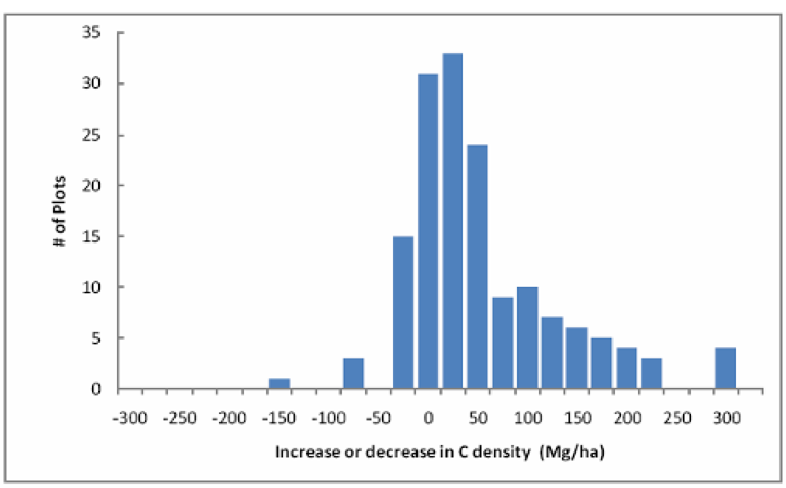
(+) and (-) in change column indicate increases or decreases, respectively, during the 1997 to 2010 time period.

Estimates for 2010 pools are slightly adjusted from previous section because this analysis included plots that were land in 1997 but now submerged in 2010 (land subsidence, etc.). These were excluded from the land-based C density estimate for the current C stock analysis, but were included as negatively changing plots in the change assessment. The difference is minor.

Comparing the two time points, the 2010 tree C pools were significantly higher than those from the same plots in 1997, suggesting an increase in C storage over this time period (Table 7.1). The estimated total increase, accounting for trees only, was 41 Mg/ha (95%CI: ±17 Mg/ha). The majority of plots, 68%, showed an increase in C density between the time points, while 32% showed a decrease (Figure 7.1). The distribution of changes was positively skewed, with the median change being +17 Mg/ha, but the mean change being +41 Mg/ha due to several plots that apparently showed very large increases.

Converting this difference to changes in C stocks (multiplying the mean per-hectare change by the entire land area of SRF) indicates an increase of 16.9 Mt of C storage over this time period (95% CI: 10.0 – 23.7 Mt). The confidence interval is strongly different from zero and suggests that the change is significant. Over the 13-year time interval, this change in C stocks suggests an average annual sequestration rate of 1.3 Mt C per year (95% CI: 0.8 – 1.8 Mt C per year). In CO_2 equivalents, the estimated change in stocks was 62.0 Mt CO_2 (95% CI: 36.7 – 87.0 Mt C). If we take the median C change of 17 Mg/ha over the 13 years period, then the annual C increase was estimated as 1.3 Mg/ha which worked out (by multiplying by 3.67) as 4.8 Mg CO_2e per ha per year. The estimated annual sequestration rate, therefore, over the 13-year period was 4.8 Mt CO_2 per year (95% CI: 2.9 – 6.6 Mt CO_2 per year), or ~10% of Bangladesh's annual fossil fuel CO_2 emissions.

Figure 7.1: Histogram showing the number of plots that increased or decreased in C density between 1996-97 and 2009-10.



Overall, 105 plots (68%) showed an increase in C density over this time period, while 50 plots (32%) showed a decrease. The shape of the histogram is skewed, with the median change across the whole sample being +17 Mg/ha, but the mean change being +41 Mg/ha due to several plots apparently showing quite large increases (see also Table 7.1).

Table 7.2: Estimated changes in total C stock and CO_2 equivalents across the SRF, 1996/97 to 2009/10

Δ C stock		Δ CO_2 equivalents		Annual sequestration rate	
Change in C stock over whole SRF (Mt)	95% CI for change in C stock (Mt)	Change in CO_2 equivalents (Mt)	95% CI for change in CO_2 equivalents (Mt)	Sequestration rate in CO_2 equivalents (Mt/yr)	95% CI for sequestration rate (Mt/yr)
16.9	10.0 – 23.7	62.0	36.7 – 87.0	4.8	2.9 – 6.6

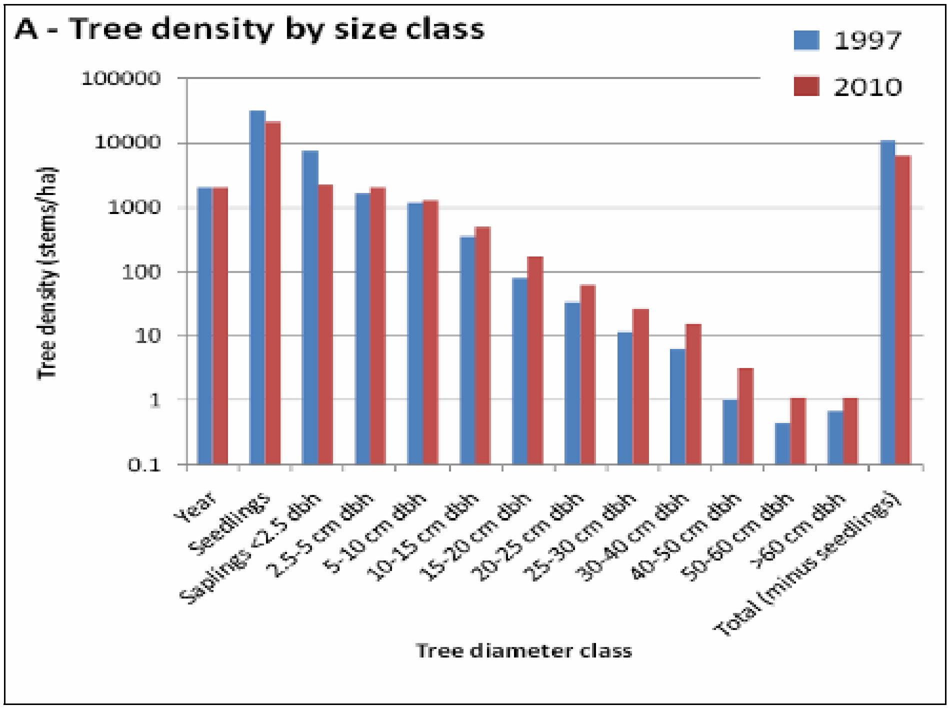
Note: Only includes trees pools, as these were the only pools measured in 1996-97 inventory.

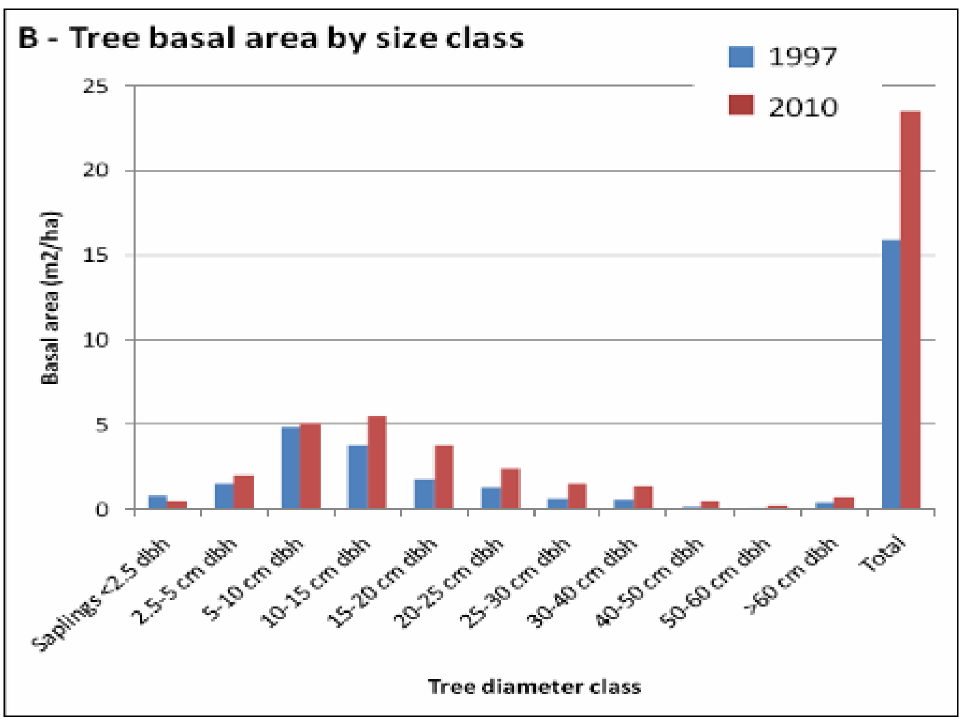
The change quantified here was strongly positive, with confidence intervals significantly different from zero. A significant portion of this difference could be an artifact of sampling error. Some of the changes in C density within particular plots were extremely high (e.g., >200 Mg/ha change in 13 years) and likely unrealistic in biological terms. Errors in re-locating exact plot locations could also play a role. In addition, metadata and protocol descriptions for the 1996-97 inventory were lacking, meaning that the data had to be interpreted through the inventory report results only. Moreover, dead trees were not measured in that survey and adding those would have increased the 1997 C stocks and reduced the amount of positive change between surveys. The quality of the 2010 field data collection and data management was documented for the current inventory, but documentation of QA/QC for the 1996-97 inventory was not available. The degree to which any or all of these errors may have affected the change estimate is almost impossible to know with certainty.

The general pattern of observed change is ecologically sensible. In the absence of commercial harvesting, a typical stand development pattern is that tree densities thin out over time (through competitive exclusion and other mortality), with the remaining trees increasing in size. Indeed, compared to the 1997 data, the 2010 inventory showed lower stem densities, especially of small trees, but larger mean stem size and total basal area (Figure 7.2). The magnitude of this difference was large for a 13-year period, but the general pattern is fairly reasonable. Whether due to actual successional dynamics, sampling error, or some combination of the two, this difference is largely what explains the higher C stocks in 2010.

Changes in the density and basal area of the major tree species of the Sundarbans show a similar trend (Figure 7.3). This analysis was limited to overstory trees (>15 cm dbh), and this larger size class showed increases in density and basal area for most of the major species, especially Sundri and Gewa.

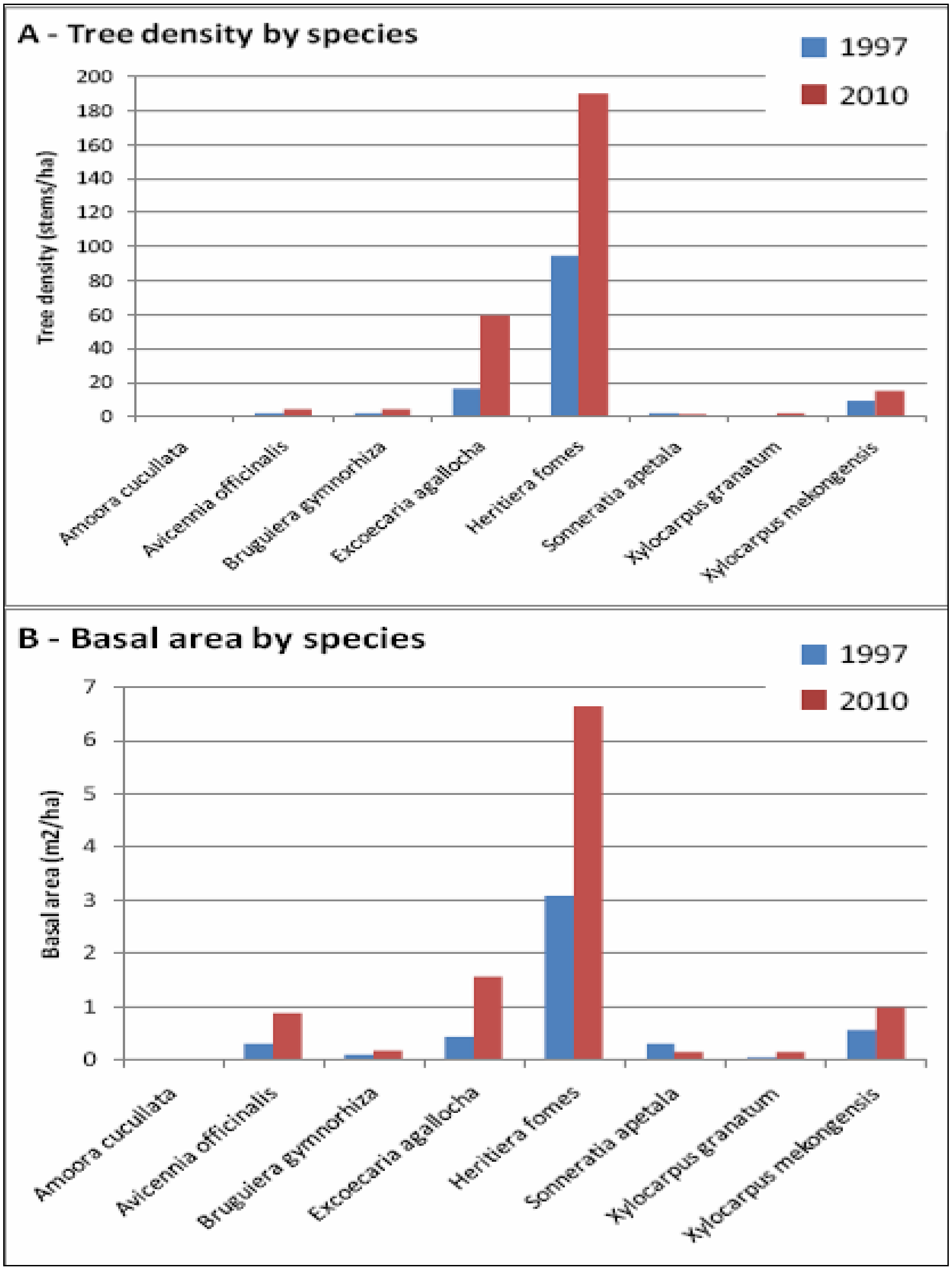
Figure 7.2: Tree density (A) and basal area (B) by tree diameter class in the 1996-97 and 2009-10 inventories





Note log-transformed y-axis in panel A. The 2010 inventory showed fewer small stems, and fewer total stems (apparent reduction in stem density), but more large stems. The basal area trend was similar.

Figure 7.3: Tree density (A) and basal area (B) by species in 1996-97 and 2009-10 inventories



Only overstory trees (>15 cm dbh) of the 8 most common species are included here. Trends in stem density and basal area were generally similar. Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) dominated compositionally, and both were substantially higher in density and basal area in 2010 compared to 1997.

Plot-wise disaggregated analyses were done to estimate the additionality due to REDD. Forest C (estimated based on trees, saplings and seedlings) was found increasing (72.51 Mg/ha over 13 years period) in 105 plots (representing approximately 2/3rd of the total forests area of 412,000 ha) and decreasing (26.47 Mg/ha over 13 years period) in 50 plots (representing approximately 1/3rd of the total forests area of 412,000 ha or say 137,333 ha). Additionality due to REDD can be estimated based on the following two emerging scenarios.

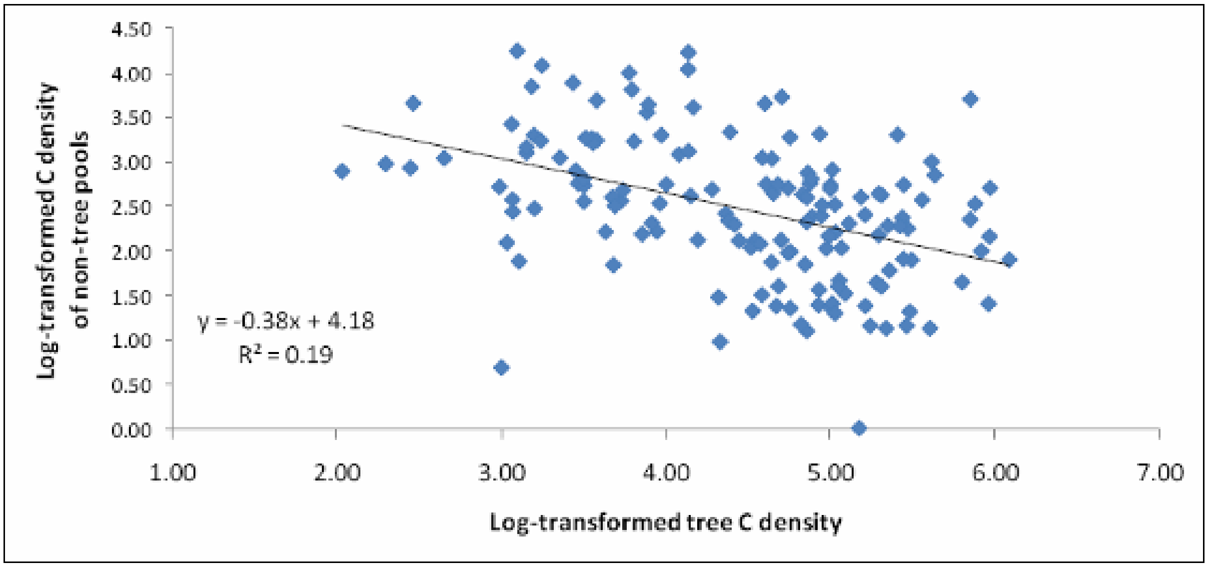
In case we account only for avoided forests degradation and deforestation and not for the increase in carbon stocks, we need to work out C estimates only for the forests area (1/3rd of the total forests area of 412,000 ha or say 137,333 ha of forest area) where C was decreasing (26.47 Mg/ha over 13 years period). The total C loss due to this decrease over 1/3rd of the forest area of the SRF was therefore 3635205 Mg C over 13 years period or 13,341,201 Mg CO_2e (by multiplying by 3.67) over 13 years, or 1,026,246 Mg CO_2e annually. For the project period of 30 years the decrease in CO_2e stocks, therefore, was 30,787,380 Mg CO_2e and this is the additionality when we target to avoid forests degradation and deforestation as a result of the CRISP interventions.

As an alternative scenario, in addition to gradually reducing the loss of C over 1/3rd of the forest area of the SRF where C is decreasing, the C stocks will be enhanced to the level of C stocks present in the 2/3rd of the forest area of the SRF where C is increasing (72.51 Mg/ha over 13 years period). In such a situation our plausible assumptions are that during the first 10 years of the CRISP the C stocks in the 1/3rd of the forest area of the SRF are stabilized by gradually reducing the C loss and then over the subsequent 20 years the C stocks in the 1/3rd of the forest area of the SRF are gradually increasing to reach to the level of the C stocks in the 2/3rd of the SRF. This means that for the first 10 years the forest stocks are increasing at the level of 1,026,246 Mg CO_2e annually. For the remainder project period of 20 years starting at 11th year, the stocks are increasing at the level of 46.04 (72.51-26.47) Mg C/ha over a period of 13 years or 23205157 (=46.04x137,333x3.67) Mg CO_2e over the entire 1/3rd of the SRF over a period of 13 years. So over the period of 20 years (starting from the year 11 to the year 30) the CO_2e stocks will increase at the level of 1785012 (=23205157/13) annually. Thus over a period of 20 years the total stocks of CO2e over the 1/3rd of the forest area of the SRF would be 35,700,240 (=1785012x20) Mg. By adding the total CO_2e stocks over the 1/3rd of the forest area of the SRF for the entire project period of 30 years (first 10 years + the remainder 20 years) work out to be as 45,962,702 Mg.

7.1.2 Assessment of Other (non-tree) C Pools

To see whether tree C density was strongly related to that of other C pools, thereby allowing predictive ability for other pools based on tree pools, a regression was made between tree C density and all other pools combined from the 2010 dataset. Data were log-transformed to better meet the assumptions of linear regression. The observed relationship was quite weak, with tree C density explaining less than 20% of the variation in other C pools (Figure 7.4). For this reason, assessment of changes in non-tree C pools in the recent past is not reasonably possible based on the inventory data alone. This report therefore focuses on changes in tree C pools only.

Figure 7.4: Relationship between tree C pools and non-tree C pools for the 2009-10 dataset



The relationship is weak and does not support prediction of other C pools (e.g., down wood, shrubs, soils) based on knowledge of tree pools. As such, the change assessment was limited to tree pools only.

7.2 Additionality due to Improved Forests Management

The temporary moratorium, which was applied to all natural forests in Bangladesh since 1989, was intended to give enough time to the natural forests to regenerate, as well as to stop further loss of natural forests through conversion (to plantation). For the Sundarbans, the moratorium was justified as timely to avert depletion of the growing stock, the trend which was already manifested in the results of the Forestall and ODA inventories in 1959 and 1983 respectively. However, the FRMP inventory (1996-97) showed that the depletion of sundari resources persisted in spite of the moratorium. The number of sundari trees per hectare of the 15 cm and above diameter classes was found to go down to 102 by the FRMP inventory period, from 125 of the ODA inventory period, and from 211 during the Forestall Inventory period. In the FRMP estimation in 1997, over a past period of 37 years, the number of trees per hectare in the growing stock was found to reduce by 52%. Between the ODA and FRMP inventories, the reduction was 18%. However, the number of stems per hectare in the 10 cm and above diameter classes has remained stable in the last 13 years prior to FRMP inventory, and this indicated that the sundari trees with large diameters were running down rapidly.

There were several possible causes of such unexpected depletion. Fishermen used sundari poles as anchor post for their boats, liberally obtained from the forests. With more than 25,000 registered boats in the Sundarbans, and probably an equal number of unregistered ones, the use of sundari for boat alone was substantial, considering that fishermen operated year round. Top-dying of sundari during this period also had an effect with almost 3% of the growing stock infected (IFMP, 1998). Erosion of river embankments added to the causes of depletion. Since the ODA inventory, it appeared that there was a net loss of land area of 3026 hectare, representing 1% of the growing stock. For the most part, timber theft was the cause of the greatest damage (ibid, 1998). The moratorium created an artificial shortage of the valued sundari and in all likelihood that might have induced some pilferage and smuggling. While regular confiscation and apprehensions were made, the FD, with its limited forest protection force, was and continues to be ill-equipped of fully guarding the vast Sundarbans.

7.2.1 Growing Stock Analyses, 1996/97 – 2009/10

Inventory data, 1996-97 collected from 1204 sample plots under the FRMP, and the inventory data, 2009-10 collected from 150 sample plots under IPAC, were employed for the temporal vegetation analyses. These two sets of data were used to estimate the growing stock details based on which a number of important conclusions about additionality are drawn as discussed below. Data from the common 150 sample plots of the 1996-97 and 2009-2010 inventory were compiled and analyzed. The basal areas (BA) of each big pole and tree were estimated and added to get the total for each species and then these totals were divided by the sampled area to covert to per hectare basis. Similarly, the volume of each big pole and tree were estimated first by using the desired volume equation, followed by conversion on per hectare basis.

From the results (Table 7.3) it is inferred that about 53,806/ha number of seedlings were grown in 2009-10 compared to 34,723/ha seedlings in 1996-97. Main reason for this increase is due the fact that the seedlings grow during rainy seasons and gradually a number of them dye out during the following dry season. Only a small portion of seedlings thus survive. Additionally, seedlings regeneration during the period is high due to non-harvesting of timber species including sundari and gewa, due mainly to the ban on commercial felling. The total number of saplings for all the species survived (5,545/ha) from the previous years' seedlings in 2009-10 is less compared to 8,088/ha in 1996-97. The total number of poles for all the species of sizes 2.5-5.0 cm and 5.0-10.0 cm DBH classes increased from 1,008 to 5,003 and 1,133 to 4,364 per hectare, which amounts to 31 and 21 percent increase respectively (Table 7.4) . The number of poles of size 10-15 cm DBH classes and number of trees for all the species have also increased from 384 to 507 and 142 to 297 respectively, which are about 396% and 109% increase respectively. Similarly, the BA/ha and V10/ha for poles of DBH class 10-15 cm and trees increased about 285, 32, 113 and 135 percent respectively. The tree N/ha, BA/ha and V10/ha have increased for all the DBH classes. The volume increment for the species sundari was 29.188 m^3/ha (from 19.016 m^3/ha in 1996-97 to 48.204 m^3/ha in 2009-10). Similarly, the volume increment for the species gewa was 5.572 m^3/ha (from 2.268 m^3/ha in 1996-97 to 7.84 m^3/ha in 2009-10).

Table 7.3: Number of seedlings, saplings and poles for the years 2009-10 and 1996-97 in the Sundarbans

Year 2009-10	Seedlings	Saplings	Poles in DBH class in cm				
Size class	Ht<1.5m	DBH<2.5 cm	2.5 – 5	5 -10	10-15		
Species	N/ha	N/ha	N/ha	N/ha	N/ha	BA/Ha (m^2)	V10/ha (m^3)
Sundari	34776	3044	2166	1596	234	2.818	13.922
Gewa	13235	1266	1984	2393	255	2.929	9.844
Baen	42	0	0	0	0	0.001	0.005
Keora	5	5	3	9	1	0.016	0.067
Others	5748	1231	850	366	17	0.199	0.651
Total	53806	5547	5003	4364	507	5.963	24.490
Year 1996-97							

Species	N/ha	N/ha	N/ha	N/ha	N/ha	BA/Ha(m^2)	V10/ha (m^3)
Sundari	20522	3957	428	523	188	2.165	10.397
Gewa	5971	2627	476	560	184	2.045	6.647
Baen	23	6	1	1	1	0.002	0.005
Keora	5	3	1	0	0	0.006	0.025
Others	8203	1495	100	49	10	0.118	0.384
Total	34723	8088	1008	1133	384	4.336	17.457

Table 7.4: Changes in between 2009-10 and 1996-97 for seedlings, saplings and poles

	Seedlings H<1.5 m	Saplings D<2.5	Poles 2.5-5	Poles 5-10	Poles 10-15 cm DBH (D)		
Species	N/ha	N/ha	N/ha	N/ha	N/ha	BA/Ha (m^2)	V10/ha (m^3)
Sundari	14255	-913	1737	1073	46	0.653	3.525
Gewa	7264	-1361	1508	1833	70	0.884	3.197
Baen	19	-6	-1	-1	0	-0.001	0.000
Keora	0	1	2	9	1	0.010	0.042
Others	-2456	-264	750	317	7	0.082	0.267
Total	19083	-2542	3995	3231	123	1.627	7.032

The number of trees (N/ha), basal area (BA/ha, m^2)) and volume up to 10 cm top end diameters (V10/ha, m^3) for the poles with DBH 10-15 cm have increased for all the important species (Table 7.4). The number of trees per hectare (N/ha), BA/ha and V10/ha has increased for all the species sundari, gewa, baen and others (Table 7.6). Only, keora has decreased. The N/ha for poles and trees have also been presented in Figure 7.5 to show the change.

From the data, it is observed that although the number of seedlings is high, there is reduction in number of saplings. So there is a need for taking appropriate measures to increase the number of saplings, followed by small poles, by protecting the huge number of seedlings that come up after rains. The volumes of the big poles and trees for all the species (sundari, gewa, keora + baen + others as others) are given in Table 7.8 and the emerging trends are presented in Figure 7.8. The distribution of numbers of saplings, poles and trees for sundari, gewa, keora, baen and others in different DBH classes have been estimated for 1996-97 and 2009-10 (Table 7.9) and the emerging trends presented in Figures 7.9 and 7.10 for sundari, gewa and others.

Figure 7.5: The number of poles of different sizes and trees (N/ha) in 2009-10 and in 1996-97

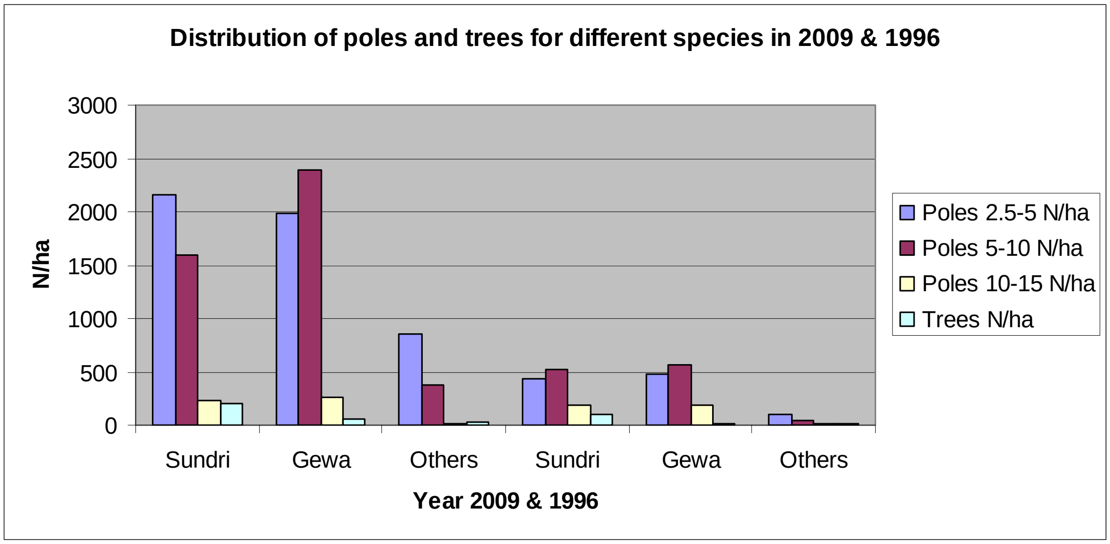


Table 7.5: Trees Statistics (N/ha, BA (m^2) and V10 (m^3) in 2009-10 for different DBH (cm) classes and important species

Year 2009-10												
DBH Class	**15-20**			**20-25**			**25-30**			**30-40**		
Species	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha
Sundari	117.4	2.733	16.028	54.02	2.084	14.479	21.69	1.235	8.883	10.64	0.931	6.917
Gewa	50.0	1.116	5.143	8.78	0.323	1.613	2.18	0.121	0.623	0.73	0.065	0.344
Keora	0.2	0.004	0.012	0.18	0.007	0.039	0.18	0.010	0.070	0.36	0.033	0.271
Baen	0.7	0.018	0.088	0.68	0.028	0.148	0.73	0.042	0.234	0.82	0.075	0.449
Others	7.4	0.171	0.648	6.09	0.238	0.948	4.64	0.276	1.076	4.23	0.392	1.381
Total	175.7	4.042	21.919	69.76	2.680	17.227	29.42	1.684	10.885	16.78	1.496	9.362
DBH Class	**40-50**			**50-60**			**60+**			**Total**		
Species	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha
Sundari	1.09	0.164	1.203	0.32	0.066	0.485	0.09	0.029	0.211	205.26	7.242	48.204
Gewa	0.14	0.022	0.118	0.00	0.000	0.000	0.00	0.000	0.000	61.80	1.647	7.840
Keora	0.27	0.041	0.379	0.05	0.009	0.083	0.09	0.034	0.212	1.32	0.139	1.066
Baen	0.50	0.076	0.471	0.36	0.085	0.535	0.82	0.655	3.147	4.64	0.978	5.071
Others	1.36	0.199	0.578	0.50	0.112	0.242	0.23	0.072	0.111	24.46	1.461	4.984
Total	3.36	0.502	2.748	1.23	0.272	1.344	1.23	0.790	3.681	297.48	11.467	67.166

Year 1996-97												
DBH Class	**15-20**			**20-25**			**25-30**			**30-40**		
Species	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha	N/ha	BA/ha	V10/ha
Sundari	63.4	1.509	7.874	30.4	1.157	6.613	8.4	0.473	2.880	2.6	0.217	1.413
Gewa	14.4	0.320	1.473	3.0	0.116	0.580	0.6	0.032	0.164	0.1	0.010	0.052
Keora	0.4	0.010	0.034	0.3	0.013	0.070	0.1	0.007	0.045	0.8	0.072	0.611
Baen	0.6	0.014	0.068	0.6	0.022	0.115	0.3	0.015	0.082	0.4	0.034	0.206
Others	4.4	0.104	0.395	3.3	0.130	0.516	3.3	0.191	0.746	2.9	0.258	0.922
Total	83.1	1.957	9.844	37.6	1.438	7.893	12.6	0.718	3.917	6.7	0.590	3.203
DBH Class	**40-50**			**50-60**			**60+**			**Total**		
Sundari	0.0	0.007	0.035	0.0	0.009	0.038	0.0	0.040	0.165	104.8	3.412	19.016
Gewa										18.1	0.477	2.268
Keora	0.5	0.085	0.778	0.2	0.043	0.368	0.2	0.097	0.523	2.6	0.327	2.429
Baen	0.1	0.017	0.109	0.1	0.025	0.159	0.4	0.217	1.214	2.4	0.345	1.953
Others	0.5	0.071	0.207	0.1	0.019	0.037	0.1	0.038	0.054	14.5	0.811	2.877
Total	1.2	0.180	1.128	0.4	0.096	0.602	0.8	0.393	1.956	142.4	5.372	28.543

Table 7.6: Differences in between 2009 and 1996 for trees Statistics in DBH (cm) Classes and Species (data 2009/10 - data 1996/97)

DBH	15-20			20-25			25-30			30-40		
Species	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)
Sundari	33.672	0.750	5.372	14.281	0.565	5.353	9.546	0.548	4.462	6.238	0.553	4.303
Gewa	26.945	0.603	2.777	4.209	0.151	0.753	1.240	0.068	0.351	0.489	0.044	0.232
Keora	-0.263	-0.007	-0.024	-0.188	-0.007	-0.037	0.038	0.002	0.012	-0.451	-0.045	-0.387
Baen	-0.038	0.001	0.005	0.000	0.001	0.007	0.338	0.020	0.112	0.301	0.027	0.165
Others	1.766	0.038	0.140	1.729	0.067	0.267	0.564	0.037	0.143	0.564	0.067	0.220
Total	62.084	1.384	8.271	20.031	0.777	6.344	11.725	0.674	5.079	7.140	0.646	4.534
DBH	40-50			50-60			60+			Total		
Species	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)
Sundari	0.864	0.128	0.959	0.225	0.046	0.363	0.038	-0.016	0.010	64.865	2.573	20.822
Gewa	0.113	0.018	0.097	0.000	0.000	0.000	0.000	0.000	0.000	32.996	0.884	4.211
Keora	-0.301	-0.051	-0.464	-0.150	-0.035	-0.300	-0.150	-0.069	-0.348	-1.466	-0.212	-1.548
Baen	0.301	0.045	0.280	0.188	0.045	0.283	0.301	0.324	1.387	1.390	0.463	2.239
Others	0.639	0.093	0.271	0.338	0.073	0.163	0.075	0.021	0.037	5.675	0.396	1.242
Total	1.616	0.234	1.143	0.601	0.129	0.509	0.263	0.260	1.086	103.46	4.105	26.966

Table 7.7 : The Change for different statistics expressed in percentage (%)

	Seedlings	Saplings	Pole 2.5-5	Pole 5-10	Poles 10-15			Tree		
Species	N/ha	N/ha	N/ha	N/ha	N/ha	BA/ha (m^2)	V10/ha (m^3)	N/ha	BA/ha (m^2)	V10/ha (m^3)
Sundari	578	-23	-19	-51	398	421	436	62	75	109
Gewa	787	-52	-33	-32	453	473	492	183	185	186
Others	182	-18	33	20	564	588	599	29	44	27
Total	520	-31	-21	-38	428	450	461	73	76	94

Table 7.8: Volume of poles (DBH 10-15 cm) and Trees in the Sundarbans in 2009-10 and 1996-97

	Year 2009-10	Year 1996-97	Year 2009-10	Year 1996-97
Size class	**Pole 10-15**	**Pole 10-15**	**Tree**	**Tree**
Species	**V10/ha (m^3)**	**V10/ha (m^3)**	**V10/ha (m^3)**	**V10/ha (m^3)**
Sundari	13.922	10.397	48.204	19.016
Gewa	9.844	6.647	7.840	2.268
Others	0.723	0.414	11.121	7.259
Total	24.490	17.457	67.166	28.543

Figure 7.6: Volumes of big poles and trees in the Sundarbans in 2009-10 and 1996-97

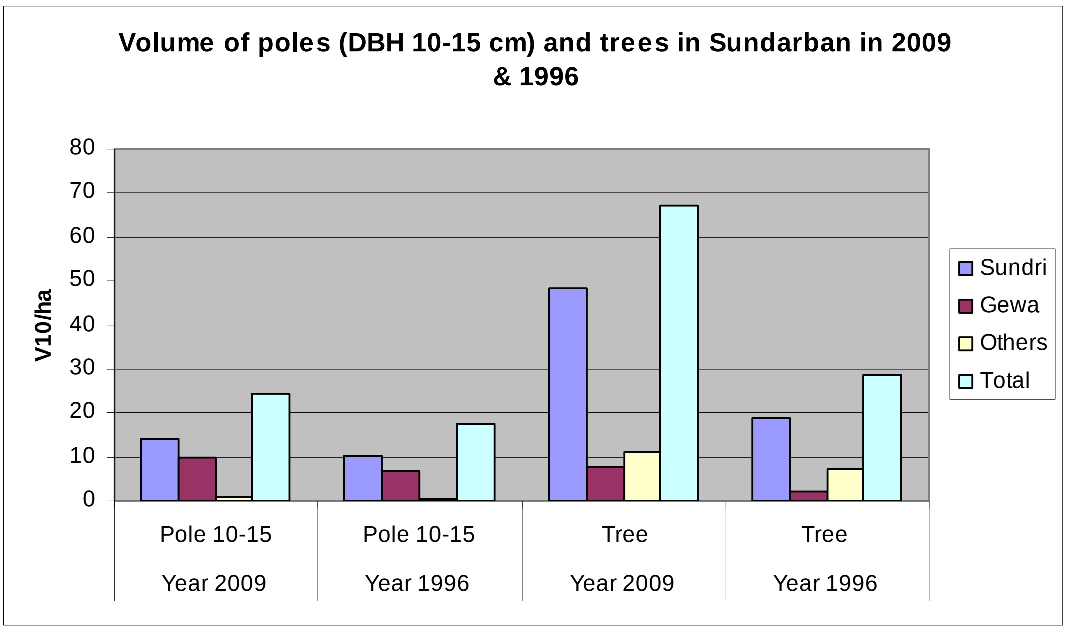


Table 7.9: DBH (cm) class distribution of different important species of the Sundarbans in 2009-10 and 1996-97

	2009-10	1996-97	2009-10	1996-97	2009-10	1996-97
DBH Class	**Sundari**		**Gewa**		**Others**	
Saplings	3044	3957	**1266**	2627	1236.0	1503.0
Pole 2.5-5	2166	428	1983	476	853.0	102.2
Pole 5-10	1596	523	2393	560	375.1	176.4
Pole 10-15	**234**	**188**	**255**	**184**	18.1	10.7
15-20	117.4	63.4	50.0	14.4	8.3	5.4
20-25	54.0	30.4	8.8	3.0	7.0	4.2

25-30	1.2	8.4	0.1	0.6	0.3	3.6
30-40	10.6	2.6	0.7	0.1	5.4	4.1
40+	1.4	0.1	0.1	0.0	3.8	2.2
	4180.7	1243.8	4690.7	1238.1	1271.0	308.8

Figure 7.7: Diameter class distribution (N/ha) for sundari in the Sundarbans in 2009-10 and 1996-97

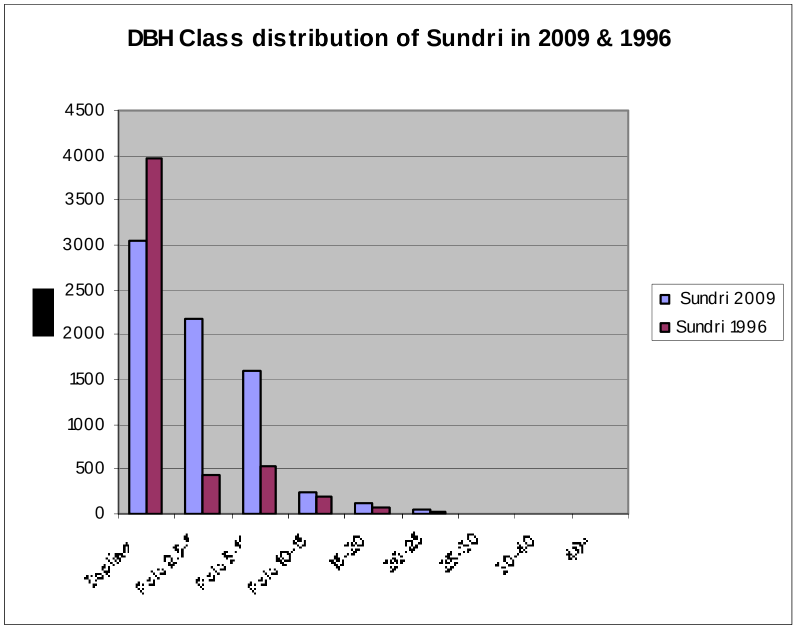


Figure 7.8: Diameter class distribution (N/ha) for gewa in the Sundarbans in 2009-10 and 1996-97

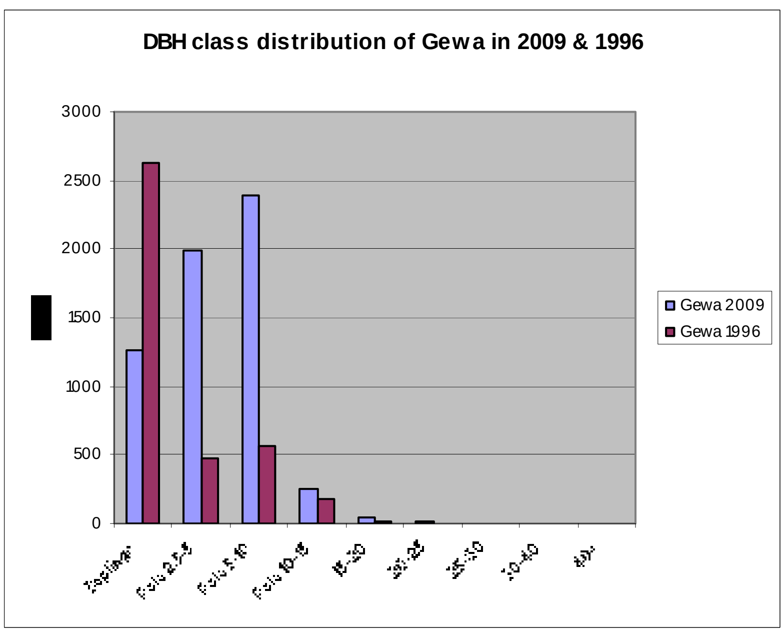
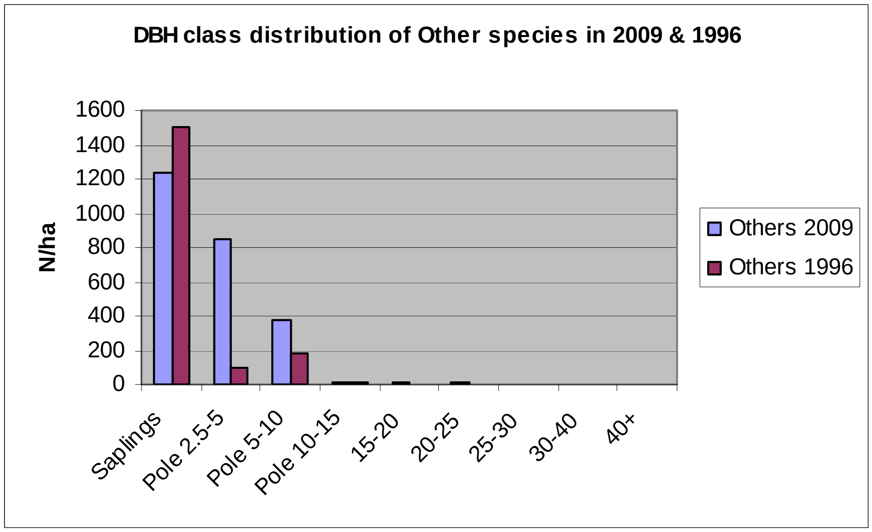


Figure 7.9: Diameter class distribution (N/ha) for other species in the Sundarbans in 2009-10 and 1996-97



Goran is an important fuel wood species present in many compartments of the Sundarbans. Therefore, an estimate for number of goran stems, volume and weight per hectare were estimated and the summary is given in Table 3.9. The data collection procedures in 1996-97 and 2009-10 were not the same : The data were collected in 2009-10 as small stems, medium stems, large stems and x-large stems based on basal diameters classes as 0-0.6, 0.6-2.5, 2.5-7.6 and above 7.6 cm respectively, whereas the data in 1996-97 were collected for seedlings (Height<1.5 m), saplings (DBH<2.5 cm) and poles/trees with DBH≥2.5 cm. The data were divided into two basal diameter classes, 0-2.5 cm and 2.5+ cm for comparison. It is observed from the Table 7.10 that N/ha, Volume/ha and weight/ha have increased.

Table 7.10: Goran in different size classes (N/ha, Volume & Weight) in the Sundarbans in 2009-10 & 1996-97

	Size Class (Basal diameter in cm)	Small Stems	Medium Stems	Large Stems	X-large Stems		Total
		0-0.6	0.6-2.5	2.5-7.6	>7.6		DBH>=2.5 cm
2009	N/ha	5853	9734	4270	471		4741
	Vol/ha	6.64	7.09	28.22	3.74		31.96
	Wt/ha (KG)	6482	8632	28260	3711		31971
	Size Class	Seedlings	Saplings	2.5 – 4.9	5 – 9.9	10 cm & +	Total 2.5 cm +
		Seedlings	Saplings	2.5-5	5-10	10+	
1996	N/ha	4719	2306	2497	186	22	2704
	Vol/ha		1.68	5.58	2.14	5.87	14

	Wt/ha (KG)		2045	6091	2082	5359	13532
Increment	N/ha						2036.14
	Vol/ha						18.37
	Wt/ha (KG)						18439.04

The number of trees of sundari, gewa and others (keora, baen and others) were estimated and converted into percentages of the total (Table 7.11). The results show that the percentage of sundari trees has reduced to about 4.58% followed by others. The percentage of gewa trees has increased by 8.08%. The results are shown in Figure 7.10 and 7.11. The species compositions were also estimated including the poles with trees. It is also observed from the Table 7.11, that if the poles are included with trees then the species compositions are changed in a same way. Latif *et al* (1992) also reported from 13 years study that sundari is in the similar decreasing trend and gewa in increasing trend.

Table 7.11: Comparative species compositions in 2009-10 and 1996-97

	Composition with trees					**Composition with trees and poles**						
	2009-10	**1996-97**	**2009-10**	**1996-97**	**Change**	**2009-10**	**1996-97**	**2009-10**	**1996-97**	**2009-10**	**1996-97**	**Change**
Species	N/ha	N/ha	%	%	%	Poles	Poles	Tree+ Poles	Tree+ Poles	%	%	%
Sundari	205	105	69.00	73.58	-4.60	3996	1140	4201	1244	41.30	46.69	-5.39
Gewa	62	18	20.77	12.70	8.10	4631	1220	4693	1238	46.14	46.46	-0.32
Others	30	20	10.23	13.72	-3.60	1247	163	1277	183	12.56	6.85	5.71
Total	297	142	100	100	0	9874	2523	10172	2665	100	100	0

Figure 7.10: Change in species (Trees) compost ions in the Sundarbans during the period 1996-97 to 2009-10

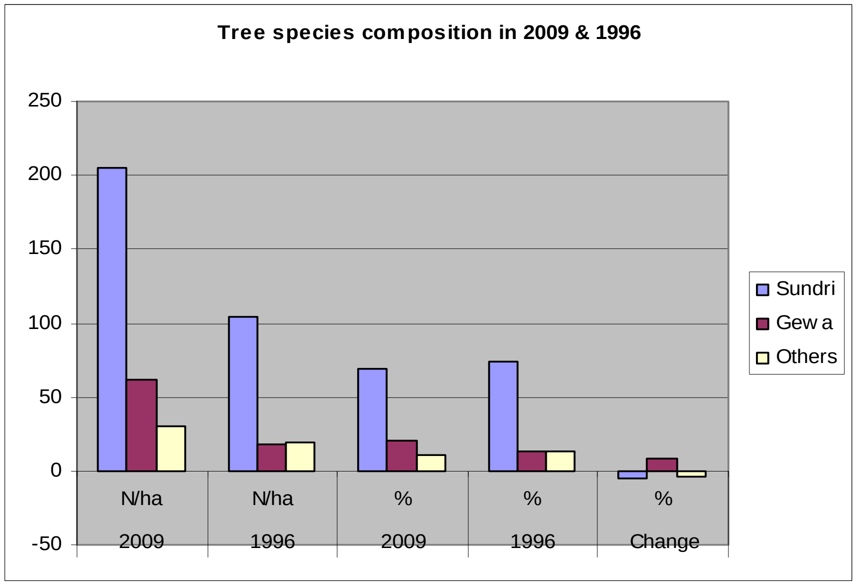
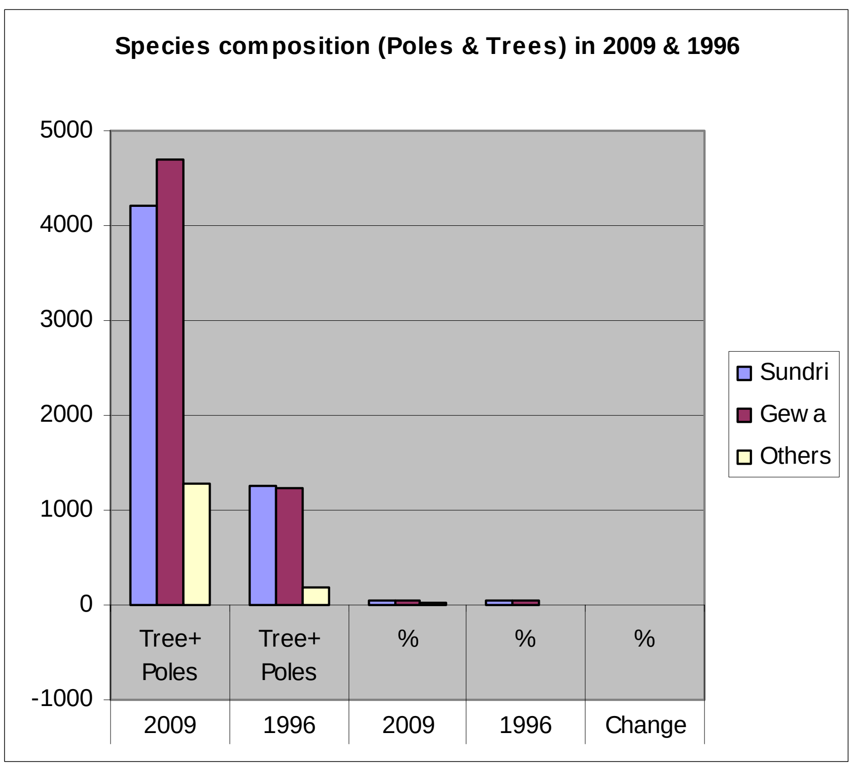


Figure 7.11: Change in species (Poles+ Trees) compost ions in the Sundarbans during the period 1996-97 to 2009-10



Sundari top-dying syndrome has been afflicting the Sundarbans forests for many years, and has been cited by several authors as a significant ecological and management problem. The 2009-10 inventory indicates that top-dying was not a major factor at that time. While 58% of plots with sundri trees had some sign of top-dying, an average of just 3% of individuals were affected within plots. The maximum proportion of individuals affected within a plot was 28%. Moreover, it was not always clear in the field whether a given tree with a partially dead top was actually affected by top-dying versus some other factor; as such, these percentages may be overestimates.

On average, two or three cyclones strike Bangladesh per year. Several cyclones recently impacted the Sundarbans area, most notably Cyclone Sidr in 2007 and Cyclone Aila in 2009. Aerial reconnaissance in late 2009 and the inventory plot data both indicated a range of apparent cyclone damage, but only a small portion of the forest area was affected overall. Additionally, there was apparently high resilience to all but the most severe storm effects. According to the crew's assessment at each inventory plot, a total of 22 plots, or 14% of the total sample, showed some evidence of cyclone damage. However, nearly half of these 22 plots showed only light damage. A total of 8 plots, or only 5% of the total sample, showed severe damage.

7.2.2 Temporal Comparison

An attempt was made to compare the results as inferred from the current inventory with those of the previous inventories. The result are summarized in Tables 7.12 and 7.13 and presented in Figures 7.12, 7.13 & 7.14. The comparisons show that the number of stems and volume/ha had decreased after the Forestal inventory (in 1959-61) but the growing stock condition has improved after ODA inventory (in 1983).

Table 7.12: Comparative per hectare estimate of no. of trees and volumes of trees 15-cm DBH and bigger

			Species			
Year	Sundari		Gewa		Others	
	N/ha	V10/ha	N/ha	V10/ha	N/ha	V10/ha
2009	205	48.2	62	7.8	30.4	11.2
1996	106	17.8	20	2.1	20	7.5
1983	125	19.9	35	2.7	20	7.1
1959	211	33.6	61	5.0	24	5.9

Figure 7.12: Comparison of stems/ha with previous inventories of the Sundarbans

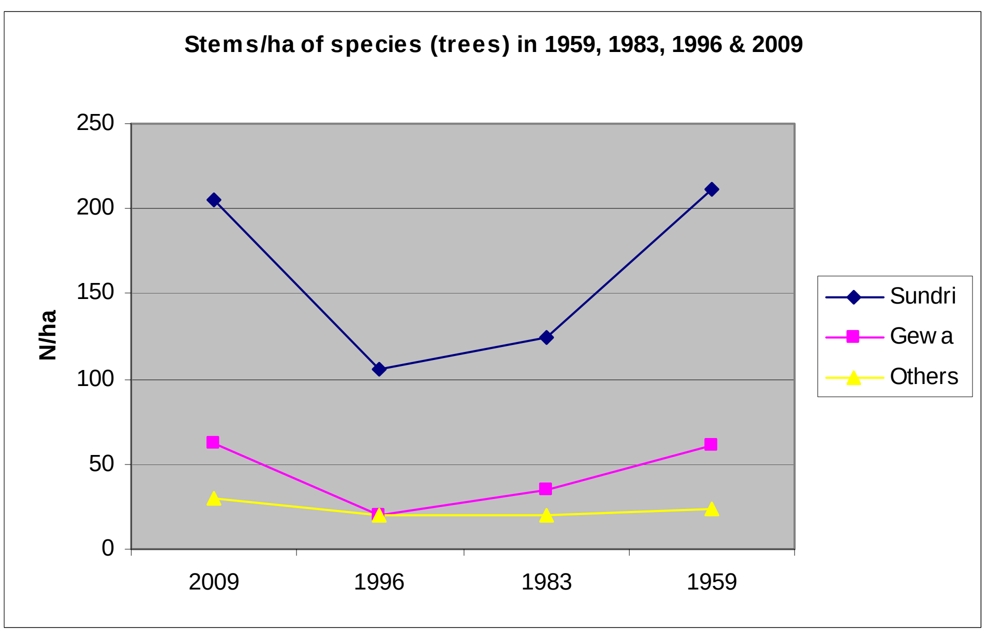


Figure 7.13: Comparison of V10/ha (cum) with previous inventories of the Sundarbans

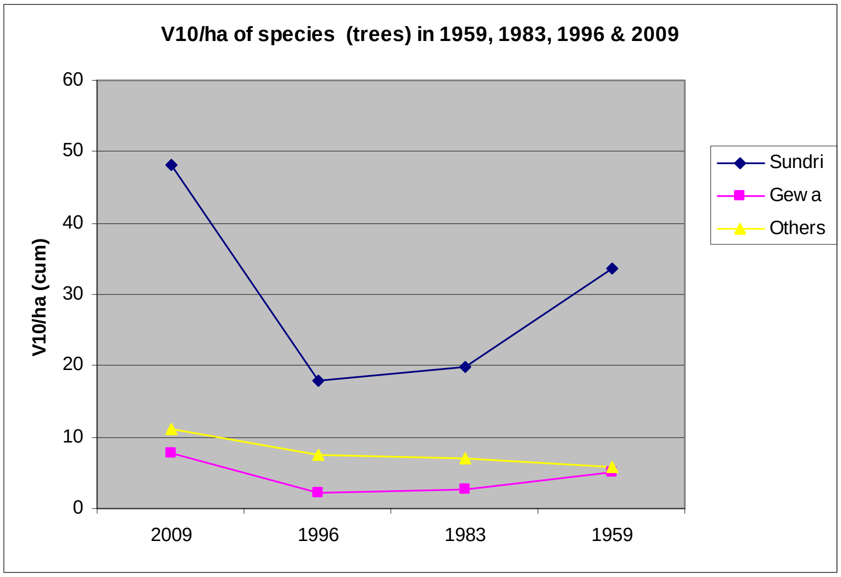
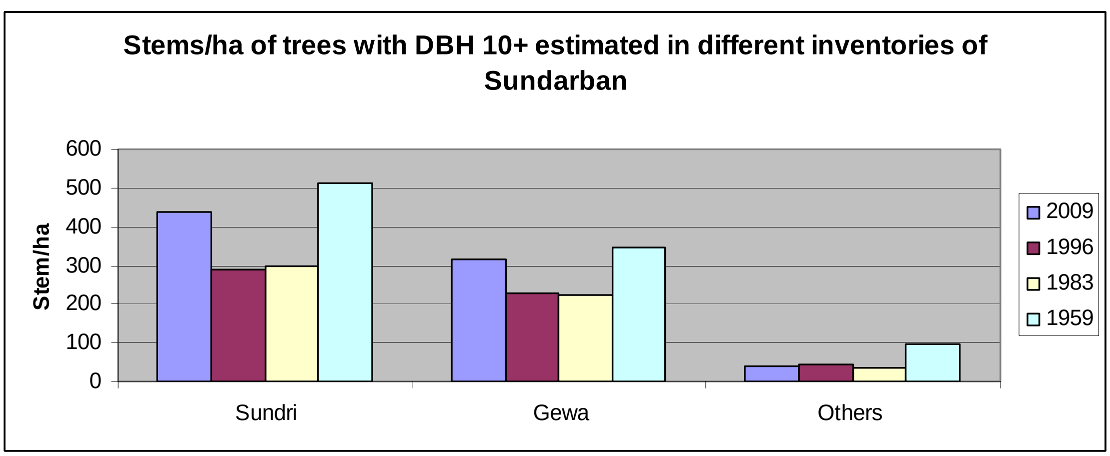


Table 7.13: Comparative per hectare estimate for number of stems of big pole & trees 10-cm DBH and bigger

	Species						
Year	Sundari		Gewa		Others		Total
	N/ha	%	N/ha	%	N/ha	%	
2009	439	55	317	40	41	5	797
1996	290	51.79	228	40.71	42	7.5	560
1983	296	53.14	224	40.22	37	6.64	557
1959	511	53.68	345	36.24	97	10.19	952

Figure 7.14: Estimate for number of stems/ha of big pole & trees 10-cm DBH and bigger



7.2.3 Estimation of Annual Growth

The Annual Allowable Cuts (AAC) have been prescribed in the IFMP based on the 1996-97 inventory. Based on 2009-10 inventory the AAC for different species in the Sundarban Reserved Forest was estimated (Table 7.14) using the following formulae:

1. AAC = (Present standing mature volume+ ½ growth during the period) / Period of cutting cycle

The estimated AAC is presented in Table 3.11 (column 7).

2. As per the Austrian formula:
   AAC = I + (Ga – Gr)/A

   where, I = annual increment,

   Ga = present Growing stock,

   Gr = desired growing stock (indicated by yield table or some other empirical standards)

   A = an arbitrary adjust period, which may be a full rotation or any selected period

Here, if we consider Ga = Gr, then AAC approximates to the annual increment. The annual increment is estimated and is given in Table 3.11 (column 9) and presented in Figure 8. It is evident that the figures for annual increment (and thence ACC) are close to the IFMP prescriptions, except for keora.

Table 7.14: Annual Growth Statistics for different species in the Sundarban RF

Species	Growing Stock (V10/ha)	Increment (V10/ha)	AAC (V10/ha /year)	DBH limit (cm)	Total area (ha)	Estimated AAC (V10/ha/y ear)	IFMP AAC (cum)	Increm-ent (cum)
1	2	3	4	5	6	7	8	9
Sundari	8.815	7.165	0.620	30	231159	143285	54000	82808
Gewa	0.462	0.410	0.033	15	296698	9887	53000	6081
Keora	0.945	-1.335	0.014	25	319201	4424	29852	-21308
Baen	4.601	2.914	0.303			0		0
Others	2.313	1.092	0.143	25	231159	33041	23000	12626
Goran (Volume)	1.357	0.346	0.077	2.5				0
Goran (kg)	1458	402	82.96					0

7.2.4 Estimates for Additionality due to IFM

The total annual increment (Table 7.14) for sundari, gewa, keora and other species (except goran) works out to be as 80,207 m^3 (=0.67x80,207 tons) whereas the annual harvests for goran averaged as 62,400 metric tons. This means that the annual biomass increment is approximately 116,139 metric tons or 58,068.5 metric tons of carbon. If multiplied by the molecular conversion factor of 3.67 (=44/12), the total annual CO_2 equivalent (CO_2e) is 213,115 metric tons. Thus for 30 years project the CO_2e will be 6,393,452 metric tons.

In order to ensure permanence of the carbon due to IFM a provision was included in the IRMP (2010-2020) that the ongoing short-term ban on commercial harvesting will be made permanent. This IRMP has now been approved by the MOEF order No. PaBaMa/Parisha-4/207/Misc./2011 (Part-1)/139 dated 4 December, 2011 resulting in a permanent ban on commercial felling in the SRF.

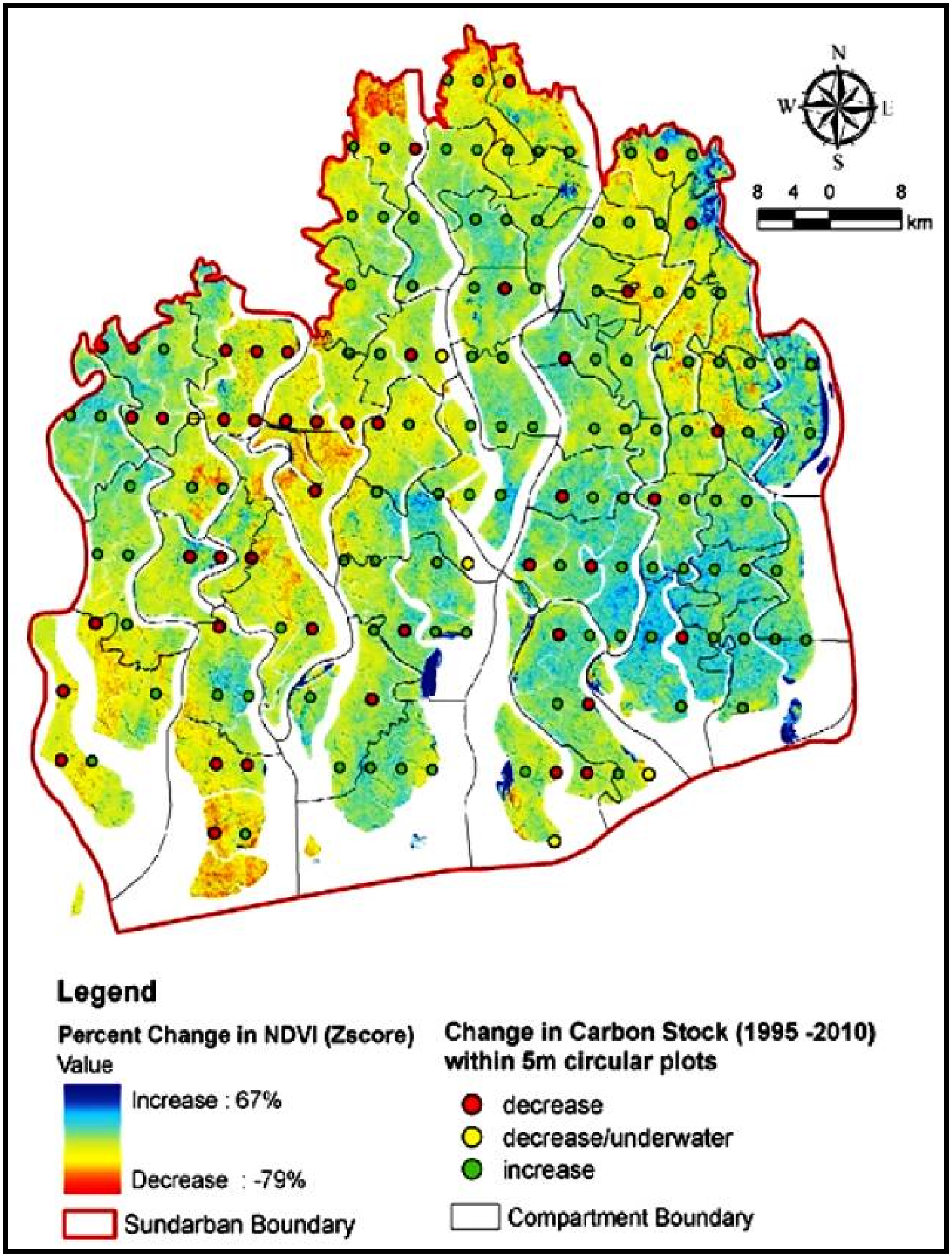
7.3 Remote Sensing Assessment of Deforestation and Degradation

In order to temporally assess deforestation and degradation, remote sensing technology was employed by using LANDSAT imageries that are available free of charge on Internet. Three LANDSAT data (the entire SRF is covered by two satellite scenes) from 1989, 1999 and 2009 were employed for developing a vegetation change detection based on Normalized Difference Vegetation Index (NDVI). The results from this study were found to be aligned well with the change in carbon stock and biomass as estimated above. The 10m circular plots that showed a decline in carbon stock were located within the compartments with a decline in NDVI or canopy cover (Figure 7.15). This agreement among the two studies conducted independently confirms that the pattern observed at a plot level is a representative of the overall compartment level pattern and vice versa. Although deforestation has not happened in the project area during the study period, forests degradation was identified based on the imagery analyses. The various compartments having carbon stock change are shown in Figure 5.7. The compartments with decline in carbon will particularly be focused while strengthening protection efforts by actively associating CMCs and CPGs.

7.4 Additionality due to Mangrove Forests Soils

Disaggregated soil analyses were done at plot-level for estimating forest soil C additionality as a result of the CRISP interventions. In all, 71 soil samples were grouped from the plots in $2/3^{rd}$ of the SRF forest area where forest C was found increasing and 28 soil samples were grouped from the plots in $1/3^{rd}$ of the SRF forest area where forest C was found decreasing. Average soil C stock estimated from the soil samples taken from 0-30 cm and 30-100 cm soil profiles were found as 61.73 and 55.44 Mg/ha in the increasing and decreasing forest C areas of the SRF respectively. Assuming that the soil C in the forest C decrease area would reach to the level of soil C in the forest C increase area over the project period of 30 years, there will be an additionality of 6.29 Mg C/ha, estimated by taking the difference between the two. Over an area of 137,333 ha, the soil C additionality of 3169646 (=6.29x137,333x3.67) Mg CO_2e will be generated over the project period of 30 years or say 105655 Mg annually.

Figure 7.15: Change in C-stock (1995-2010) sampled from 10m circular plots overlaid on percent change in NDVI Z-score of pixels from 1999 to 2009



8 Permanence and Leakage

8.1 Measures to Ensure Permanence

Identified project risks fall into the following categories:

- Project – Risk of unclear land tenure and user rights, and financial, technical, and/or management failure
- Economic – Risk of rising land opportunity costs
- Regulatory and social – Risk of political and/or social instability
- Natural disturbance – Risk of devastating fire, pest and disease attacks, extreme weather events such as storms and cyclones, and geological occurrences

In terms of project risks related to land tenure and user rights, the SRF is formally managed/owned by the FD on behalf of the GOB. However, as noted in our discussion of the causes of deforestation and degradation, some gaps exist over user rights, with local communities, exploiting forest resources to meet domestic needs or to serve as a source of income. By involving the CMCs to raise awareness amongst local communities regarding the importance of forest conservation, and leveraging existing co-management activities to help enforce protection of the forest reserves, this risk will be reduced considerably. The project will also seek to mitigate this risk by involving local communities through the CMCs and CPGs in implementation and monitoring activities, thereby offering alternative income streams. Furthermore, by increasing the attractiveness of the SRF to eco-tourists and strengthening the eco-tourism facilities, the project will offer alternative employment opportunities in tourism to members of local communities, diminishing the risks related to user rights.

There is little risk of technical failure, as the technologies proposed by the project are ones with which the FD and CMCs are familiar, and their knowledge and expertise will be further enhanced through appropriately targeted training in areas such as data collection and monitoring during the course of the project. The risk of management failure is also minimal, as the FD and CMCs have experience in carrying out and managing the type of activities proposed under this project. Moreover, NGOs familiar with the FD and the CMCs such as the Arannyak Foundation and CODEC will be brought in to assist with administrative, operational, and financial management as needed. Financial risk poses the greatest barrier at this point in time, due to the fact that funding for the project has yet to be secured. Regarding economic risk, the measures discussed under user rights risks will promote immediate, tangible benefits of retaining land as forests, and enhance the value of forest protection and sequestration, so that forests as a land use category are competitive to others such as shrimp culture and agriculture. This will help to mitigate the risk that rising land opportunity costs will lead to a reversal of forest protection and sequestration.

Political instability at the national level is a relatively minor risk in Bangladesh, as a parliamentary democracy. Although elections are held every five years, most regimes recognize the importance of addressing climate change through mitigation and adaptation, and are committed to the protection of the environment and forests. At the local level, collaboration with local political entities such as the CMCs serves as a means to reduce and manage the risk of instability. The factors affecting risks related to users rights noted above also have an impact on the risk of social instability; the measures implemented to reduce the former including the provision of alternative employment options will also advance social stability. Facilitating improvements in people's standard of living and alleviating poverty will further help to minimize both political and social instability at the local level.

In the category of natural disturbance risks, the probability of geological risks is low in the SRF. The risk of extreme weather events is high, with the SRF bordering the Bay of Bengal most vulnerable due to their exposure to tropical storms and cyclones. However, the protection activities in these areas will help to establish a buffer to enable both human populations and natural resources to better withstand such extreme events. Pest and disease outbreaks tend to be infrequent in the project area. However, the risk of pest and disease outbreaks will be reduced through close monitoring and improved management of the SRF.

8.2 Measures to Address Leakage

Leakage is defined by the Inter-governmental Panel on Climate Change as the "indirect impact that a targeted land use, land-use change and forestry activity in a certain place at a certain time has on carbon storage at another place or time”[7], and the “unanticipated decrease or increase in GHG benefits outside of the project’s accounting boundary as a result of the project activities”[8]. Despite the fact that leakage can be either positive (i.e., result in greater sequestration and emissions removals) or negative (i.e., lead to less sequestration and fewer emissions removals), it is often characterized as the latter. As a result, and due to standards’ explicit stipulation that accounting for positive leakage is impermissible[9], project management of negative leakage[10] is focused.

The two types of leakage that are likely to be relevant to the proposed project and that will be taken into consideration are activity-shifting and market-effect[11]. The former refers to the project-induced movement of deforestation and degradation activities from inside to outside project areas. Market-effect leakage takes place when project activities affect prices and the market, leading to an increase in the attractiveness of deforestation and degradation activities. For instance, reductions in illegal felling in the SRF may lead to reductions in the supply of illegally logged wood, thereby pushing up prices and placing greater pressure on forests elsewhere. The project will prevent leakage by offering alternative sources of income to surrounding communities, thereby helping to address the greatest incentive for illegal harvest of forest resources. Moreover, increased monitoring of forest activities in the SRF will further minimize leakage.

Leakage is not an issue in the project area as all the forests fall within the SRF. However, we will seek to ensure that an adequate risk buffer is established in order to be able to compensate for the anticipated risk posed by the two types of leakage discussed above. Continuous monitoring of leakage will be conducted in order to be able to adjust activities and the risk buffer as needed. This will include assessing rates of deforestation and forests degradation in the SRF; potential means for accomplishing this include field monitoring and remote sensing. Potential leakage will be compensated for by holding a risk buffer of 15 percent of tons of carbon equivalent sequestered.

8.3 Adapting to climate change

Climate change may have an impact on the environment of the SRF over the thirty-year project period. Projections for Bangladesh suggest that the country will experience changes in rainfall patterns, with precipitation becoming heavier and more erratic during the monsoon season, and lesser and more erratic during the dry season[12]. Recent experience also indicates that the frequency of tropical storms may increase. These changes may have implications for the forests and wetlands ecosystems that comprise the proposed project area. Changes in precipitation may affect the growth of certain species, and greater frequency of extreme events such as storms may cause damage to forests or result of flooding. The proposed project will seek to promote climate resilience of both the ecosystems and communities it works with through continuous monitoring and adjustment.

[7] IPCC (2000: 71).
[8] IPCC (2000: 246).
[9] Voluntary Carbon Standard (VCS) *Tool for AFOLU Methodological Issues* (2008: 7).
[10] All further references to leakage will only be to negative leakage unless explicitly stated otherwise.
[11] Other types of leakage that may occur are life-cycle emissions shifting and ecological. The former refers to an increase in emissions in upstream or downstream activities (e.g., forest conservation may ensue in greater road traffic from tourists), while the latter occurs when ecosystem level changes are caused in surrounding areas by the project, which causes greater carbon release into the atmosphere. Ecological leakage will not be measured because its magnitude in comparison to other types of leakage and implications remain unstudied. Life-cycle emissions shifting leakage will not be included because project activities have yet to be confirmed with the CMCs.
[12] GOB (2009).

9 Participatory Monitoring

Monitoring of both project parameters and carbon sequestered will be conducted in order to gauge the effectiveness and impacts of project activities; to measure forest carbon; and to inform any adjustments needed to ensure the efficacy of methodologies, implementation activities, or the monitoring plan itself. Key aspects of the project to be monitored include: project boundaries; forest protection; forest management; carbon stock changes; and leakage. It is envisioned[13] that the CMCs, together with the FD, will play a central role in participatory monitoring, with assistance from relevant NGOs in the areas of administrative, managerial, and financial monitoring.

9.1 Monitoring of Project Parameters

Several aspects of the project will be monitored to ensure that project activities are successfully carried out and adhere to conservation principles. Regarding the boundaries of the SRF, although they are clearly defined in the field and on maps as per GOB notification[14], periodic monitoring of the boundaries of the project areas will be conducted. This will be accomplished through the use of appropriate technologies, such as remote sensing with assistance from the FD's Resources Information Management System (RIMS) unit, as well as through monitoring and ground-truthing in the field. Maps will be updated regularly to ensure that monitoring is based on the most current situation. In terms of forest protection, which will be undertaken by the CMCs through the CPGs, although the FD will be responsible for supervising their implementation, an NGO such as CODEC may be brought in to undertake regular monitoring. The capacity of institutions such as the CMCs and the FD to understand and utilize monitoring technologies and techniques will be strengthened through targeted trainings primarily during the first three to five years of the project, with follow-up trainings as necessary.

9.2 Monitoring of Carbon Stocks

Measuring of soil carbon as well as below- and above-ground carbon and biomass will be carried out through permanent sample plots determined by systematic random sampling as developed during the initial field inventory. The dominant pools of biomass and carbon stock (i.e., trees) will be measured every five years, along with periodic independent verification. Measurement of pools that comprise a less significant portion of the overall carbon stock or that are likely to change more slowly, such as soil carbon, may be measured less frequently, for instance every ten years. Best practices such as remote sensing and field methods will be employed to inform the land use categorizations that are used in measuring and monitoring changes in biomass and carbon. Similar to the case of the project parameters, carbon stock monitoring will be carried out largely by the CMCs through the CPGs and the FUGs, with the FD providing guidance on field inventory protocols. To ensure they are equipped with the necessary knowledge and skills for carbon stock monitoring, NGOs and other relevant institutions such as the FD's RIMS unit will be brought in during the first three to five years to provide training-of-trainers to FD field staff as well as the CPGs and FUGs on the use of remote sensing and field inventory technologies. Targeted follow-up training will be offered, particularly if technologies used change.

9.3 Monitoring, Reporting and Verification (MRV) System

Main elements of a feasible monitoring, reporting and verification (MRV) system are discussed in this section. Sundarbans mangrove forests form an important bio-geographical zone (the country's other such strata/zones include hill forests, sal forests, social forests and homestead forests) and shall thus form a stratum when a national MRV system is designed and implemented. Within the two Sundarbans Forest Divisions (East and West) and four field Forest Ranges, sample plots (temporary and permanent) will be laid out by estimating

[13] A full monitoring plan for the project will be developed within six months of the project start date.
[14]SRF maps will be updated by RIMS.

appropriate sampling design, sampling intensity, number and location of sample plots on a grid, and the methodology adopted as above for establishing baseline is recommended for application. A two year cycle inventory will be carried out in the sample plots laid out as per the grid by marking them in the field. Mangrove forests of the Sundarbans will be categorized in the following 4 categories:

- Dense forests (more than 70% crown density)
- Moderately dense forests (30-70% crown density)
- Open forests (10-70% crown density)
- Scrub forests (less than 10% crown density)

Carbon gain-loss method estimates net balance of additions to and removals from a carbon stock (based on annual growth rates), whereas the carbon stock change method estimates the difference in carbon stocks at two periods. As the temporal inventories for the SRF provide time series data on growing stock, particularly for trees, the later method is suitable for carbon monitoring and reporting. The following carbon pools will be estimated:

- Above-ground carbon (tree, sapling, seedling, bamboo, cane, crown foliage, branches)
- On-ground carbon (woody debris, dead trees, leaf litter, grass)
- Below-ground carbon (soils, roots)

Average carbon stock for each of the above-identified stratum will be estimated by following the carbon inventory methods as described in the Inventory Manual (USFS, 2009). Species specific volume equations and specific gravity will be used in estimating carbon stock. Historical deforestation and degradation rates will be assessed either by employing temporal inventory data and/or temporal analyses of imageries such as LANDSAT/IRS. Maps will be generated by using facilities at RIMS of FD and/or SPARSO. Base maps of the LGED available at 1:50,000 scale will be helpful in generating these maps. However, it is important to know that carbon inventory and mapping pose some challenges as forests inventory are generally characterized by uncertainty and data limitations. Emission factors are neither available for the country nor for the Sundarbans. Land-use changes in Bangladesh are happening rather fastly due to heavy biotic pressure. RIMS of FD requires being equipped with the latest equipments and technology, and manned with trained staff

9.4 Participatory Monitoring Plan

A participatory monitoring plan will be developed with active participation of the CMCs and other local stakeholders and will focus on : i) monitoring of project implementation, including purpose of monitoring; ii) monitoring of project boundary (methods and technologies used); and monitoring of forest management to ensure forests are managed according to the description in the forest management plan and are consistent with the approved methodology. The project proponent will commit to developing a full monitoring plan within 6 months of the start date, and will disseminate the plan and the results of monitoring, ensuring they are made publicly available on the internet, and are communicated to stakeholders. The plan would include data and parameters as in following table:

Table 9.1: Parameters for participatory monitoring

Data / Parameter	
Data unit	
Description	
Source of data to be used	
Value of data applied for the purpose of calculating expected emission reductions	
Description of measurement methods and procedures to be applied	
Recording frequency	
QA/QC procedures to be applied	
Any comment	

Sampling design and stratification would be based on :

1. Stratification of the project area
   a. Factors to be considered in *ex post* stratification – to reflect characteristics of proposed activity, stand type, age class, and planting year
2. Sampling frame
   a. Sample size
   b. Plot size
   c. Locating permanent sample plots

Monitoring of the baseline net GHG removals by sinks will be taken up as provided in Table 9.2.

Table 9.2 Parameters for baseline monitoring

ID number	Data variable	Data unit	Measured (m), calculated (c), estimated (e) or default (d)	Recording frequency	Number of sample plots at which the data will be removed	Comment

Monitoring of the *ex post* baseline net GHG removals by sinks after the start of the project will be taken up as provided in Table 9.3 below:

Table 9.3 Parameters for ex post baseline monitoring

ID number	Data variable	Data unit	Measured (m), calculated (c), estimated (e) or default (d)	Recording frequency	Number of sample plots at which the data will be removed	Comment

Monitoring of the actual net GHG removals by sinks will be taken up. Data to be collected in order to monitor the verifiable changes in carbon stock in the carbon pools within the project boundary resulting from the proposed project (including units of measurement and origin of the data) would include:

i. Monitoring the actual net GHG removals by sinks

ii. Measuring and estimating carbon stock changes within the project activity boundary

iii. Carbon stocks of the living biomass

Possible parameters for measurements along with sampling details for actual net GHG removals are indicated in Table 9.4 as below:

Table 9.4 Parameters for actual net GHG removals

ID number	Data variable	Data unit	Measured (m), calculated (c), estimated (e) or default (d)	Recording frequency	Number of sample plots at which the data will be removed	Comment
	Stratum ID					
	Sub-stratum ID					
	Confidence level					
	Accuracy					
	Standard deviation of each stratum					
	Number of sample plots					
	Sample plot ID					
	Plot location					
	Tree species					
	Age of plantation					
	Number of trees					
	Diameter at breast height (DBH)					
	Mean DBH					
	Tree height					
	Mean tree height					
	Merchantable (standing) volume					
	Wood density					
	Biomass expansion factor (BEF)					
	Carbon fraction					
	Root-shoot ratio					
	Carbon stock in above-ground biomass of plots					
	Carbon stock in below-ground biomass of plots					

	Mean Carbon stock in aboveground biomass per unit area per compartment per species					
	Mean Carbon stock in belowground biomass per unit area per compartment per species					
	Area of Compartment					
	Carbon stock in aboveground biomass of compartment per species					
	Carbon stock in belowground biomass of r compartment per species					
	Carbon stock change in aboveground biomass of compartment per species					
	Carbon stock change in belowground biomass of compartment per species					
	Total carbon stock change					

Quality control and quality assurance procedures undertaken for data monitored will include uncertainty assessment as in Table 9.5.

Table 9.5; Uncertainty assessment

Data	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are unecessary

Measures to reduce uncertainty would include:

i. Quality assurance of field monitoring

ii. Data collection

iii. Data entry and analysis

Description of the operational and management structure(s) (roles and responsibilities) to be implemented to monitor actual GHG removals by sinks by the proposed project will be provided. Monitoring times and periods, considering the intended users, will be included in the monitoring plan.

Name of person(s) implementing the monitoring plan will be recorded as in Table 9.6.

Table 9.6: Information about the implementers of monitoring plan

Name	Affiliation	Contact Information

10. Project Financial Structure

Detailed item-wise budget and financial estimates for implementing the project interventions will be worked out, based on the IRMP budget estimated under habitat protection programs, after wide consultations with the CMCs and other important stakeholders. However, aggregate financial costs and benefits estimates are presented in Annexure 3 and the estimated Internal Rate of Return (IRR) works out to be as 14.10%. The costs are currently incurred under IPAC (until May 2013), SEALS (until December 2015), and by FD and CMCs. The benefits stream include FD revenues mainly from non-timber forest products, carbon revenues from forest C due to REDD and IFM and soil C.

Bibliography

BIDS, 2010. *A study of the principal marketed value chains derived from the Sundarbans Reserved Forests.* Bangladesh Institute of Development Studies and IPAC, Dhaka.

FAO, 2005. *Global Forest Resources Assessment. Country Reports*. Bangladesh. Rome: Forest Resources Assessment Programme, FAO.

FAO, 2000. *Forest Resources of Bangladesh. A Country Repor*t. Rome: Forest Resources Assessment Programme, FAO.

FAO, 2011. *Forests Resources Assessment*. Rome.

Forestal, 1960. *Forest Inventory, 1958-59. Sundarbans Forests*. Forestal Forestry and Engineering International Ltd., Canada.

FSP, 2001. *Guidelines for the Development of Conservation Area Facilities.* Forest Department. Dhaka.

IFMP, 1998. *Integrated Forests Management Plans for the Sundarbans Reserved Forests*, Forest Department, Dhaka.

IRMP, 2010. *Integrated Resources Management Plans for the Sundarbans*. Forest Department, Dhaka.

GOB, 1973. *Bangladesh Wildlife Preservation Order*. Dhaka.

GOB, Forest Department, 2010. *Land and Forest Area*. <URL: http://www.bforest.gov.bd/land.php> [Accessed September 19, 2010]

Hasan, M.M. and Mazumder, A.H. 1990. Distribution of organic matter in some representative forest soils of Bangladesh. *Indian Journal of Forestry*, 13(4).

Hossain, Z. and Acharya, G. 1994. *Mangroves of the Sundarbans*. The IUCN Wetlands Program, IUCN, Thailand.

Karim, A. 1988. *Top dying of sundari trees : an ecological view point*. Proceedings of the seminar on top dying of sundari trees. Bangladesh Agricultural Research Council, Dhaka.

Ministry of Environment and Forest, 2005. *Bangladesh Climate Change Strategy and Action Plan.* Ministry of Environment and Forests, Dhaka.

Ministry of Environment and Forest, 2005. *Bangladesh National Adaptation Program of Action. Dhaka: Ministry of Environment and Forests.* Dhaka.

International Disaster Database (EM-DAT), 2010. *Cyclones in Bangladesh*. <URL: http://www.emdat.be> [Accessed September 19, 2010]

IPAC, 2010. *Joint Forests Patrolling Guidelines*, IPAC. Dhaka.

IPCC, 2000. *Special Report. Land Use, Land-Use Change, and Forestry. Summary for Policymakers*.

SEALS, 2009. *Formulation Study for the Sundarbans Environmental and Livelihoods Security (SEALS) Project.* AGRIFOR Consult, Dhaka.

Umitsu, M. 1991. Late quaternary sedimentary environment and form evolution in Bengal lowland. *Geographical Review of Japan.* (Ser.B). 64(2).

USFS, 2009. *Protocols for Measuring and Reporting Carbon Stocks in Mangrove Forests.* USAID, Dhaka.

VCS, 2008. *Tool for AFOLU Methodological Issues.* VCS Association.

Annexure1: Villages in the Reference Region

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
1	Sarankhola	530					
2	Khuriakhali	523	N	Y	-	Y	-
3	Bogi	726	N	Y	-	Y	-
4	Sonatola	1200	N	Y	-	Y	-
5	Dakhin Tafalbari	800	N	Y	-	Y	-
6	Uttar Southkhali	550	N	Y	-	Y	-
7	Dakhin Southkhali	635	N	Y	-	Y	-
8	Chaletabunia	590	N	Y	-	Y	-
9	Rayenda	600	N	Y	-	Y	-
10	Bakultola	400	N	Y	-	Y	-
11	Uttar Tafalbari	400	N	Y	-	Y	-
12	Rajeshwar	650	N	Y	-	Y	-
13	Lakurtala	165	N	Y	-	Y	-
14	Uttar Tafalbari	600	N	Y	-	Y	-
15	Uttar Rajapur	1100	N	Y	-	Y	-
16	Dakhin Rajapur	950	N	Y	-	Y	-
17	Malia	863	N	Y	-	Y	-
18	Daser Varani	250	N	Y	-	Y	-
19	Chal Rayenda	600	N	Y	-	Y	-
20	Khada	700	N	Y	-	Y	-
21	Rosia Rajapur	450	N	Y	-	Y	-
22	Poschim Rajapur	837	N	Y	-	Y	-
23	DhanSagar	278	N	Y	-	Y	-
24	Khejurbaria	300	N	Y	-	Y	-
25	Amarbunia	920	N	Y	-	Y	-
26	Gulsakhali	750	N	Y	-	Y	-
27	Paschim Geodhara	800	N	Y	-	Y	-
28	Picha Baroikhali	890	N	Y	-	Y	-
29	Baddamari	64	N	Y	-	Y	-
30	Dhakhin Bastala	550	N	Y	-	Y	-
31	Bazikarkhondho (Uttor+Dhakhin)	867	N	Y	-	Y	-
32	Kachubunia	210	N	Y	-	Y	-
33	Boraitala	90	N	Y	-	Y	-

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
34	Golbunia	410	N	Y	-	Y	-
35	Katakhali	257	N	Y	-	Y	-
36	Hoglabunia	70	N	Y	-	Y	-
37	Goraburburia	500	N	Y	-	Y	-
38	Dhakhin Haldibunia	575	N	Y	-	Y	-
39	Haldibunia	450	N	Y	-	Y	-
40	Dhakhin Chila	450	N	Y	-	Y	-
41	Ulukata	300	N	Y	-	Y	-
42	Chila Gabunia	280	N	Y	-	Y	-
43	Joymoni	1350	N	Y	-	Y	-
44	Phaschim Chila	350	N	Y	-	Y	-
45	Kanainagar	860	N	Y	-	Y	-
46	Dakhin Kainmari	300	N	Y	-	Y	-
47	North Modinabad	967	N	Y	-	Y	-
48	South Modinabad	1047	N	Y	-	Y	-
49	Gobra	305	N	Y	-	Y	-
50	Ghata Khali	270	N	Y	-	Y	-
51	Horin Khola	355	N	Y	-	Y	-
52	1 no Koyra	1046	N	Y	-	Y	-
53	2 no Koyra	1105	N	Y	-	Y	-
54	3 no Koyra	1077	N	Y	-	Y	-
55	4 no Koyra	1291	N	Y	-	Y	-
56	5 no Koyra	745	N	Y	-	Y	-
57	6 no Koyra	570	N	Y	-	Y	-
58	Gilabari	320	N	Y	-	Y	-
59	Amtola	335	N	Y	-	Y	-
60	Shingher Choak	315	N	Y	-	Y	-
61	Moheshoripur	1828	N	Y	-	Y	-
62	Chowkuni	989	N	Y	-	Y	-
63	Sathalia	840	N	Y	-	Y	-
64	Kalikapur	782	N	Y	-	Y	-
65	Tetultila	959	N	Y	-	Y	-
66	Vagbah	760	N	Y	-	Y	-
67	Middle Hadda	630	N	Y	-	Y	-
68	East Hadda	765	N	Y	-	Y	-
69	Kathmarchor	319	N	Y	-	Y	-

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
70	West Hazat Khali	300	N	Y	-	Y	-
71	Bedkashi	339	N	Y	-	Y	-
72	East Hazat Khali	320	N	Y	-	Y	-
73	Sheakh Sardarpara	398	N	Y	-	Y	-
74	Borobari	470	N	Y	-	Y	-
75	Botul Bazar	300	N	Y	-	Y	-
76	Pathor Khali	230	N	Y	-	Y	-
77	Gazipara	150	N	Y	-	Y	-
78	Gabubunia	110	N	Y	-	Y	-
79	Shakh Baria	102	N	Y	-	Y	-
80	Horihoropur	220	N	Y	-	Y	-
81	Gatir Gheri	180	N	Y	-	Y	-
82	Padmapukur	380	N	Y	-	Y	-
83	Goal Khali	650	N	Y	-	Y	-
84	Matiavanga	300	N	Y	-	Y	-
85	Ghorilal	500	N	Y	-	Y	-
86	Choto Angtihara	754	N	Y	-	Y	-
87	Angtihara	838	N	Y	-	Y	-
88	Jorr Shingh	825	N	Y	-	Y	-
89	Patakhali	720	N	Y	-	Y	-
90	South Bedkashi	449	N	Y	-	Y	-
91	Chora Mukho	540	N	Y	-	Y	-
92	Meder Chor	200	N	Y	-	Y	-
93	Binapani	721	N	Y	-	Y	-
94	Holud Bunia	300	N	Y	-	Y	-
95	Moharajpur	1800	N	Y	-	Y	-
96	East Mothbari	1000	N	Y	-	Y	-
97	West Mothbari	850	N	Y	-	Y	-
98	Kalna	500	N	Y	-	Y	-
99	Megharite	400	N	Y	-	Y	-
100	Gobindapur	300	N	Y	-	Y	-
101	Lota	250	N	Y	-	Y	-
102	Doshania	250	N	Y	-	Y	-
103	Shimlarite	320	N	Y	-	Y	-
104	Joypur	450	N	Y	-	Y	-
105	Acra	330	N	Y	-	Y	-

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
106	Antabunia	220	N	Y	-	Y	-
107	Srirampur	350	N	Y	-	Y	-
108	Khoria	230	N	Y	-	Y	-
109	Deara	925	N	Y	-	Y	-
110	Motherbaria	850	N	Y	-	Y	-
111	Laxmikhola	300	N	Y	-	Y	-
112	Shyam Khali	250	N	Y	-	Y	-
113	Kulkhali	300	N	Y	-	Y	-
114	Gonari	450	N	Y	-	Y	-
115	Sutorkhali	450	N	Y	-	Y	-
116	Nalian	450	N	Y	-	Y	-
117	Kalabogi	450	N	Y	-	Y	-
118	North Banisanta	416	N	Y	-	Y	-
119	Andharmanik	130	N	Y	-	Y	-
120	Jhor khali	94	N	Y	-	Y	-
121	Kakrabunia	152	N	Y	-	Y	-
122	Amtola	160	N	Y	-	Y	-
123	East Amtola	146	N	Y	-	Y	-
124	West Banisanta	110	N	Y	-	Y	-
125	North Amtola	349	N	Y	-	Y	-
126	Banisanta Bazar	336	N	Y	-	Y	-
127	East Banisanta	164	N	Y	-	Y	-
128	East Dhangmari	447	N	Y	-	Y	-
129	Bhozonkhali	234	N	Y	-	Y	-
130	East Khejuria	338	N	Y	-	Y	-
131	West Khejuria	399	N	Y	-	Y	-
132	West Dhangmari	210	N	Y	-	Y	-
133	Portkata	175	N	Y	-	Y	-
134	Lowdove Poshurdhar	695	N	Y	-	Y	-
135	Low136dove Middlepara	510	N	Y	-	Y	-
136	Khutakhali	305	N	Y	-	Y	-
137	Khutakhali Bazar	152	N	Y	-	Y	-
138	Harintana	298	N	Y	-	Y	-
139	Kalikabati	65	N	Y	-	Y	-
140	Ruakata Borobak	58	N	Y	-	Y	-
141	Burirdabur	105	N	Y	-	Y	-

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
142	Kamarkhola	539	N	Y	-	Y	-
143	Jelia Khali	228	N	Y	-	Y	-
144	Channirchok	164	N	Y	-	Y	-
145	Shibnagar	76	N	Y	-	Y	-
146	Fakirdanga	52	N	Y	-	Y	-
147	Rajnagar	72	N	Y	-	Y	-
148	Rekha Mari	49	N	Y	-	Y	-
149	Joynagar	296	N	Y	-	Y	-
150	Per Joynagar	250	N	Y	-	Y	-
151	Bhitavanga	150	N	Y	-	Y	-
152	Kalinagar	270	N	Y	-	Y	-
153	Satghoria	155	N	Y	-	Y	-
153 4	Shaharabad	215	N	Y	-	Y	-
155	Srinagar	294	N	Y	-	Y	-
156	Ramnagar	602	N	Y	-	Y	-
157	Ramnagar Dhopadi	554	N	Y	-	Y	-
158	Dhopadi	575	N	Y	-	Y	-
159	Koilashgong	1460	N	Y	-	Y	-
160	Harintana	971	N	Y	-	Y	-
161	North Kodomtola	394	N	Y	-	Y	-
162	South Kodomtola	196	N	Y	-	Y	-
163	Dhankhali	456	N	Y	-	Y	-
164	Kachu Khali	227	N	Y	-	Y	-
165	Kultoli	278	N	Y	-	Y	-
166	Harinagar	570	N	Y	-	Y	-
167	Central Kalinagar	790	N	Y	-	Y	-
168	Hetal Khali	470	N	Y	-	Y	-
169	Jeil-e Khali	495	N	Y	-	Y	-
170	East Kalinagar	686	N	Y	-	Y	-
171	Mothurapur	355	N	Y	-	Y	-
172	Shinghortoli	250	N	Y	-	Y	-
173	Chunkuri	476	N	Y	-	Y	-
174	Choto Vatekhali	509	N	Y	-	Y	-
175	Boro Vatekhali	300	N	Y	-	Y	-
176	Jatindranagar	550	N	Y	-	Y	-

Sl. No.	Village Name	# house holds	Village Location		Community role in control of deforestation/degradation		
			Core Zone	Land scape Zone	Major	Moderate	Low
177	Mirgang	560	N	Y	-	Y	-
178	Pershee Khali	367	N	Y	-	Y	-
179	Abad Chondipur	500	N	Y	-	Y	-
180	Chuna	480	N	Y	-	Y	-
181	Bon Bibi tola	520	N	Y	-	Y	-
182	Pan Khali	500	N	Y	-	Y	-
183	Burigoalini	230	N	Y	-	Y	-
184	Kolbari	484	N	Y	-	Y	-
185	East Durgabati	240	N	Y	-	Y	-
186	West Durgabati	220	N	Y	-	Y	-
187	Datinakhali	878	N	Y	-	Y	-
188	Vamia	1052	N	Y	-	Y	-
189	East Porakatla	180	N	Y	-	Y	-
190	West Porakatla	206	N	Y	-	Y	-
191	Kholpetua	450	N	Y	-	Y	-
192	Gabura	450	N	Y	-	Y	-
193	Lebu Bunia	450	N	Y	-	Y	-
194	Jail-e Khali	450	N	Y	-	Y	-
195	Kholisha Bunia	450	N	Y	-	Y	-
196	Tengra mari	450	N	Y	-	Y	-
197	Kagramari	450	N	Y	-	Y	-
198	Parshee mari	450	N	Y	-	Y	-
199	Navidolkhali	450	N	Y	-	Y	-
200	Chandimukha	450	N	Y	-	Y	-
201	9 No Sora	450	N	Y	-	Y	-
202	10 No Sora	450	N	Y	-	Y	-
203	Dumuria	450	N	Y	-	Y	-
204	Chalkbara	450	N	Y	-	Y	-
205	Middle Khulishabunia	450	N	Y	-	Y	-
206	Vate Khali	980	N	Y	-	Y	-
207	Tengrakhali	373	N	Y	-	Y	-
207	Kalinchi	560	N	Y	-	Y	-
209	Golakhali	86	N	Y	-	Y	-
210	East Koikhali	1700	N	Y	-	Y	-
211	West Koikhali	1300	N	Y	-	Y	-
212	Middle Koikhali	145	N	Y	-	Y	-

Sl. No.	**Village Name**	**# house holds**	**Village Location**		**Community role in control of deforestation/degradation**		
			Core Zone	**Land scape Zone**	**Major**	**Moderate**	**Low**
213	Shap Khali	520	N	Y	-	Y	-
214	Joya Khali	1160	N	Y	-	Y	-
215	Boish Khali	495	N	Y	-	Y	-

Annexure 2: Contact information of the proponents of the proposed project activity

Organization	
Name	Bangladesh Forest Department and Co-Management Committees for the Sundarbans
Street/P.O.Box	Agargaon
Building	Ban Bhaban
City	Dhaka
State/Region	
Postfix/ZIP	1212
Country	Bangladesh
Telephone	00880 2 811 8671
Fax	00880 2 811 8671
E-mail	info@bforest.gov.bd
URL	www.bforest.gov.bd
Represented by	
Title	Project Director
Salutation	Mr.
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