



# Building Resilience for Sustainable Development of the Sundarbans

## *Strategy Report*



# Building Resilience for Sustainable Development of the Sundarbans

through Estuary Management, Poverty Reduction,  
and Biodiversity Conservation

## *Strategy Report*

Report No. 88061 - IN

South Asia Region  
Sustainable Development Department  
Environment & Water Resources Management Unit



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The International Bank for Reconstruction and Development / The World Bank

1818 H Street NW

Washington, DC 20433

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Designed and printed by: JS Print O Pack, B-198, Okhla Industrial Area, Phase-I, New Delhi-110020

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# ACKNOWLEDGEMENTS

This report is the product of a collaborative effort between the World Bank and several department and agencies of the Government of West Bengal under the overall coordination of the Sundarban Affairs Department of the Government of West Bengal. Most of the background studies and analysis were undertaken during 2009-11; synthesis and the final recommendations emerged out of consultative processes organised during 2012-13. Special gratitude is extended to Ms. Mamata Banerjee, Chief Minister, GoWB; Mr. Buddhadeb Bhattacharya, former Chief Minister, GoWB; Mr. Jairam Ramesh, former Union Minister for Environment and Forests; Mr. Sanjay Mitra, Chief Secretary, GoWB; Mr. Samar Ghosh, Mr. Ardhendu Sen and Mr. A. M. Chakraborty, former Chief Secretaries, GoWB; Mr. M. Farooqui, former Special Secretary, MoEF; Mr. Hem Pande, Additional Secretary, MoEF, and Ms. Sunita Singh, Director, MoEF for their guidance and support during the entire duration of this collaborative effort.

Overall study coordination was provided by the Sundarban Affairs Department, GoWB. The team would especially like to thank Ms. Nandini Chakraborty, Secretary, and the former secretaries of the Department – Late Mr. Arun Bal and Mr. Raghavendra Singh for their support, review and advice throughout the study. Other heads of departments and officials of the GoWB provided reports, information, analysis, technical reviews and support to organize stakeholder meetings - Mr. K.S. Rajendra Kumar, Mr. K. Sathivasan, Mr. Trilochan Singh, Mr. M.N. Roy, Mr. Rinchen Tempo, Mr. Subesh Das, Mr. Anil Kumar Agarwal, Mr. Anjan Kumar Chatterjee, Mr. Vikram Sen, Mr. Sarthak Barma, Mr. Paritosh Bhattacharyya, Mr. S.C. Acharya, Mr. S. B. Neogi, Mr. S. Sarkar, Mr. Choten Lama, and Mr Rabindranath De; and the team acknowledges their contribution.

The World Bank team was led by Ernesto Sánchez-Triana and Tapas Paul, and included Priti Kumar, Anna C. O'Donnell, Anupam Joshi, Cecilia Belita, Charles Joseph Cormier, Dan Biller, Ghazal Dezfali, Jack Ruitenbeek, Jean-Noel Guillosoy, John Pethick, Leonard Ortolano, Nalin Jena, Rahul Kanakia, Ramachandran R. Mohan, Roshni Sarah John, Ruma Tavorath, Sanjay Gupta, Santiago

Enriquez, Sarah Martiny, Shakil Ahmed Ferdausi, Snehashish Raichowdhury, Soumya Kapoor, and Surbhi Goyal. Additional background papers and analyses were produced by Anurag Danda, Bjorn Larsen, Chandreyee Das, Christine Heyniger, Damanjit Singh Minhas, D.M. Mohan, Elena Strukova Golub, Gautam Gupta, Ishtiaque Ahmed, Juan Luna-Kelser, Kakoli Sen Sarma, Lidvard Gronnevet, Nirmala Banerjee, Peter Webster, Pranabes Sanyal, Priyanka Roy, Ratul Saha, Samir Mehta, Samuel Taffesse, S.C. Rajshekar, Somenath Battacharya, Subimal Roy, the Institute of Environmental Studies and Wetland Management, IMRB Consultants, Jadavpur University, Sundarban Rural Development and Training Centre, West Bengal Green Energy Department Corporation, and the Worldwide Fund for Nature-India.

Peer reviewers were Darrel Hueth, Ede Ijjasz-Vasquez, John Redwood, Marea Eleni Hatzios, Richard Damania, Sussanne Scherling and Yewande Aramide Awe. Helpful comments and contributions were received from World Bank staff representing several sectors and regions, including Anna Wellenstien, Brigitte Duces, Stefania Aberkali, Thomas O'Brien, Valerie Hickey and Martien van Nieuwkoop. Special thanks are due to Karin Erika Kemper; Rachid Benmessaoud; Isabel Guerrero, former Vice-President for South Asia region; late Gajanand Pathmanathan, former Senior Manager, South Asia Sustainable Development Department; and Christine F. Allan, former Country Director for Bangladesh for their guidance, especially in the early stages of the study. Karin Erika Kemper and Herbert Acquay, former and current Sector Managers, South Asia Environment and Water Resources Unit; N. Roberto Zagha, former Country Director for India and Giovanna Prennushi, Lead Economist guided the overall effort. The team is particularly grateful to the Australian, Netherlands, Norwegian and United Kingdom Trust Funds.

The team gratefully recognizes the contributions of the many people including the community leaders in the Sundarbans who assisted in preparation of this report and provided insights. The opinions presented here and any errors are the sole responsibility of the authors and should not be attributed to the individuals and institutions acknowledged above.

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# CONTENTS

<b>Abbreviations .....</b>	<b>iii</b>
<b>Preface .....</b>	<b>vii</b>
<b>Executive Summary .....</b>	<b>1</b>
1. Introduction and Context .....	13
2. Findings and Lessons .....	21
3. Pillar 1: Vulnerability Reduction .....	27
4. Pillar 2: Poverty Reduction .....	33
5. Pillar 3: Biodiversity Conservation .....	49
6. Pillar 4: Institutional Change .....	57
7. Next Steps .....	67
References .....	75
<b>Annex 1: Historical Overview and Current Trends in Development in the Sundarbans</b>	
Abstract .....	79
1.1 Introduction .....	79
1.2 History of the Sundarbans .....	79
1.3 The Sundarbans Today .....	83
1.4 Conclusion .....	90
References .....	90
<b>Annex 2: Methodology for the Non-Lending Technical Assistance</b>	
Abstract .....	93
2.1 Introduction .....	93
2.2 Methodology .....	95
2.3 Pillar 1: Vulnerability Reduction .....	95
2.4 Pillar 2: Poverty Reduction .....	96
2.5 Pillar 3: Biodiversity Conservation .....	99
2.6 Pillar 4: Institutional Change .....	100
References .....	101
<b>Annex 3: Effective Forecasting Systems for Reducing the Impacts of Cyclones and Extreme Weather Events</b>	
Abstract .....	103
3.1. Tropical Cyclones and Severe Local Convective Storms .....	103
3.2. Cyclone Case Studies .....	107
3.3. The Sundarbans: A Region of Particular Vulnerability .....	110
3.4. Disaster Preparation and Response .....	110
3.5. Critical Evaluation of Current Tropical and Severe Local Convective Storm Forecasting .....	115
3.6. Use of Extended Probabilistic Cyclone System in the Bay of Bengal .....	117
3.7. Bay of Bengal Tropical Cyclones and Climate Change .....	118
3.8. Conclusions and Recommendations .....	119
References .....	122

## **Annex 4: Disaster Risk Management for Addressing Immediate Needs**

Abstract .....	125
4.1 Introduction: Adaptation and Climate Change in India's Sundarbans .....	125
4.2 Risk Management, Climate Change, and Adaptation .....	126
4.3 Hazards: Cyclones, Sea Level Rise, Flooding, and Salinization .....	127
4.4 Embankments: Part of the Solution or Part of the Problem? .....	132
4.5 Modern Prescripts of Disaster Risk Management: Implications for Adaptation .....	132
4.6 Current Approach to Disaster Risk Management in the Sundarbans .....	134
4.7 Some Alternatives: A General Overview of Possibilities .....	135
4.8 Building Resilience through Estuary Management: Recommendations .....	136
4.9 Building Resilience through Disaster Risk Management: Recommendations .....	138
4.10 Summary .....	138
References .....	139

## **Annex 5: Management Practices in Addressing Sea-level Rise, Floods, and Erosion**

Abstract .....	141
5.1 Introduction .....	141
5.2 Sundarbans Embankments .....	142
5.3 Sundarbans Estuaries: Tides and Channels .....	143
5.4 Sundarbans Estuaries: Impact of Sea Level Rise .....	144
5.5 Embankment Realignment: A Modeling Approach .....	146
5.6 Results .....	148
5.7 Discussion .....	149
5.8 Conclusions .....	153
References .....	154

## **Annex 6: Policies and Programs in the Sundarbans**

Abstract .....	157
6.1 Introduction .....	157
6.2 Background on Public Service Delivery: Local Institutions .....	160
6.3 Analysis of Key Current Programs in the Sundarbans .....	161
6.4 Moving Away from Business As Usual: Institutional Strengthening .....	169
6.5 Conclusion and Recommendations .....	170
References .....	171

## **Annex 7: Environmental Risks and Measures to Reduce Their Costs**

Abstract .....	173
7.1 Introduction .....	173
7.2 Cost of Health Effects of Inadequate Water Supply, Sanitation, and Hygiene, and Household Air Pollution .....	173
7.3 Environmental Health: Benefit–Cost Assessment of Select Interventions .....	176
7.4 Cost of Environmental Degradation .....	179
7.5 Natural Resources: Benefit–Cost Assessment of Development and Conservation Alternatives .....	181
7.6 Conclusion and Recommendations .....	183
References .....	184

## **Annex 8: Spatially Blind Policies to Promote Human Development**

Abstract .....	187
8.1 Introduction: Human Development .....	187
8.2 Education .....	187
8.3 Health .....	190
8.4 Recommendations on Improving Human Development .....	192
8.5 Summary and Conclusion .....	195
References .....	195

## **Annex 9: Enhancing Livelihood Opportunities**

Abstract .....	197
9.1 Introduction .....	197
9.2 Agriculture .....	197
9.3 Fisheries and Aquaculture .....	200
9.4 Forestry .....	202
9.5 Tourism .....	204
9.6 Livelihood Opportunities in Stable Zone .....	207
9.7 Conclusions .....	207
References .....	208

## **Annex 10: Spatial Transformation and Increased Economic Growth Opportunities**

Abstract .....	211
10.1 Introduction .....	211
10.2 Current Patterns of Spatial Transformation in the Sundarbans .....	211
10.3 Linking Residents to Economic Opportunities in Urban Spaces .....	216
10.4 Managing Urban Spaces to Promote Human Development .....	218
10.5 Conclusion .....	219
References .....	219

## **Annex 11: Spatially-based Approach to Infrastructural Development in the Sundarbans**

Abstract .....	221
11.1 Introduction .....	221
11.2 Transportation .....	221
11.3 Energy .....	224
11.4 Water Supply .....	228
11.5 Sanitation .....	230
11.6 Conclusions .....	232
References .....	233

## **Annex 12: Regulatory Instruments and New Market-based Incentive Mechanisms to Preserve Biodiversity**

Abstract .....	235
12.1 Introduction .....	235
12.2 Current Status and Trends in Biodiversity .....	236
12.3 Natural and Anthropogenic Factors Contributing to Biodiversity Loss .....	237
12.4 Management Strategies and Recommendations .....	241
12.5 Conclusion .....	246
References .....	253



## Annex 13: Institutional Approaches for Addressing Priority Challenges in the Sundarbans

Abstract .....	255
13.1 Introduction .....	255
13.2 Background .....	255
13.3 Current Institutional Framework of the Sundarbans .....	256
13.4 Recommendations to Strengthen the Institutional Framework of the Sundarbans .....	266
13.5 Conclusions .....	268
References .....	269

## List of Figures

Figure E.1	Map of Sundarbans Showing Approximate Zone Outer Boundaries .....	3
Figure E.2	Sundarbans: Pillars to Build Resilience and Adaptive Capacity .....	7
Figure 1.1	Sundarbans Region of India and Bangladesh .....	14
Figure 1.2	Percentage of People Living in Poverty in the Sundarbans .....	15
Figure 1.3	Costs of Environmental Degradation and Damage in the Sundarbans .....	16
Figure 1.4	Rice Production and Consumption Scenarios in the Sundarbans Compared to Business as Usual .....	17
Figure 3.1	Cyclone Aila Path in 2009 .....	29
Figure 4.1	Visitor Travel Interest in the Sundarbans .....	36
Figure 4.2	Cropping Intensity in the Sundarbans .....	37
Figure 4.3	Total Forest Cover Changes in the Indian Sundarbans .....	38
Figure 4.4	Incidence of Diarrhea in the Sundarbans .....	41
Figure 4.5	Annual Cost of Health Effects (Percentage of GDP, 2007–08) .....	43
Figure 6.1	Overlap in Functioning between State Government Departments .....	60
Figure A1.1.	Percentage Change in Land Use of Three Sundarbans Districts (Khulna and Bakarganj, Bangladesh; 24 Parganas, including Calcutta, India), 1880–1950 .....	81
Figure A1.2.	Sundarbans Districts and Blocks, West Bengal, India (2011) .....	84
Figure A3.1.	Tropical Weather Events Considered in Report: Cyclone and Severe Convective System .....	104
Figure A3.2.	Frequency of Bay of Bengal Region Cyclones and Severe Convective Storms by Month, 1971–2010 .....	106
Figure A3.3.	JTWC Tracking of Cyclone Sidr and Cyclone Nargis .....	116
Figure A3.4.	Probability Forecasts for Cyclone Sidr .....	117
Figure A3.5.	Probability Forecasts for Cyclone Nargis .....	118
Figure A3.6.	Trends in Intensity of Tropical Cyclones in North Indian Ocean .....	119
Figure A4.1.	People at High Risk in Different Indian States .....	127
Figure A5.1.	The Indian Sundarbans .....	142
Figure A5.2.	Tidal Curves for the Saptamukhi Estuary .....	143
Figure A5.3.	Channel Cross-Sections from the Head and Mouth of Kalchara Channel, Saptamukhi Estuary (Vertical Exaggeration x10) .....	144
Figure A5.4.	Mean Depth and Hydraulic Radius Variation with Distance Upstream, Kalchara Channel .....	144
Figure A5.5.	Comparison between Cross-Sections from an Embanked Channel (Kalchara Channel, Saptamukhi Estuary) and an Unembanked Channel (Gosaba Estuary) (Vertical Exaggeration x10) .....	145
Figure A5.6.	Study Area Showing Estuaries Referred to in Text .....	147
Figure A5.7.	Study Area Showing Channels of Saptamukhi Estuary .....	147
Figure A5.8.	Comparison of Observed and Predicted Channel Mean Depths .....	148
Figure A5.9.	Comparison of Observed and Predicted Channel Width .....	148

Figure A5.10. Comparison of Observed and Predicted Channel Cross-Section Areas with 95 Percent Confidence Limits (Dashed Lines) Superimposed .....	148
Figure A5.11. Existing Average Width of Estuarine Channels Compared to Predicted Equilibrium Values for Zero Sea Level Rise .....	149
Figure A5.12. Response to 1 m Sea Level Rise Compared to Equilibrium Width .....	149
Figure A5.13. Comparison between Existing Channel Widths and Predicted Width after 1 m Rise in Sea Level .....	149
Figure A5.14. Changes in Mangrove, Intertidal Mud Flat, and Low Water Surface Areas in 1968, 1989, and 2006 .....	151
Figure A5.15. Changes in Estuary Water Surface Area at High Tide and Mangrove Area in 1968, 1989, and 2006 .....	151
Figure A5.16. Predicted Compared to Observed Channel Widths for Banstala Channel, Saptamukhi Estuary .....	151
Figure A5.17. Predicted Compared to Observed Channel Widths for Kalchara Channel, Saptamukhi Estuary .....	151
Figure A5.18. Areas of Aquaculture Ponds (Shaded) Mapped from Satellite Imagery (2004) .....	152
Figure A7.1. Annual Cases of Mortality and Years of Life Lost from Illness Due to Major Environmental Health Risks in the Sundarbans, 2008 .....	174
Figure A7.2. Annual Cost of Health Effects (Billions of INR and Percentage of GDP, 2007-08) .....	174
Figure A7.3. Benefit–Cost Ratios of Household Air Pollution Control Interventions .....	177
Figure A7.4. Benefit–Cost Ratios of Household Water Supply, Sanitation, and Hygiene Interventions .....	177
Figure A7.5. Annual Cost of Environmental Damage (Million INR per Year) .....	180
Figure A7.6. Share of Damage Cost by Environmental Category .....	181
Figure A7.7. Benefit–Cost Ratios of Interventions .....	182
Figure A7.8. Estimated Annual Benefits per Hectare of Mangroves .....	182
Figure A8.1. Highest Level of Education (Sundarbans Blocks) Completed by Those Aged 22 or Older Who Attended School .....	188
Figure A8.2. Reasons for Never Attending School or Not Attending in Current Academic Year (2010–11) .....	188
Figure A8.3. Diarrheal Disease Prevalence in Sundarbans .....	191
Figure A8.4. Sources of Medical Care for Sundarbans Residents .....	192
Figure A9.1. Cropping Intensity in the Sundarbans .....	198
Figure A9.2. Irrigation Intensity in the Sundarbans .....	198
Figure A9.3. Percentage of Irrigated Land in the Sundarbans compared to the 24 Parganas Districts .....	198
Figure A9.4. Paddy Yield in Sundarbans, 24 Parganas Districts, and State of West Bengal .....	199
Figure A9.5. Location of Traditional Inland Fishing Zones (Shaded Blue) .....	201
Figure A9.6. Current Tourism Sites in Sundarbans Tiger Reserve and National Park .....	204
Figure A9.7. Visitor Travel Interest in the Sundarbans .....	205
Figure A10.1. Occupation of Seasonal Migrant by Asset Quintile (1 = Poorest; 5 = Richest) .....	213
Figure A10.2. Primary Reason for Migration (%) .....	213
Figure A10.3. Destination of Seasonal Migrants .....	214
Figure A10.4. Population and Population Growth of Kolkata .....	217
Figure A11.1. National Highway NH-117 south of Kolkata .....	223
Figure A11.2. Location of Alternative Energy Systems in the Sundarbans .....	226
Figure A11.3. Electricity Demand (MU) Projections under Various Scenarios .....	227
Figure A11.4. Percentage of Households with Piped Water Supply in South 24 Parganas .....	229
Figure A11.5. Percentage of Households with Piped Water Supply in North 24 Parganas .....	229
Figure A11.6. Status of Piped Rural Water Supply Schemes .....	231
Figure A11.7. Household Treatment of Drinking Water in the Sundarbans .....	232
Figure A12.1. Sundarbans Species Threat Matrix .....	236
Figure A12.2. Diversity of Mangroves in Indian Sundarbans and Other Locations .....	237
Figure A12.3. Total Forest Cover Changes in the Indian Sundarbans .....	238
Figure A12.4. CPUE of Winter Migratory Bag Net Fisheries 1984–2003 .....	239

Figure A13.1. Main Categories of Reserve Areas in the Sundarbans .....	257
Figure A13.2. Actual Expenditure of State Departments in 2009–10 (INR Million) .....	264
Figure A13.3. Overlaps in Functioning between State Government Departments .....	265
Figure A13.4. Socioeconomic Indicators for North and South 24 Parganas and Sundarbans .....	267

## List of Tables

Table E.1	Sundarbans at a Glance: Current Conditions .....	2
Table E.2	Sundarbans at a Glance: Summary of Identified Priority Interventions .....	6
Table E.3	Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans .....	10
Table 1.1	Selected Programs and Policies in the Sundarbans .....	18
Table 2.1	Analysis of Alternative Approaches in the Sundarbans .....	22
Table 3.1	Pillar 1: Options for Vulnerability Reduction .....	31
Table 4.1	Estimated Annual Child Mortality from Inadequate Water Supply, Sanitation, and Hygiene (WSH) in the Sundarbans, 2008 .....	42
Table 4.2	Summary of Benefit–Cost Ratios of Environmental Health Interventions .....	43
Table 4.3	Pillar 2: Options for Poverty Reduction .....	46
Table 5.1	Funding Details of Key Schemes Implemented in the Sundarbans .....	50
Table 5.2	Pillar 3: Options for Biodiversity Conservation .....	56
Table 6.1	Role of State-Level Agencies in the Sundarbans .....	58
Table 6.2	Pillar 4: Options for Institutional Change .....	65
Table 7.1	Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans .....	72
Table A1.1.	Changes in Land Use of Three Sundarbans Districts (Khulna and Bakarganj, Bangladesh; 24 Parganas, including Calcutta, India) 1880–1950 (area in km <sup>2</sup> , population in '000) .....	81
Table A1.2.	Comparative Population Figures for India, West Bengal, North 24 Parganas, South 24 Parganas, and the Sundarbans Blocks .....	84
Table A1.3.	Proneness of Gram Sansads in the Sundarbans Districts to Floods and Cyclones .....	85
Table A1.4.	Source of Getting Information about the Adverse Event (Cyclone Aila) .....	85
Table A1.5.	Prices of Items before and within Three Months of a Flood .....	86
Table A1.6.	Percentage of Households Suffering from Saline Water in Fields .....	87
Table A1.7.	Major Sources of Income for Households in Different Seasons .....	88
Table A1.8.	Migration of Household Members (Percentage) .....	89
Table A1.9.	Willingness to Send Children Away for Education .....	90
Table A1.10.	Frequency of Receiving Government Assistance through Established Schemes .....	90
Table A2.1.	Background Papers Completed under the NLTA .....	93
Table A2.2.	Sources of Information .....	97
Table A3.1.	Tropical Cyclones Ranked by Number of Fatalities .....	104
Table A3.2.	Impacts of Storms and Cyclones in Bay of Bengal 1971–2009 .....	105
Table A3.3.	Occurrence of Tropical Cyclones and Mesoscale Convective Clusters in Bay of Bengal Region by Month, 1971–2010 .....	105
Table A3.4.	Impact by Country of Tropical Cyclones and Mesoscale Convective Clusters, 1971–2009 .....	107
Table A4.1.	Summary of Hazards in the Sundarbans .....	126
Table A4.2.	Historical Records of Severe Cyclones Forming in the Bay of Bengal and Making Landfall at the Eastern Coast of India, 1970–1996 and 2009 .....	128
Table A4.3.	Damage Details in West Bengal as of June 1, 2009 .....	131
Table A5.1.	Contribution of Aquaculture Ponds to Tidal Prism in the Bhanga (Raimangal), Bidya, and Matla estuaries .....	153
Table A6.1.	Selected Programs and Policies in the Sundarbans .....	159

Table A6.2.	Impact of Disaster Risk Management Schemes .....	162
Table A6.3.	Impacts of Livelihood Development Schemes .....	164
Table A6.4.	Impacts of Education Schemes .....	165
Table A6.5.	Impacts of Health Schemes .....	166
Table A6.6.	Impacts of Water Supply and Sanitation Schemes .....	168
Table A6.7.	Impacts of Transportation Schemes .....	168
Table A6.8.	Impacts of Energy Schemes .....	169
Table A6.9.	Impacts of Biodiversity Conservation Schemes .....	170
Table A7.1.	Benefit–Cost Ratios of Interventions to Control Household Air Pollution from Solid Cooking Fuels .....	178
Table A7.2.	Benefit–Cost Ratios of Household Water Supply, Sanitation, and Hygiene Interventions .....	180
Table A7.3.	Annual Cost of Environmental Damage: Low and High Estimates, Million INR per Year .....	181
Table A8.1.	Willingness to Send School-Age Children outside the Sundarbans for Education .....	189
Table A8.2.	Willingness to Participate in Technical Institute or Vocational Training outside Sundarbans .....	190
Table A8.3.	Estimated Annual Child Mortality from Inadequate WSH in Sundarbans, 2008 .....	191
Table A9.1.	Fish Production in West Bengal, by District, 2005–07 .....	200
Table A9.2.	Mangrove Plantations .....	203
Table A10.1.	Comparative Population Figures for India, West Bengal, North and South 24 Parganas, and Sundarbans Blocks .....	212
Table A10.2.	Migration of Household Members (%) .....	212
Table A10.3.	Migration Patterns by Season and Asset Quintile (%) .....	213
Table A10.4.	Migration Rates to Urban and Rural Area by Asset Quintile (%) .....	214
Table A10.5.	Education Levels of Nonresident Migrants by Asset Quintile (%) .....	215
Table A10.6.	Willingness of Households to Send Children to Kolkata or Other Parts of West Bengal for Educational Purposes (%) .....	216
Table A11.1.	Block Headquarters with Long Distances to Nearest Railway Station .....	222
Table A11.2.	Household Water Supply in the Sundarbans .....	228
Table A12.1.	Salinity Trends in the Sundarbans .....	239
Table A12.2.	Toxic Metals Affecting Various Species in the Sundarbans .....	240
Table A12.3.	Funding Details of Key Schemes Implemented in the Sundarbans .....	242
Table A12.4.	Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans .....	247
Table A13.1.	Key Functions of the Ministry of Environment and Forests .....	262
Table A13.2.	Role of State-level Agencies in the Sundarbans .....	262
Table A13.3.	Recommendations for Restructuring of Institutional Arrangements .....	269

## List of Boxes

Box 5.1	Government Schemes Implemented for Biodiversity Protection in the Sundarbans .....	50
Box A1.1.	Livelihoods in the Sundarbans .....	87
Box A1.2.	Migration Patterns in the Sundarbans .....	89
Box A1.3.	Financial Dimensions of Migration .....	89
Box A6.1.	Factors Inducing Negative Behavior and Threatening Biodiversity Conservation .....	158
Box A12.1.	Government Schemes Implemented for Biodiversity Protection in the Sundarbans .....	242

# ABBREVIATIONS AND ACRONYMS

<b>APL</b>	Above the Poverty Line	<b>m<sup>3</sup></b>	cubic meter
<b>APT</b>	Automatic Picture Transmission	<b>mg/L</b>	milligrams per liter
<b>BAU</b>	Business-As-Usual	<b>mm</b>	millimeter
<b>BPL</b>	Below the Poverty Line	<b>MW</b>	megawatt
<b>CFAN</b>	Climate Forecast Applications Network	<b>LPG</b>	liquid petroleum gas
<b>cm</b>	centimeter	<b>MCC</b>	mesoscale convective cluster
<b>CO<sub>2</sub></b>	carbon dioxide	<b>MGNREGA</b>	Mahatma Gandhi National Rural Employment Guarantee Act
<b>COI</b>	cost of illness	<b>MoEF</b>	Ministry of Environment and Forests
<b>CPUE</b>	Catch Per Unit Effort	<b>mm</b>	millimeter
<b>CRZ</b>	Coastal Regulation Zone	<b>NAPCC</b>	National Action Plan on Climate Change
<b>CSS-PT</b>	Centrally Sponsored Scheme of Project Tiger	<b>NFHS</b>	National Family Health Survey
<b>CWRA</b>	Central Wetland Regulatory Authority	<b>NGO</b>	nongovernmental organization
<b>DALY</b>	Disability-adjusted life year	<b>NLTA</b>	Non-Lending Technical Assistance
<b>DDG</b>	decentralized distributed generation	<b>OBC</b>	other backward classes
<b>DLHS</b>	District Level Household and Facility Survey	<b>PES</b>	Payment for Ecosystem Services
<b>DMH</b>	Department of Meteorology and Hydrology	<b>PHED</b>	Public Health Engineering Department
<b>DRM</b>	Disaster Risk Management	<b>ppt</b>	parts per thousand
<b>DRR</b>	Disaster Risk Reduction	<b>REDD</b>	Reducing Emissions from Deforestation and forest Degradation
<b>DSA</b>	Department of Sundarban Affairs	<b>REDD-plus</b>	Enhanced version of REDD
<b>ECMWF</b>	European Centre for Medium-Range Weather Forecasts	<b>RHS</b>	Rural Health Survey
<b>GDP</b>	gross domestic product	<b>RIMES</b>	Regional Integrated Multi-Hazard Early Warning System
<b>GoI</b>	Government of India	<b>RO</b>	reverse osmosis
<b>GoWB</b>	Government of West Bengal	<b>RSMC</b>	Regional Specialized Meteorological Center
<b>GP</b>	Gram Panchayat	<b>SC</b>	Scheduled Caste
<b>GPS</b>	Global Positioning System	<b>SDB</b>	Sundarban Development Board
<b>ha</b>	hectare	<b>ST</b>	Scheduled Tribe
<b>hPa</b>	hectopascal	<b>TC</b>	tropical cyclone
<b>HCA</b>	human capital approach	<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>HCV</b>	human capital value	<b>UNESCO</b>	United Nations Educational, Scientific and Cultural Organization
<b>ICT</b>	information and communication technology	<b>UNISDR</b>	United Nations Office for Disaster Risk Reduction
<b>IMD</b>	Indian Meteorological Department	<b>UN-REDD</b>	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
<b>IMRB</b>	<i>Indian Market Research Bureau</i>	<b>VarEPS</b>	Variable Ensemble Prediction System
<b>IPCC</b>	Intergovernmental Panel on Climate Change	<b>VSL</b>	value of a statistical life
<b>IT</b>	information technology	<b>WHO</b>	World Health Organization
<b>IUCN</b>	International Union for Conservation of Nature	<b>WMO</b>	World Meteorological Organization
<b>JTWC</b>	Joint Typhoon Warning Center	<b>WSH</b>	Water Supply, Sanitation, and Hygiene
<b>kg</b>	kilogram	<b>WTP</b>	Willingness to pay
<b>km</b>	kilometer		
<b>km<sup>2</sup></b>	square kilometer		
<b>kWh</b>	kilowatt hour		
<b>m</b>	meter		
<b>m<sup>2</sup></b>	square meter		







# EXECUTIVE SUMMARY



## The Sundarbans

The Sundarbans region is one of the richest ecosystems in the world. The region contains arguably the world's largest remaining area of mangroves, and is known for its exceptional biodiversity, including numerous threatened species such as the emblematic Royal Bengal tiger and several species of river dolphin. About 40 percent of the nearly 10,000 square kilometers (km<sup>2</sup>) of the Sundarbans forest lies within West Bengal; the rest is in Bangladesh. The forests of the Sundarbans form a powerful natural barrier that protects Kolkata Metropolitan Region's roughly 14 million inhabitants and other human settlements from cyclones, rising sea tides, and other adverse natural events that otherwise would have taken a massive toll on human life and property.

Recognizing the importance and uniqueness of the Sundarbans, the United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the Indian portion of the forest a World Heritage Site in 1987, and the UNESCO Man and the Biosphere Program has included the Sundarbans Biosphere Reserve in the Global Network of Island and Coastal Biosphere Reserves Contributing to Action on Climate Change and Sustainable Development.

While the Sundarbans region is celebrated for its ecological attributes, it is a difficult place to live in. The inhabited portions of India's Sundarbans are characterized by severe poverty, which both contributes to and arises from the vulnerability of the population to a growing range of natural hazards. Resilience is characterized by a capacity to adapt to changing conditions and persistent stresses by responding effectively. However, the resilience of those residing in the Sundarbans has been undermined by a long series of persistent pressures. Sea level rise, salinization of soil and water, cyclonic storms and flooding have combined over the past century to render this one of the most hazardous areas in the Indian subcontinent.

Ironically, the embankment system initially constructed to protect the inhabitants has itself become a liability: it provides a false sense

of security while being increasingly prone to erosion and failure. Natural stresses have been recently compounded by human-induced stresses, which include reductions in fresh-water flows to the delta and an expansion in tidal water aquaculture. The predicted changes associated with global climate change will provide no respite: increased intensity of cyclonic storms coupled with continuing sea level rise will further increase hazards to the local population.

Many other coastal communities worldwide face development challenges that test the adaptive capacity of individuals, their social networks, the biophysical systems on which their livelihoods depend, and the institutions responsible for addressing these challenges. In the face of growing populations and declining carrying capacity of natural habitats, planning exercises for such communities are further confounded by uncertain future impacts of current unsustainable practices coupled with phenomena such as biodiversity loss and climate change. While there are many coastal communities facing such challenges, the Indian Sundarbans in the state of West Bengal provides an extreme case.

Over 4.4<sup>1</sup> million people that make this region their home find themselves geographically and socioeconomically placed between two extraordinarily different contexts: the economic growth opportunities in nearby Kolkata, one of the largest conurbations of Asia, and the exceptional ecological values of one of the richest and most unique mangrove ecosystems in the world.

The living standards of residents of the Sundarbans are dismal. The findings of a household survey conducted as part of this Non-Lending Technical Assistance (NLTA) indicate that, of a typical group of a thousand residents, 190 get only one meal a day, for 60 of whom it would be a substandard meal. Of those thousand, 510 (mostly children) suffer from some form of malnutrition. If the sample came from the "richest" administrative block of the region, 310 of those thousand would still be below the poverty line; a sample in the poorest parts of the region would see 650 of those thousand live below the poverty line. In May 2009, 250 of a typical thousand residents would have been living close to an embankment that failed in the wake of Cyclone Aila, and on land on which

<sup>1</sup>Government of India Census 2011.

households, livestock, and human lives were lost. Of these 250, only a dozen would have had access to a cyclone shelter. Flooding and salinity intrusion contribute to lower land fertility and higher diarrhea incidence to this day. This difficult land of risk and hardship can be termed the “transition zone” – the area between the peri- and semi-urban parts of the Sundarbans on the mainland (the “stable zone”) and the Sundarbans Reserve Forest (See Table E.1 and Figure E.1).

## The Study Beneficiaries

The work contained in this volume addresses, first and foremost, the immediate and long-term welfare of the inhabitants of the Sundarbans, with a particular emphasis on the transition zone. The current plight of populations residing in the transition zone is characterized by poverty in all its dimensions: poor health and education conditions, limited livelihood opportunities, and high risks of persistent hazards that threaten people’s gains. Their best and safest prospects for improving this plight are outside this zone and further afield; some residents, in fact, move back and forth to work at menial jobs outside the transition zone (often in and around Kolkata) but for various reasons they will still call the Sundarbans their home. Others take their chances in the Sundarbans Reserve Forest (here termed the “core zone”<sup>2</sup>), illegally gathering forest products while risking attacks from tigers and other animals.

An overarching goal of this NLTA is to identify options to help build: (a) social resilience among individuals, communities, and local organizations; and (b) the resilience of the ecosystem. For the former, the focus is on equipping residents and institutions in the

region with the capacity to effectively deal with poverty and adverse natural events. Recommended measures to address these difficulties include increasing livelihood opportunities and lifting people out of poverty by enhancing human capital; creating cyclone shelters to protect residents from storms; increasing emphasis on preventive healthcare to reduce the high levels of illnesses and diseases, such as diarrhea; and enhancing the capacity of institutions to tackle problems in the Sundarbans. Measures are also recommended to enhance ecosystem resilience,<sup>4</sup> a term that refers to the capacity of an ecosystem to function effectively without collapsing into a qualitatively different state. In other words, a resilient ecosystem is one that can withstand anthropogenic and natural shocks. Measures to promote ecosystem resilience include allowing mangroves to regenerate naturally in critical areas where they were previously destroyed by storms in order to reinforce their protective and productive functions; enforcing bans on illegal wood harvesting; and implementing modern aquaculture practices to prevent the further decline of aquatic species, which have been degraded by overexploitation.

The situation of the Sundarbans begs the question: why would people remain in such a hostile living environment? It might be expected that people would choose to leave such challenging areas permanently. However, here, people remain attached to their homeland and find themselves with limited abilities to pursue more attractive options. Only by improving their mobility through education, better health, and increased incomes would they have the personal capacity to pursue better and more promising opportunities in urban areas. In the Sundarbans, the situation is made worse by implicit or explicit actions – in the form of perverse incentives and maladaptations – that retain people in the area

**Table E.1: Sundarbans at a Glance: Current Conditions**

Indicator	Stable zone	Transition zone	Core zone
Land area (km <sup>2</sup> )	2,500	1,700	4,260
Population (est. 2011)	~2.85 million	~1.54 million	0 permanent
Embankments	1,500 kilometer	2,000 kilometer	0
Cyclone shelter access	<5%	<2%	0
Dominant land use	Peri-urban/rural agriculture	Rural agriculture	Protected mangroveforest
Community development blocks (includes overlaps, total = 19)	13	9	6
Villages (unique Census codes)	706	358	22 (abandoned)
Literacy rate (2001) <sup>3</sup>	51–59%		n.a.
Population with safe water access	~850,000 (30%)	~350,000 (23%)	0
Energy	17% of households have grid access		n.a.
Average annual income	~US\$180/capita		n.a.

<sup>2</sup>In the context of this report, the “core zone” refers to *all* legally protected areas of the Sundarbans – the National Park, Wildlife Sanctuaries, and the Reserve Forest that form a contiguous area without human habitations.

<sup>3</sup>Government of India Census 2001.

<sup>4</sup>Definition of ecosystem resilience derived from the Resilience Alliance: <http://www.resalliance.org/index.php/resilience>.

**Figure E.1: Map of Sundarbans Showing Approximate Zone Outer Boundaries<sup>5</sup>**



**Stable zone boundary**

**Transition zone boundary**

**Core zone boundary**

## Notes:

1. The stable zone depicted here also includes some area outside the Sundarbans community development blocks.

2. A “high-risk” management zone is also defined by local authorities involved in protected area management; it includes the entire core zone and extends partially into the transition zone to varying distances depending on the extent of human–wildlife conflicts or nonsustainable forest use.

3. All figures estimated through NLTA are based on best available information for 2011 (unless otherwise indicated).

4. Not all base information is available in formats commensurate with stable/transition/core zone boundaries.

<sup>5</sup>For the purposes of this study, the World Bank proposed a designation of core, transition, and stable zones different from the definitions for the core area, buffer area and transition area of the Sundarban Biosphere Reserve adopted by the Ministry of Environment and Forests and the GoWB. The criteria (that is, geographical limits) used for the designation of the core, transition and stable zones of this NLTA differ from the criteria used in MoEF designations. In the context of this report, the “core zone”, the “transition zone” and the “stable zone” refer to the definitions below:

**Core zone:** In the context of this report, the “core zone” comprises all the legally protected areas of the Sundarbans (the National Park, the Wildlife Sanctuaries, and the Reserve Forests) – areas which are contiguous without human habitations.

**Transition zone:** In the context of this report, it is the area in the

Sundarbans surrounding the forest and consisting primarily of rural communities with limited infrastructure and high levels of poverty. This area is sandwiched between the core and stable zones (in the context of this report) and comprises areas that are along major tidal rivers.

**Stable zone:** In the context of this report, it is the densely populated areas far from the Sundarbans Reserve Forest. Further, this is the zone where the delta is relatively stable and further away from the mouths and tidal river courses. Any ongoing geomorphological processes are mainly involved with sedimentation and accretion (as opposed to erosion), enhancing the stable nature of the zone. Most of this land is attached to the mainland and contains the peri- and semi-urban environments closer (and relatively well connected) to Kolkata. The stable zone contains established settlements, such as Bakkhali, Canning, Jaynagar-Majilpur, Kakdwip, Minakhan, Namkhana, Sagar Island, and Tengrabichi.



without contributing meaningfully to their improved welfare.<sup>6</sup> Perverse incentives are illustrated by seemingly small incentives that encourage people to remain in poverty. Maladaptations are illustrated by uncontrolled aquaculture development schemes that contribute to erosion and instability of many protective embankments and encourage further ecosystem degradation as a result of unsustainable prawn seedling collection practices.

## Key Findings

When first conceived, this NLTA was framed in the language of climate change adaptation and biodiversity conservation, with a view to identifying the potential scenarios to support socioeconomic development under future uncertain conditions. There was an unstated assumption that economic development could proceed largely following conventional processes that improve infrastructure, social welfare, and incomes while having ample time to adapt to the vagaries of a real but slowly moving increase in climate change hazards. But after three years of research through 21 studies, the picture that emerged was quite different, as exemplified by the following lessons.

**Lesson 1.** The highest priority is not to address future uncertain impacts, but the very certain impacts of past events and current conditions that keep people trapped in poverty. Findings from this NLTA reveal that the cost of environmental damage and health effects is as high as 10 percent of the Sundarban's gross domestic

product (GDP) in 2009.<sup>7</sup> Many socioeconomic and biophysical tipping points have already been exceeded; others rapidly approach. Compromised embankment systems cause irreparable loss of assets and livelihoods.<sup>8</sup> Hurricane Aila in 2009 damaged nearly 1,000 kilometers (km) of embankments, removing the only protection available to many people along the coast.<sup>9</sup> Increases in salinity due to freshwater reduction from the upstream and sea level rise continue to reduce the availability of human staples such as safe drinking water. In some areas, salinity has increased beyond the safe threshold for agriculture.<sup>10</sup> In the Sundarbans blocks of South 24 Parganas, 87 percent of the population lacks food security.<sup>11</sup> Declines in these human staples are evidence of systems approaching thresholds. Moreover, findings from the NLTA reveal that nearly 30 percent of households have a family member migrate in search of work,<sup>12</sup> a figure indicative of how economically vulnerable the region is. Regardless of the conditions that might exist in 2020 or 2050, today's realities must be addressed first.

**Lesson 2.** The role of future climate change adaptation is less urgent in comparison to current challenges, but climate change casts a long shadow over ongoing degradation of the resource base. Flooding from past sea level rise and land subsidence as well as increasing cyclonic storm intensity call for enhancement of the resilience of the biophysical system, especially the resilience of the mangrove system, given its important protective and productive functions. A silent threat is the real but poorly understood process of salinization which is a result of anthropogenic and geomorphological<sup>13</sup> factors as well as natural events including sea

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<sup>6</sup>The state and local governments that govern the Sundarbans in West Bengal are heavily dependent on the central government for most of their development activities. Key central schemes implemented in the Sundarbans in India include: the Mahatma Gandhi National Rural Employment Guarantee Scheme; Pradhan Mantri Gram Sadak Yojana (program for providing road connectivity in rural areas); Indira Awas Yojana (program for providing rural housing to the poor); National Rural Health Mission, Accelerated Irrigation Benefits Programme, Rajiv Gandhi Grameen Vidhyautikaran Yojana (program for providing access to electricity to rural households); Mid-Day Meals Program, and the National Social Assistance Program.

<sup>7</sup>See Annex 7 "Environmental Risks and Measures to Reduce their Costs" for more details.

<sup>8</sup>In the Sundarbans, of a total of 3,500 km of embankments, 800 km is vulnerable to breaching as a result of high intensity weather events. The embankments developed in the mid-19th century have already been degraded at various locations. Source: Chand, B.K., R.K. Trivedi, and S.K. Dubey. 2012. Climate Change in Sundarbans and Adaptation Strategy for Resilient Aquaculture. In: *CIFRI Compendium on Sundarbans, Retrospect and Prospects*. CIFRI, Barrackpore, Kolkata, India.

<sup>9</sup>(i) Annual Report 2009-10, page 15, Ministry of Water Resources, GoI; and (ii) GoWB, Racing Against Time to Mend Embankments by Rajdeep Datta Roy and Romita Datta in *Live Mint*, New Delhi, June 7, 2009 (<http://www.livemint.com/Politics/YfNZNT1fKs6vJTKTozNQL/West-Bengal-govt-racing-against-time-to-mend-embankments.html>).

<sup>10</sup>For rice, the acceptable limit of salinity is 4-6 parts per thousand (ppt). Source: Center for Science and Environment. 2012. Living with Changing Climate: Impact, Vulnerability and Adaptation Challenges in Indian Sundarbans. New Delhi, India. The northern part, which is considered a low-saline region, experiences salinity of up to 8 ppt, while the southern part experiences 8 to 20 ppt. Source: Debnath, A. 2013. Condition of Agricultural Productivity of Gosaba C.D. Block, South 24 Parganas, West Bengal, India after Severe Cyclone Aila. *International Journal of Scientific and Research Publications*, Volume 3, Issue 7, July 2013. ISSN 2250-3153.

<sup>11</sup>Center for Science and Environment. 2012.

<sup>12</sup>The Rural Household Survey (RHS) of 2005-09 also finds that there is substantial out-migration from the Sundarbans, on a permanent, seasonal, or temporary basis. Over 25 percent of the principal earners of individual families in the RHS out-migrated on a temporary basis in search of work and over 24 percent did so on a seasonal basis. Temporary migration is the out-migration of a single male (or sometimes female) member of a family, for a few days up to a year, to a particular location to work, save and to return home for a while until such savings run out.

<sup>13</sup>The Periodic Review 2011 of the Sundarbans Biosphere Reserve submitted to the Man and the Biosphere Programme of UNESCO mentioned the following: "During the 16<sup>th</sup> century, the flow of the Ganga shifted almost Eastwards into river Padma, as a result of tectonic plate movement towards the East. This has resulted in cutting off the Matla and Bidyadharu river systems from the sweet water source and is presently fed by the backwater of the sea and thereby salinity of the Indian part of Sundarbans is more when compared to the Bangladesh part. The higher salinity might have affected the mangrove diversity in the Indian SBR."

level rise and climate change; salinity kills crops and adversely impacts people, soil, water supplies, and biodiversity. In some areas, salinity has increased beyond the safe threshold for agricultural production.<sup>14</sup> Nearly 70 percent of residents have no access to safe drinking water.<sup>15</sup> All of these are not tomorrow's problems; they are very present today.

**Lesson 3.** Blindly following a Business-As-Usual (BAU) development scenario will make matters worse because huge numbers of the residents of the Sundarbans will remain in harm's way. Moreover, increasing income or building extensive infrastructure throughout the region will attract more people to areas that are fundamentally in decline and hostile to human habitation. The current decennial population growth is about 17 percent.<sup>16</sup> Interventions in the region need to maintain a careful balance so that a lifeline is extended to those currently under threat while ensuring that others are not placed at risk by encouraging in-migration.

**Lesson 4.** The Sundarbans region is not homogenous geographically or socioeconomically. Opportunities exist in the stable zone that can potentially provide an important long-term magnet for the roughly 1.5 million people living in the more fragile transition zone. Efforts should focus on enabling or motivating those in the transition zone to take part in experiencing broader economic development away from the high-risk areas. It is expected that up to 250 km<sup>2</sup> of previously productive land in the transition zone will be lost in the coming five to 10 years due to erosion, cyclone impacts, and estuary changes.

**Lesson 5.** Institutions are not yet equipped to address these issues coherently and comprehensively. The state government currently implements a large number of centrally-sponsored schemes. However, most agencies work in silos and lack programs that take into account the specific characteristics of the Sundarbans. Without a fundamental shift in how government institutions and their various partners work together, the BAU scenario, with all of its many adverse effects, is unfortunately likely to prevail.

## Socioeconomic Development under Future Uncertain Conditions

This report provides a menu of policy options to address the uncertainty in the future and could contribute to improving overall social and ecosystem resilience. This document does not propose separable options arising from different development strategies but, rather, presents a menu of options that work well together as a comprehensive strategy. These interventions stand alone on their individual merits and represent best available practices.

The recommended measures address the most important necessary groundwork for long-term socioeconomic development and vulnerability reduction in the region. While there is great urgency attached to implementing some of the interventions (such as repairing embankments or meeting basic human needs), the pace of the overall strategy reflects a multigenerational time horizon. Table E.2 provides a summary of recommended interventions.

Even though the list of “things to do” seems extensive—for example, it includes items such as promoting sustainable ecotourism, introducing modernized environmentally sustainable aquaculture, and providing programs intended to target the poor social conditions of the most vulnerable parts of the population—an equally important part of this strategy is a list of “things not to do.” This list includes items such as encouraging mass tourism, building roads and bridges to connect islands, increasing or maintaining the existing wide-ranging agricultural subsidies, and installing large grid power networks in the area near the forest. In addition to “doing,” the strategy, at times, involves “undoing” the impacts of past unsustainable policy; institutional changes will play an important role in eliminating past unsustainable actions.

The organizing framework for this advice distinguishes among:

**Time frame.** Near-term priorities need to be addressed within 10 years with a view to achieving broader long-term goals over a period of 30–100 years.

**Spatial distinctions.** The analyses and discussion focus on three “zones”—stable, transition and core—but space is also used in a different sense: interventions that are distinguished as being spatially blind, spatially connective, and spatially targeted. Spatially blind interventions concern basic entitlements and needs regardless of where people reside in the Sundarbans. Spatially connective interventions remove barriers and address issues concerning access between the stable zone and urban areas. Spatially targeted interventions are reserved for strong economic development and growth interventions in the stable zone and strong conservation interventions that are unique to the core zone.

**Sectoral dimensions.** Much of the diagnostic analysis was conducted along conventional sectoral boundaries. Because of the institutional setting, many recommendations will also rely on a sectoral approach where possible. In a number of instances, the recommendations can be carried out by a single responsible sectoral organization (for example, energy concerns are assessed by energy specialists). However, some actions may require paired, cooperative initiatives between sectors (for example, irrigation and forestry agencies will need to work together for mangrove restoration near embankments). Finally, more complex problems will require innovative coordination mechanisms to bring actors together in productive ways.

<sup>14</sup>Center for Science and Environment. 2012.

<sup>15</sup>Center for Science and Environment. 2012.

<sup>16</sup>Government of India Census 2011.

## The Four Pillars

An appropriate strategy for responding to the challenges of the Sundarbans involves four pillars that, collectively, build the resilience of the socioeconomic and biophysical systems (Figure E.2). The pillars are each important to long-term sustainable development, and the order in which they are presented is not arbitrary. The first pillar (vulnerability reduction) responds to the needs for basic human survival, and the second pillar (poverty reduction) concerns the needs

for improving quality of life and livelihoods. The third pillar (biodiversity conservation) focuses on conserving biodiversity not as an end in itself but as a means for supporting livelihoods and the broader long-term ecosystem functions and services on which local populations depend, and from which all citizens of the state of West Bengal can benefit. Finally, the fourth pillar (institutional change) centers on the ways and means for institutions active in the Sundarbans to effectively implement the recommended actions.

**Table E.2: Sundarbans at a Glance: Summary of Identified Priority Interventions**

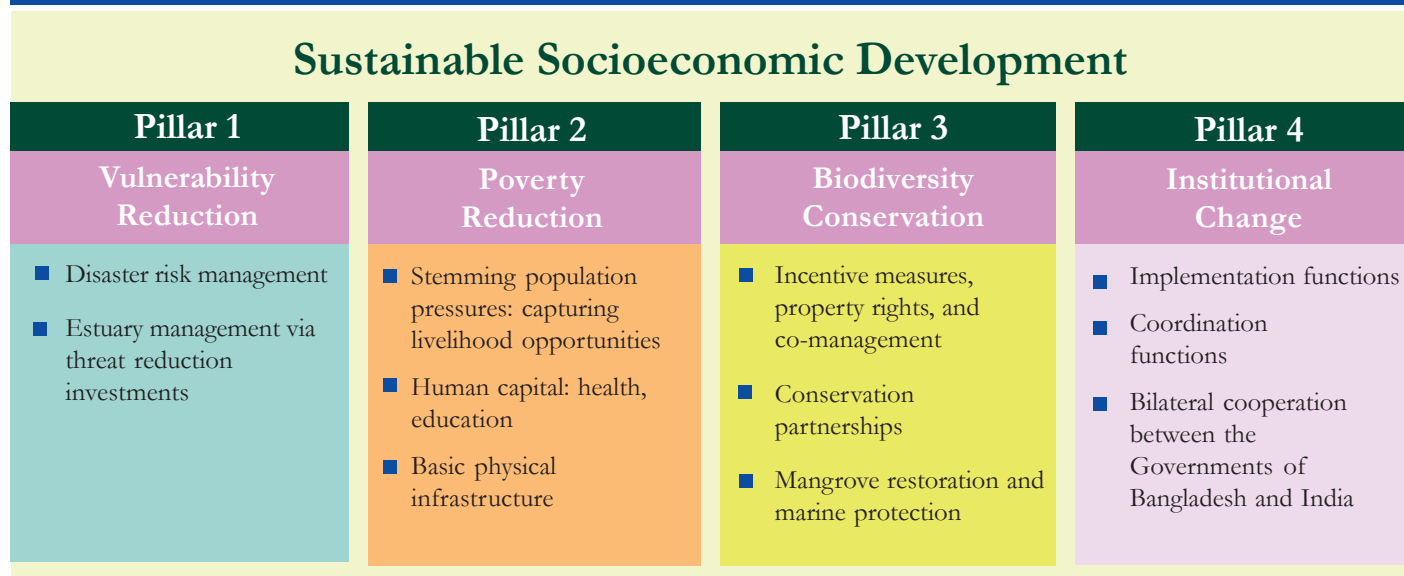
Pillar (VPBI)*: Intervention	Zone**			Time Scale** (years)		
	Stable	Trans	Core	0–10	10–30	30+
V: Embankment realignment/crest height to 5.25 meters	•	•		•	•	
V: Embankment crest height increase with sea level rise	•	•			•	•
V: Early warning system established	•	•		•		
V: Cyclone shelters	•	•		•	•	
V: Selective channel closures		•		•	•	
VB: Mangrove bioshield restoration	•	•		•	•	
VP: Risk awareness/communication	•	•		•	•	
VP: Establish transnational platform for early warning system	•	•		•	•	
VP: Desalination plant	•				•	•
P: Lifeline energy services (grid and renewable)	•	•		•	•	
P: Healthcare services and access	•	•	•	•	•	•
PI: Reform healthcare referral system		•		•	•	
P: Financial assistance for health, education, training		•		•	•	•
P: Road connectivity	•	•		•	•	
P: Clusters of development program including services, infrastructure and incentives for private investments	•			•	•	
P: Sustainable tourism development	•	•	•	•	•	•
P: Nontimber forest product production		•	•	•	•	•
P: Sustainable traditional agriculture	•	•				
PV: Modernize aquaculture: tidal water management	•	•		•	•	
PB: Modernize aquaculture: hatcheries	•	•		•	•	
B: Enforcement of prevention of poaching and cutting			•	•	•	•
B: Social forestry co-management		•	•	•	•	•
B: Capture of biodiversity values (REDD-plus, payment for ecosystem services)		•	•	•	•	•
B: Establishment of marine reserve		•	•	•	•	
BP: Establish transnational platform for biodiversity			•	•	•	
I: Focus DSA role in monitoring/evaluation	•	•	•	•	•	
I: Enable West Bengal Coastal Zone Management Authority	•	•	•	•	•	
I: Create Sundarbans Steering Committee	•	•	•	•	•	
I: Initiate paired cooperation between lead agencies		•	•	•	•	
I: Strengthen implementation capacity in all lead agencies	•	•	•	•	•	
I: Create research and development unit within the Sundarbans Steering Committee			•	•	•	

\* V=Vulnerability reduction; P=Poverty reduction; B=Biodiversity conservation; I=Institutional change.

\*\* Zone and time scale are at times represented as “partial fills” representing their spatial or temporal orientation (if any); for example, health services handling animal attacks would generally need to serve an area overlapping the core and transition zones. Similarly, a very urgent item that can be established relatively quickly (for example, early warning systems) may occur only in the early period of the 0–10 year time scale.



**Figure E.2: Sundarbans: Pillars to Build Resilience and Adaptive Capacity**



## Pillar 1: Vulnerability Reduction

### Goal: Protect human lives

Appropriate disaster risk management and estuary management interventions must address the fact that a significant proportion of the inhabited delta has become unstable and difficult to live in because of past and current maladaptive management actions. Recommended new interventions include a combination of “hard investments” (embankment realignment), “soft investments” (restoration of mangrove bioshields), and defensive safety net investments (early warning systems, cyclone shelters, and safe water supplies). Interventions must also reverse unsustainable tidal aquaculture that accelerates erosion and places at risk investments to defend against flooding.

## Pillar 2: Poverty Reduction

### Goal: Improve quality of human life

Appropriate “lifeline” poverty reduction mechanisms should be implemented to reverse the effects of the existing poverty trap and build social resilience among individuals and local community organizations. The new interventions focus on improving basic social conditions, including education, health, and nutrition, and providing sufficient sustainable livelihood opportunities to increase individuals’ adaptive capacity. The interventions *must* also remove current incentives and practices that decrease mobility and keep people trapped in poverty; the removal of these practices could be complemented by new incentives, such as continuing and intensifying financial assistance in the form of scholarships for education to allow residents, particularly those from disadvantaged groups, to enhance their education so that, in the long term, they can pursue economic opportunities in urban areas.

These steps should all be taken to enable and encourage vulnerable populations to access lower-risk areas in and beyond the stable zone.

## Pillar 3: Biodiversity Conservation

### Goal: Capture benefits of ecosystem services

Biodiversity conservation focusing on the core forest zone will be key for maintaining biophysical system resilience. Many ecosystem functions – including nutrient cycling, local erosion control, and sediment deposition – are currently intact within the Sundarbans mangrove forest. Interventions should focus on reinforcing these ecosystem functions by permitting the forest ecosystem to expand and reducing high-visibility short-term pressures, such as overexploitation of timber products and other unsustainable forest uses. The largely intact core forest zone can serve as an important buffer for maintaining overall system resilience. Moreover, there are opportunities for the potential capture of carbon credits under the enhanced version of the Reducing Emissions from Deforestation and forest Degradation (REDD-plus) program or similar initiatives. The resulting revenue streams can assist in funding programs that help residents of the Sundarbans to leave the high-risk transition zone as well as other development efforts.

## Pillar 4: Institutional Change

### Goal: Enable organizations to effectively address problems in the Sundarbans

Implementation will generally rely on sectoral agencies acting individually or agencies engaged in paired cooperation; the latter will be for selected areas, such as mangrove restoration, aquaculture

management, and healthcare access. Institutional changes recommended herein would have the Department of Sundarban Affairs (DSA) in an important new role: overall monitoring and evaluation of sectoral agency activities. In addition, the institutional changes would reinforce emerging structures such as the West Bengal Coastal Zone Management Authority, especially in its regulatory functions overseeing India's new Coastal Zone Notification of 2011. GoWB (2012) has recommended that a new organization – the Sundarbans Steering Committee<sup>17</sup> – be established to handle the significant near-term coordination and management requirements of a proposed natural hazards adaptive investment program over the next decades. A near-term step could be to create a high-level Steering Committee at the state level to coordinate developmental activities and to enforce various regulations related to the region.

These institutional changes should be complemented by a comprehensive set of policies, laws, and enabling regulations for the Sundarbans Steering Committee and its partners to fulfill a mandate that can be broadly defined as one of building the resilience of the biophysical and socioeconomic systems with priority given to a high-risk “transition zone” that is most vulnerable to future climate change impacts. The change in the scale and orientation of institutional management schemes is similar to that in other estuarine systems that have exceeded or approach multiple tipping points (most notably the Delta Program in the Netherlands), and the Sundarbans approach can build on such models through, for example, adopting the Netherlands’ “Faster and Better” policy, which advocates use of assessment mechanisms that involve continual evaluations by beneficiaries of services.

## Impacts of the NLTA

While some of these proposed interventions might appear difficult to implement, the NLTA itself has contributed to real-time problem solving and consensus building. Thus an initial start has been made on a number of the recommended interventions. A knowledge base has been developed and shared while the NLTA has proceeded. The NLTA studies have improved information quality and capacity to use that information. Specific examples include the following:

- The current embankment reconstruction strategy employed by the Irrigation Department after Cyclone Aila is influenced by the recommendations of this NLTA that substantial embankment realignment may, at times, be necessary, and that mangrove restoration is an important element for providing a protective bioshield;
- Mapping conducted by the Kolkata-based Institute of Environmental Studies and Wetland Management has been used as a basis for planning appropriate areas for mangrove restoration

consistent with international protocols in the context of carbon markets. India's first small-scale mangrove reforestation activity was registered with the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC) in the mid-2011;

- The NLTA has given impetus to local nongovernmental organizations (NGOs) to expand the construction of multipurpose cyclone shelters in the transition zone; NGOs mobilized eight communities and attracted local private financing to reduce vulnerability;
- Study tours, organized by the NLTA, relating to disaster risk management have added to institutional capacity to identify future needs and make suitable plans; and
- The NLTA contributed to technical exchanges involving issues relating to biodiversity conservation, environmentally sustainable ecotourism, and coordination of early warning systems for cyclones among organizations from Bangladesh and India.

## Next Steps

The greatest near-term challenge will be to garner ongoing support for the recommendations presented in this report. To this end, the report is presented in terms of “lessons,” and will be translated into local languages to improve dissemination and facilitate discussion on the key elements of the recommended development strategy. The matrix capturing priority interventions (Table E.2) also provides a starting point for understanding the timing, location, and nature of some of the key initiatives.

## Realistic and Innovative Strategy Requiring Improved Institutional Capacity

The strategy elaborated here recommends that interventions promoting economic growth and development prospects focus on the stable zone, a relatively safe part of the delta, while efforts in the more hazard-prone portions of the transition zone focus on ways that empower people to take advantage of the greater employment opportunities offered in urban areas (in and beyond the stable area) gradually over multiple generations. The recommendations are far reaching and are different from the current development approach in the Sundarbans, which has worked under an assumption that people can and should be supported on the land they currently occupy.

GoI recognizes that the current development approach is no longer feasible for the Sundarbans. Its 2011 Notification, dealing with the

<sup>17</sup>GoWB. 2012. Comments of the Government of West Bengal on the Draft Final Report under NLTA by the World Bank on Sustainable Development of the Sundarbans Region.

coastal zone, empowers regulatory authorities to limit development initiatives in sensitive areas and enforce the notification. Ongoing work involves hazard line mapping that explicitly defines such areas as functions of storm surges, tides, and natural processes. Upon release of the Coastal Zone Notification in early 2011, all of the Sundarbans was designated Coastal Regulation Zone-I (CRZ-I), recognizing specifically that it is a “critical vulnerable coastal area” within the context of an “ecologically sensitive area.” Although this designation may change after various review processes, the intent clearly shows that it is no longer regarded as politically responsible or economically sensible to try to promote economic development in inherently hazardous areas.

The original climate change lens that initiated the NLTA required examination of an array of physical changes and hazards that might occur throughout the region, particularly sea level rise, and increases in storm intensity overtime. Remarkably, this lens provided some unexpected insights that are also of critical political importance. Perhaps the most significant insight was that many inhabitants of the Sundarbans had, in some sense, become trapped by the very system of embankments that was originally intended to protect them.

Ongoing deltaic subsidence over the past 150 years, compression and settling of soils behind embankments, and haphazard human-induced changes that affected river dynamics and tidal flows all undermined the natural processes normally responsible for natural adaptive change. Sediment deposition behind the embankments has stopped, soils have become more saline, and embankment erosion and collapse have become a routine occurrence. These changes will continue, and they imply that any attempts at poverty alleviation in the most adversely affected hazard-prone areas will involve an endless and unavailing struggle, *even in the absence of future climate change impacts*. Salinity intrusion will persist, flooding from local sea level rise associated with sinking of the delta will continue, and storms will batter weakening embankments without respite. Climate change

will only magnify and exacerbate sea level rise, salinity increases, and storm-related impacts further over time.

From a long-term policy perspective, the question of “*how* best can we alleviate poverty?” now also goes hand in hand with the question of “*where* best can we alleviate poverty?” In the long term, the most effective poverty alleviation strategies will be those that empower and equip residents of the Sundarbans with the means necessary to seek greater economic opportunities in lower-risk areas that provide improved access to employment, health, and educational services.

The recommended strategy of this NLTA recognizes and capitalizes on the increased gradual urbanization that India will experience in coming decades. Between 2008 and 2030, the number of cities in India with populations of more than 1 million is expected to increase from 42 to 68. West Bengal is expected to move from a 2008 urbanization rate of 29 percent to an urbanization rate of 40 percent in 2030. The population of the Kolkata agglomerate is projected to increase to roughly 23 million in 2030, with a total GDP of US\$169 billion in 2030 (McKinsey Global Institute 2010). Findings from the NLTA reveal the importance of urban areas, such as Kolkata and its environs, in offering better living standards (including employment opportunities and education) than those offered in the Sundarbans. Indeed, a voluminous literature points to the strong positive association between increased urbanization and augmented economic development. Interventions of the type recommended herein will be increasingly required in many parts of India because of the rapid pace of urbanization expected in the next two decades, with West Bengal expected to play a prominent role in urban expansion. Based on the analysis conducted as part of this NLTA, the recommended strategy is one that will allow many residents of the Sundarbans to remove themselves from a very hazardous context and, at the same time, significantly increase their opportunities for enhanced employment, healthcare, and education.

**Table E.3:**<sup>18</sup> Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans

Short term (5–10 years)		
Source	Condition/Pressure	Interventions
<b>Anthropogenic factors</b>	Overexploitation of forest resources in core zone	Forest regulation (for example, annual or biannual allocation of permits); emphasis on harvesting nontimber forest products, such as honey, fruits, or fish; risk communication to reduce forest pressure in the core zone
	Unregulated tourism in core zone	Development of limited, high-end and environmentally sustainable ecotourism for the core zone, including altering the current tourism policy to eliminate mass tourism
	Low agricultural productivity in transition zone	Emphasis on climate-resilient agricultural practices, including adoption of salt-resistant varieties; regulation and modernization of aquaculture practices to include strict use of hatcheries
	Embankment erosion from inappropriate location and operating characteristics of tidal aquaculture in stable and transition zones	Regulation and modernization of aquaculture practices in the stable zone; regulation of timing of recharge and location of ponds, especially strict limitations on tidal aquaculture in the transition zone
	Biodiversity loss from harmful fishing and prawn seed collection practices in the transition/core zone	Regulation and modernization of aquaculture practices in the transition zone, for example, implementation of state-of-the-art hatcheries
	Poor human development outcomes in the transition and stable zones	Offer financial assistance to families in the transition zone to attend schools in the relatively safer stable zone
	Lack of employment opportunities in the transition zone	Promoting limited high-end and environmentally sustainable ecotourism, modernized aquaculture, sustainable agriculture, and the harvesting of nontimber forest products; continue offering financial assistance to families in the transition zone to attend schools in the stable zone
<b>Geomorphological processes</b>	Embankment erosion and failure from historical processes in the transition zone and parts of the stable zone	Systematic retreat of embankments by 100–500 meters over the next 20 years and an increase in embankment heights to 5.25 meters above mean sea level; outer (existing) embankments will need to be maintained until the interior embankments are completed
	Salinization of soil water sources and soil from sea level rise, reduction in fresh-water inflows to the delta, and flooding in the transition zone and parts of the stable zone	Upgrading of fresh-water point sources; changing agricultural practices to respond to salinization of soils
<b>Climate change</b>	Anticipated increases in storm intensity, local and global sea level rise, and salinization	Disaster risk management, including risk communication to reduce population pressure in the area, development of improved warning systems, development of a cyclone emergency response plan and services, provision of an adequate supply of cyclone shelters; relocation and elevation of embankments

<sup>18</sup>Table E.3 applies a stress–response organizing framework, and highlights the differences between anthropogenic and natural stresses. The table is organized around three different time frames; short term (five to 10 years); medium term (10 to 30 years); and long term (more than 30 years). For each time frame, pressures are grouped under categories: anthropogenic, geophysical, and climate change.

**Table E.3 (continued): Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans**

Medium term (10–30 years)		
Source	Condition/pressure	Interventions
Anthropogenic factors	Potential reduction in pressure on the forest as a result of a decrease in population in the transition zone and forest regulation	Community-based mangrove restoration and forest protection schemes based on carbon financing; development of high-end and environmentally sustainable ecotourism sector in the transition zone
Geomorphological processes	Persistent erosion stresses from subsidence and sea level rise	Continue systematic retreat of embankments by 100–500 meters and increase embankment heights to 5.25 meters above mean sea level; maintain outer embankments; mangrove plantation in the area between old and retreated embankments; sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds
Climate change	Potential reduction of fresh-water flows in the delta from changes in the monsoon pattern	Closure of tidal creeks to improve fresh-water storage capacity; raising existing tubewell sources at spot water supply sources by 3–4 meters; raising floors of pump assemblies; protecting fresh-water ponds by raising their encircling bunds
	Increase in intensity of storms/cyclones and sea level rise	Continue systematic retreat of embankments by 100–500 meters and increase embankment heights to 5.25 meters above mean sea level; community mangrove restoration and conservation programs based on carbon financing; sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds
Long term (30+ years)		
Source	Condition/pressure	Interventions
Anthropogenic factors	Potential increase in urbanization in the stable zone, reduced population pressure in the transition zone	Implement job training programs in the stable zone; upgrade and extend health/education/infrastructure services in the stable zone; create a new marine reserve to be co-managed by India and Bangladesh; declare entire transition zone a restricted area in which privately held land can only be sold to the GoWB for conservation purposes
	Increased sedimentation in some areas of transition and core zones from upland closure of tributaries	Restoration of protective mangrove bioshields in the transition zone; encouragement of natural regeneration of mangroves in the core zone
Geomorphological processes/ climate change	Increased salinity in the transition zone and parts of the stable zone as a result of sea level rise	Embankment realignment and retreat
	Increased sea level rise	Height of the (new) interior embankments should be increased in a stepwise fashion to keep ahead of sea level rise
Climate change	Increase in intensity of storms/cyclones and sea level rise	Sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds to adapt to sea level rise; height of the (new) interior embankments should be increased in a stepwise fashion
	Catastrophic flooding of some smaller embanked areas from storms in the transition zone	Effective early warning system in place with contingency plans to evacuate residents







# 1.

## INTRODUCTION AND CONTEXT



1. The Sundarbans region is one of the richest ecosystems in the world. It contains arguably the world's largest remaining area of mangroves forests, with globally high levels of floral and faunal diversity. The entire mangrove forest region – which covers approximately 10,200 square kilometers (km<sup>2</sup>) – is known for its exceptional biodiversity, including numerous threatened species such as the Royal Bengal tiger, estuarine crocodile, Indian python, and several species of river dolphin. It is home to more than 10 percent of mammal and 25 percent of bird species found in India. Roughly 40 percent of the forest ecoregion lies within the Indian state of West Bengal (about 4,200 km<sup>2</sup>), and the remainder in Bangladesh (about 6,000 km<sup>2</sup>). The entire Sundarbans area of India is spread over the districts of North 24 Parganas and South 24 Parganas, covering 19 administrative blocks,<sup>19</sup> and consists of roughly 4,200 km<sup>2</sup> of reserve forest and 5,400 km<sup>2</sup> of nonforested area,<sup>20</sup> the latter located along the north and northwestern fringe of the mangrove forest (which constitutes the inhabited portion of the Sundarbans). The inhabited areas consist of 54 islands populated by over 4.4 million people, whose development opportunities are limited (Figure 1.1).

2. The forests of the Sundarbans form a powerful natural barrier that protects Kolkata Metropolitan Region's roughly 14 million inhabitants and other human settlements from cyclones, rising sea tides, and other adverse natural events that would otherwise have taken a massive toll on human life and property. The loss of these vital mangroves to storms and sea level rise will

seriously affect the quality of life of communities in the region, and expected changes due to global climate change as well as local anthropogenic forces will only compound the losses. In addition, further destruction of these mangroves would threaten the long-term survival of the globally endangered Bengal tiger and the many species of fish that rely on the mangroves as a reproductive ground. Apart from its biological importance, the Sundarbans has important cultural and religious values; the hostile living conditions of the Sundarbans, especially the presence of the Bengal tiger, have formed and shaped inhabitants' religious beliefs for hundreds of years. The worship of nature is a common practice in the area, and hundreds of myths and legends have emanated from the region (Sahgal et al. 2007, p. 47). Recognizing the importance and uniqueness of the Sundarbans, the United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the Indian portion of the forest a World Heritage Site in 1987,<sup>21</sup> and the Sundarbans Biosphere Reserve<sup>22</sup> was designated under the UNESCO Man and the Biosphere Programme<sup>23</sup> in 2001; the Bangladesh portion of the Sundarbans was declared a separate World Heritage Site in 1997 (see Annex 1).

3. The Sundarbans contains over 4.4 million of the most impoverished and vulnerable people in India. About half of this population lives below the poverty line (BPL), with poverty incidence highest in the blocks close to the vast mangrove forest (Figure 1.2). Nearly 80 percent of the households pursue livelihood options that involve inefficient production methods in

<sup>19</sup>The Sundarbans is spread over 19 administrative blocks. The blocks in South 24 Parganas are Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Canning I & II, Basanti, Gosaba, Mathurapur I & II, and Jaynagar I & II. The blocks in North 24 Parganas are Haroa, Sandeshkhali I & II, Hingalganj, Hasnabad, and Minakhan.

<sup>20</sup>The total area of the Sundarbans region in India is 9,600 km<sup>2</sup>, which constitutes the Sundarbans Biosphere Reserve.

<sup>21</sup>For more information on criteria for selecting areas as World Heritage Sites under UNESCO, see <http://whc.unesco.org/en/list>.

<sup>22</sup>In 1970, the Ministry of Environment and Forests, Government of India, declared the entire 9,630 km<sup>2</sup> of the Sundarbans as the Sundarbans Biosphere Reserve. This includes approximately 4,260 km<sup>2</sup> of reserve forests, of which around 40 percent has been declared protected areas, including about 1,330 km<sup>2</sup> as a national park, and around 406 km<sup>2</sup> as wildlife sanctuaries. For more information, see [http://www.sundarbanbiosphere.org/html\\_files/sunderban\\_biosphere\\_reserve.htm](http://www.sundarbanbiosphere.org/html_files/sunderban_biosphere_reserve.htm).

<sup>23</sup>The Man and the Biosphere Programme is an intergovernmental scientific program aimed at improving the relationships between people and the environment. For more information, see <http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/>.

**Figure 1.1: Sundarbans Region of India and Bangladesh**



agriculture, fishing, and aquaculture. Residents of the Sundarbans face numerous health challenges. Many of these challenges can be attributed to poverty, lack of adequate water supply and sanitation facilities, or airborne diseases common to rural lifestyles in India. It is estimated that 1,700 children under five years of age died due to inadequate household water supply, sanitation, and hygiene in the Sundarbans in 2008, representing 29 percent of total under-five child mortality.<sup>24</sup> The public health system in the Sundarbans is extremely limited by systemic human resource challenges, such as absenteeism and vacancies, due to which many basic services cannot be offered to the population. High maternal mortality in the Sundarbans is a result of malnutrition, prevalence of anemia among pregnant mothers, and young age at marriage.

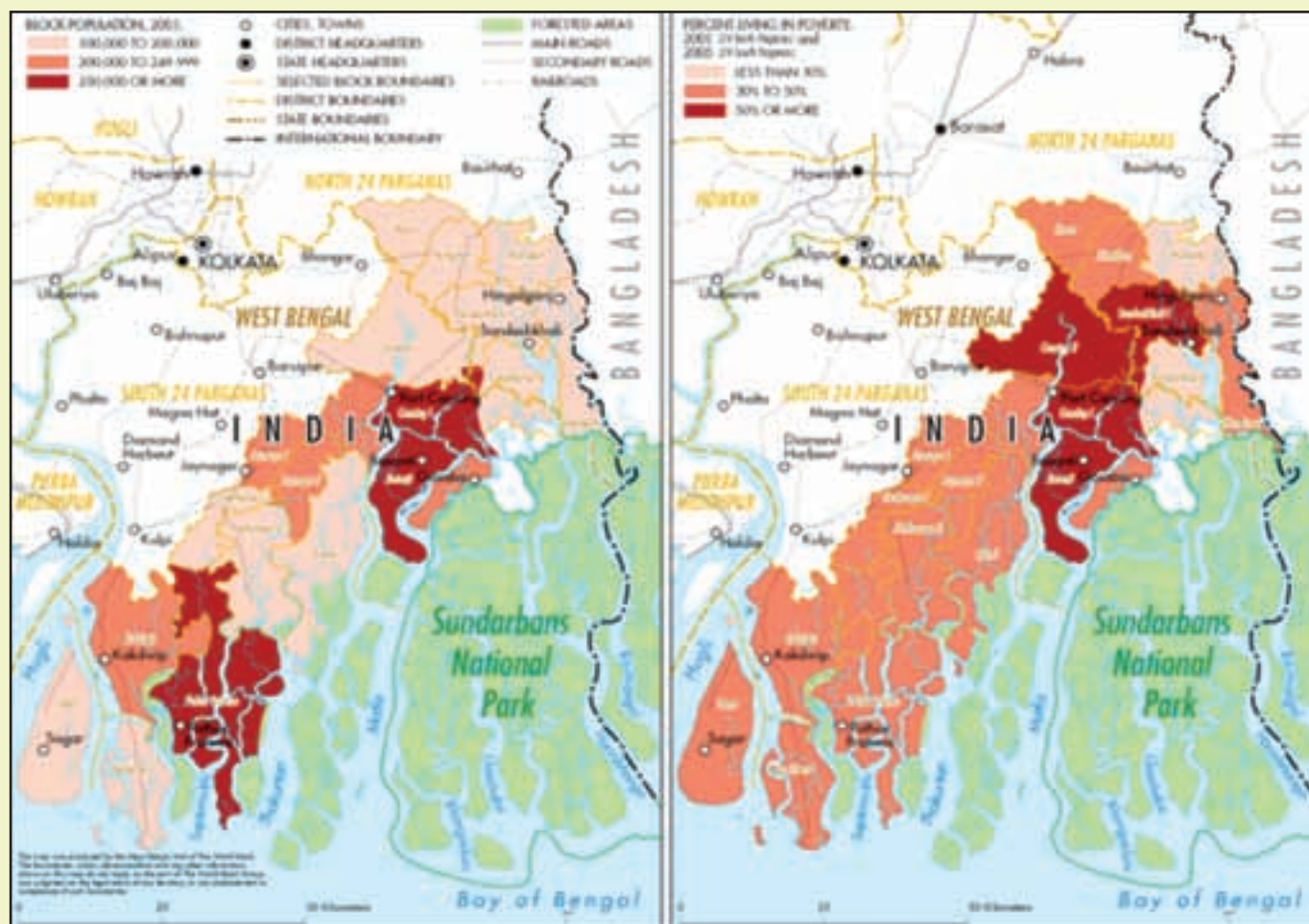
4. The people and the productivity of their holdings are under increased threat from deltaic subsidence, sea level rise, and increased cyclone intensity as climate change and the decay of a 19th century 3,500 kilometer (km) system of embankments take their toll. Climate change adversely impacts both farmers and fishermen alike; unpredictable rainfall patterns continue to make traditional crop production difficult for farmers. Moreover, the ecosystem is being adversely impacted by significant increases in salinity due, in part, to sea level rise as well as reductions in fresh-water flows to the delta. Rising sea levels place more pressure on agriculture as land continues to be lost to sea. Entire islands have disappeared under the sea, which has caused mass scale human relocation. Residents have expressed concern that the frequency and intensity of storms and cyclones have increased overtime in the region.<sup>25</sup>

<sup>24</sup>Annual mortality among children under five is estimated based on a mortality rate of 60 per 1,000 live births, a crude birth rate of 23 per 1,000 population, and a total population of 4.4 million in the Sundarbans. The crude birth rate in the Sundarbans is assumed to be the same as reported for rural West Bengal in the National Family Health Survey 2005–06, adjusted to year 2008. The cause-specific structure of child mortality is, for all of India, as estimated by the World Health Organization (WHO) for the year 2008.

<sup>25</sup>World Wildlife Fund. 2010. Sundarbans: Future Imperfect. Climate Adaptation Report.



**Figure 1.2: Percentage of People Living in Poverty in the Sundarbans**



5. The marginal economic conditions are further undermined by numerous threats to the social fabric: persistently low education levels, inadequate healthcare safety nets, and conditions so desperate that children risk falling prey to traffickers who condemn them to menial labor or sex work. Although local governments, nongovernmental organizations (NGOs), and international donors have attempted to bring economic development to the area, efforts have frequently been thwarted by poor infrastructure, deficient human capital, limited resources, or institutional capacity constraints (see Annex 1 for details on the key socioeconomic issues in the Sundarbans).

6. The ecosystem's carrying capacity has already been exceeded; this is reflected in the deterioration of the region's natural resource base, which is unable to sustain the expansion of prevailing economic activities. The estimated cost of environmental damage associated with ecosystem degradation and biodiversity loss is about INR 6.7 billion<sup>26</sup> annually, which is equivalent to about 5 percent of the Sundarbans' gross domestic product (GDP) in

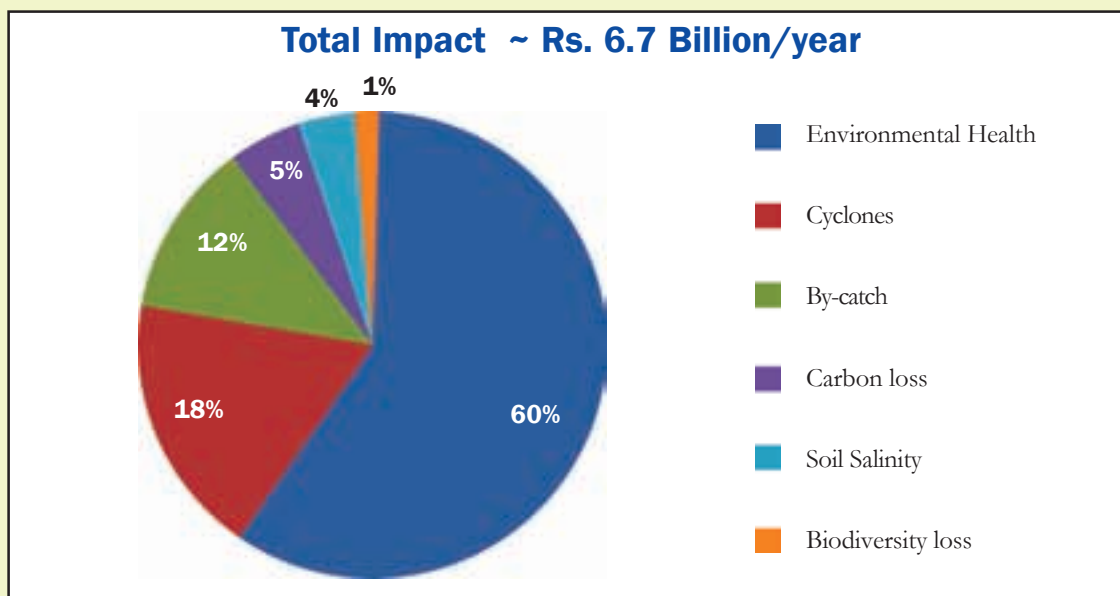
2009.<sup>27</sup> The losses stem from a combination of factors associated with unsustainable and inefficient economic activities – for example, mangrove destruction, impact of cyclones, reduced agricultural yields, and unsustainable fisheries – as well as destruction of ecosystem services. Moreover, environmental degradation associated with health impacts as a result of poor environmental conditions, particularly household air pollution and inadequate water supply, hygiene, and sanitation, is linked to losses equivalent to another 5 percent of Sundarbans GDP in 2009 (Figure 1.3). Poor environmental conditions are responsible for 3,800 premature deaths and 1.9 million cases of illness every year, mainly among young children and adult women (see Annex 7 for further details on the costs of environmental degradation).

7. Despite these dismal conditions and endemic poverty, the population is growing and exerting even greater pressure on fragile and recovering natural systems. As a result of high birth rates and migration inflows, population density is high and growing. The labor force in the Sundarbans has continued to

<sup>26</sup>See Annex 7 for details on methodology. Reflects average exchange rate in 2009: US\$1 = INR 45.

<sup>27</sup>This total damage estimate only partly captures losses from mangrove degradation and overfishing.

**Figure 1.3: Costs of Ecosystem Degradation and Biodiversity Loss in the Sundarbans**



increase; current population density is estimated to be 1,000 per km<sup>2</sup>.<sup>28</sup> In a 2011 survey of 2,188 households conducted as part of this Non-Lending Technical Assistance (NLTA),<sup>29</sup> 27 percent of the respondents said that they had migrated from Midnapore, 4.7 percent had come from other locations in southern West Bengal, 17.4 percent said that they had come from Bangladesh, and 46 percent reported that they had lived earlier in a different location within the Sundarbans.<sup>30</sup> Around 14 percent of all respondents had come to the Sundarbans from outside, suggesting that de facto open access to forest and fishery resources attracts poor migrants to the region, as a meal or two can often be gleaned from local resources, even by people with few skills. The limited education and job skills, lack of access to urban markets, and subsidies providing perverse incentives (for example, ration cards linked to a family's current address) keep many residents trapped in such an inhospitable environment. Other factors contributing to poverty are the *maladaptations*, such as an inadequate embankment system that gives a false sense of security to residents, and large and uncontrolled aquaculture development schemes that are contributing to erosion and instability of many protective embankments. Population growth, increased degradation of natural resources, and widespread prevalence of inefficient practices will likely result

in an increasing gap between the local food needs and supply, which could exacerbate malnourishment, particularly in children. For example, rice supply will decrease below the required per capita amount if the current population growth rates and agricultural yields continue in the future (Figure 1.4). Moreover, assuming continuation of the current diversion of agricultural land toward aquaculture, the gap will widen significantly over the coming year.

8. Many socioeconomic conditions in the Sundarbans have already reached tipping points. This is one of the most underdeveloped areas of the country from where people migrate outwards to survive; findings from the NLTA reveal that more than 30 percent of households have one member, male and female, migrate in search of work. Many women migrants, not employed as domestic workers, end up working in the sex trade. With employment opportunities lacking, young girls (10 to 15 years old) from poor families are often sent to distant areas to earn income and many often wind up in the sex industry. Child labor is also prevalent; a study conducted by the Kolkata-based NGO Jayaprakash Institute of Social Change in 2010 found that 20 percent of households reported child migrant laborers.<sup>31</sup>

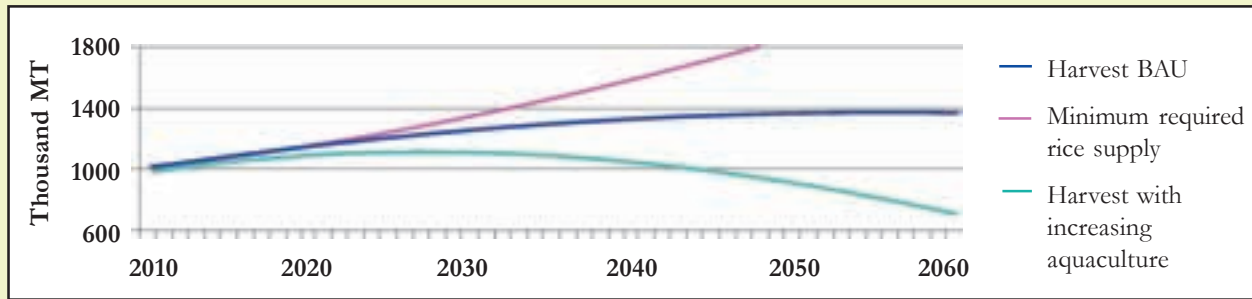
<sup>28</sup>Government of India Census (2011).

<sup>29</sup>The Government of India and the Government of West Bengal requested World Bank support to design a comprehensive program that responds to the development challenges of the Sundarbans area of West Bengal. As part of the NLTA, various studies were carried out that would enable the Government of West Bengal to develop a strategic action plan that addresses three main objectives: (a) protection of life, property, and assets; (b) income growth and poverty reduction; and (c) biodiversity conservation. Studies conducted as a part of the NLTA used a variety of methodologies to compile data on different sectors, which were then synthesized into an overarching spatial planning approach for the Sundarbans that would take better account of the unique geographic realities of the Sundarbans area, and recognize interlinkages among sectors in the area.

<sup>30</sup>As a part of the NLTA, a comprehensive household survey of more than 2,000 households was commissioned to understand the demographic and socioeconomic profile of households in the Sundarbans districts, and to better understand the dynamics of migration, livelihoods, and vulnerability to natural disasters (see Annex 1 on methodology for further details on the survey of 2,188 households).

<sup>31</sup>Source: Center for Science and Environment. 2012.

**Figure 1.4: Rice Production and Consumption Scenarios in the Sundarbans Compared to Business-As-Usual (BAU)**



9. The social and economic development strategy for the Sundarbans requires a major overhaul in order to allow residents to escape from poverty; and India's ongoing urbanization process provides a context in which an innovative development strategy can be framed. Currently, India is experiencing a spatial transformation; extensive urbanization is currently underway and is expected to continue, and this process will offer considerable economic growth opportunities (see Annex 10). By 2030, 13 cities in India will have a population of more than 4 million, and five states<sup>32</sup> in India are likely to be more than 50 percent urbanized. For example, the population of Kolkata agglomerate is projected to increase to roughly 23 million in 2030, with a total GDP of US\$169 billion (McKinsey Global Institute 2010). Urbanization is not a side effect of economic growth; it is an integral part of the process. Less than one-third of the people in India live in cities and towns, but those areas make a major contribution to the country's economy: they generate over two-thirds of the country's GDP and account for 90 percent of government revenues.<sup>33</sup> Between 2008 and 2030, job growth in cities in India is projected to be more robust than that in rural areas; rural employment is projected to grow 0.6 percent annually at best, moving from 330 million to around 380 million jobs, a net addition of less than 50 million jobs. However, job growth in cities will be far greater, increasing from roughly 100 million to 220 million in 2030, an increase of 3.6 percent annually. Cities will account for 70 percent of jobs created between now and 2030 in India (McKinsey Global Institute 2010).

10. However, current programs and policies being offered in the Sundarbans reduce the incentives of Sundarbans residents to take advantage of the urbanization process and integrate themselves into areas of greater economic opportunities and lower environmental risk. The Government of West Bengal (GoWB) is highly dependent on numerous centrally-sponsored schemes aimed at addressing socioeconomic development initiatives. In India, substantial resources flow from the center to the states and local governments through centrally-sponsored schemes aimed at addressing socioeconomic development.<sup>34</sup> Unlike other Indian states (with the exception of Karnataka and Kerala), considerable responsibilities have been devolved to the Gram Panchayats (GPs) of West Bengal, including selection of beneficiaries for welfare programs, implementation of land schemes, investment in infrastructure programs, distribution of agricultural kits, among others.<sup>35</sup> Resources allocated to the GPs include subsidies, which provide perverse incentives, and maladaptive development programs<sup>36</sup> keep residents in a poverty trap and do not contribute meaningfully to their improved welfare.

11. The development strategy that is currently being pursued in the Sundarbans is far from optimal because it is likely to place even greater populations at risk and result in additional unsustainable demands on the ecosystem. For example, some of the most promising value-added activities – such as modernized brackish water aquaculture – pose potential long-term threats to embankment stability unless the location of ponds is carefully controlled and

<sup>32</sup>These five states are Tamil Nadu, Gujarat, Maharashtra, Karnataka, and Punjab (McKinsey Global Institute 2010).

<sup>33</sup>World Bank website, South Asia portal. "Urbanization in India: Integral Part of Economic Growth." <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:21531567~menuPK:2246552~pagePK:2865106~piPK:2865128~theSitePK:223547,00.html>.

<sup>34</sup>For example, GoI provides funding for the Conservation and Management of Sundarban Mangroves, Biosphere Reserve and Wetland.

<sup>35</sup>Bardhan, P., and Mookherjee, D. 2006, May. Land Reform, Decentralized Governance, and Rural Development in West Bengal. In Conference on Challenges of Economic Policy Reform in Asia. May (Vol. 31).

<sup>36</sup>The West Bengal experience with local development programs has spanned a quarter century. (Bardhan and Mookherjee 2006). In 1950, the Indian Constitution set the foundation for decentralization in the country. The state of West Bengal developed a three-tier system of self-government under the 1957 Panchayat Act and the 1963 Parishad Act. The Left Front government successfully implemented the three-tier local government system in the late 1970s, and established the GP as the lower level of the three-tier system. The other two levels are the Panchayat Samiti and the Zila Parishad. The former are councils at the block level with jurisdiction over 115 villages, while the latter are councils at the district level. The GP is elected every five years, and includes roughly eight to 15 villages. Source: Bardhan, Mookherjee and Torrado, 2010). The main responsibilities given to the GPs of West Bengal include the selection of beneficiaries for government welfare programs, distribution of agricultural kits, and investments in public infrastructure (Ibid).



pond recharge activities regulated. Moreover, higher levels of rural development are likely to attract more people to the area, putting more lives and property at risk in the event of inevitable changes in the natural system, including, for instance, the predicted intensification of cyclonic storms (Annexes 3 and 4 discuss the vulnerability of the Sundarbans to natural adverse events). Indeed, even in the absence of any climate change impacts, the delta is sinking, and the past two centuries of estuarial changes have undermined the current embankment system (see Annex 5 for further details). Simply reinforcing the current system of embankments by building them higher or with stronger materials will not prevent them from collapsing because, in some parts of the delta, 40 meter (m)-deep channels will inevitably scour and erode them from below.

12. Poverty in the Sundarbans is severely retarding the development potential of inhabitants and keeping millions from leaving an extraordinarily hazardous setting; a development strategy that allows residents to escape poverty is called for. A part of the overall effort to improve living standards and employment opportunities requires restructuring the social assistance and redistributive programs currently offered in the Sundarbans. An evaluation of current programs and policies in place in the Sundarbans (Table 1.1) suggests that they are not fully achieving their intended purposes, and that

they might hamper long-term socioeconomic and human development, as well as long-term vulnerability reduction (Annex 6 provides an assessment of current programs in the region). Current programs that introduce perverse incentives should be considered against alternative policy measures that can help promote long-term socioeconomic development and vulnerability reduction, such as intensifying financial assistance programs in the form of scholarships for education, that can potentially serve as promising mechanisms to lift people out of poverty in the long term, and give residents the opportunity to integrate themselves into areas that offer greater job opportunities, higher wages, improved safety, and greater access to healthcare, education, and other social services. In the long term, the most effective poverty alleviation strategies will be those that empower and equip Sundarbans residents with the human capital necessary to allow them to move to safer areas with greater economic opportunities. GoWB has financial aid programs in place for students from weaker sections who are eligible to receive government scholarships to pursue their educational careers. The development strategy advocated herein is one that does not make matters worse or place more people at risk, but provides the most feasible near-term protection to vulnerable populations while offering them longer-term opportunities to extract themselves from harm's way.

**Table 1.1: Selected Programs and Policies in the Sundarbans**

Sector	Programs and Policies
<b>Livelihoods: agriculture, aquaculture, forestry, tourism</b>	<p>National job employment schemes, for example, under the Mahatma Gandhi National Rural Employment Guarantee Act</p> <p>Development of marine fisheries by the Department of Fisheries and Aquaculture through measures such as construction of deep fishing harbors</p> <p>Expansion of mass tourism programs by the Tourism Department, for example, through development of tourism infrastructure, including lodges</p> <p>Input subsidies for BPL families for sunflower, moong, and cotton provided by the Sundarban Development Board (SDB)</p> <p>Small-scale irrigation work undertaken by SDB</p> <p>Land-shaping and integrated farming programs provided by SDB, NGOs, and private landowners</p> <p>Distribution of seeds, training and demonstrations, and lessons on plant protection and pest management provided by the Department of Agriculture</p> <p>National and state programs aimed at increasing agricultural growth, for example, the Rajiv Gandhi Krishi Vikas Yojana scheme to achieve 4 percent annual growth in agriculture</p> <p>National Food Security Mission to increase production of rice, wheat, and pulses, create employment opportunities, and increase farmers' profits</p> <p>Integrated Scheme of Oilseeds, Pulses, Oilpalm, and Maize to promote crop diversification</p> <p>Technology Mission on Cotton to increase cotton productivity via training</p>



**Table 1.1 (continued): Selected Programs and Policies in the Sundarbans**

Sector	Programs and Policies
<b>Education</b>	<p>National-level education policies, such as Sarva Shiksha Abhiyan scheme for free elementary education, Mid-Day Meals program aimed at improving the nutritional status of children in schools, and provision of hostels and boarding facilities for secondary and higher secondary students</p> <p>Creation of higher education institutions provided by the Sundarban Development Authority</p> <p>Vocational training provided by NGOs at the local level in the form of short courses in modern methods of fishing, bamboo work, and other such small indigenous sectors. Examples of NGOs active in the region include the All India Council for Mass Education and Development, and Ambedkar Social Welfare Mission</p>
<b>Health</b>	<p>Public health services under national health and state programs for improving nutrition and reproductive and child health, reducing disease, decreasing maternal and infant mortality rates, increasing institutional deliveries in BPL families, developing and upgrading public health facilities, and increasing the number of health personnel. Examples of programs include the National Anti-Malaria Program, Revised National Tuberculosis Program, and Integrated Child Development Services</p> <p>NGO programs providing health and hygiene education, medical camps, and preventive medicine, and running hospitals and diagnostic centers. Examples of NGOs working in close collaboration with the Directorate of Health Services and SDB include Southern Health Improvement Samity, Bhargar, Sri Ramkrishna Ashram, Nimpit, and Tagore Society for Rural Development.</p>
<b>Water supply and sanitation</b>	<p>Subsidies for piped water supply services in the Sundarbans provided by the Public Health Engineering Department (PHED)</p> <p>District-level schemes for improving sanitation facilities, for example, through implementation of the Total Sanitation Campaign (now renamed Nirmal Bharat Abhiyan)</p> <p>Digging of tubewells and groundwater extraction provided by PHED</p> <p>Rainwater harvesting schemes provided by PHED</p> <p>National and state programs for providing safe drinking water to all villages, for example, the Rajiv Gandhi National Drinking Water Mission</p>
<b>Disaster risk management and erosion control</b>	<p>Embankment rehabilitation and realignment undertaken by the Department of Irrigation and Waterways</p> <p>National, state, and NGO programs for the development of cyclone shelters</p> <p>Forest Department and NGO schemes for planting mangroves; small-scale bilateral donor schemes for mangrove plantation</p>
<b>Energy</b>	<p>Extension of grid electricity and provision of free electricity connections to rural BPL households provided by the Ministry of Power's Rajiv Gandhi Grameen Vidyutikaran Yojana national program</p> <p>Renewable energy power plants and solar home systems (available at a subsidized rate to households in unelectrified remote villages) implemented by the West Bengal Renewable Energy Development Agency</p> <p>Diesel generator schemes operated by private operators</p>
<b>Transportation</b>	<p>Construction of roads (brick paved, bituminous, concrete), bridges, culverts, drainage structures, and jetties provided by SDB, Department of Engineering, and Public Works Department</p> <p>Forest Department and NGO schemes for planting mangroves; small-scale bilateral donor schemes for mangrove plantation (usually &lt;20 hectare (ha))</p>
<b>Biodiversity conservation</b>	<p>State programs aimed at protecting the habitat of the Royal Bengal tiger and binational programs for promoting overall biodiversity conservation</p>

*Note: Table 1.1 includes key programs and policies that have been implemented in the recent past or are currently being implemented in the Sundarbans. The programs and policies listed in the table do not cover all programs and policies implemented in the Sundarbans.*



## 2. FINDINGS AND LESSONS



### 2.1 Analysis of Different Approaches and Their Impacts

13. Determining the most appropriate approach for tackling the problems in the Sundarbans requires a careful assessment of the different courses of action that can be taken to promote socioeconomic development and conserve biodiversity. Assessing alternative approaches of current and future development efforts will provide decision makers with an improved understanding of the potential socioeconomic and environmental consequences of specific courses of action, and financial feasibility of the different approaches. The following scenarios depict how the future of the Sundarbans may unfold under each of four approaches:

14. **Business as usual approach.** The Business-As-Usual (BAU) approach refers to the base case scenario in which current policies and programs in the Sundarbans would continue their course. This scenario incorporates the existing government plans and programs for all key sectors (for example, education, health, energy) and represents the most likely path of development in the absence of major new interventions to improve livelihood and welfare of local populations. To maintain a BAU approach would mean augmented human suffering, and increased loss of life and assets due to extreme weather events. Continual migration into the region is a likely result of current development programs, and thus the BAU approach would lead to increased human vulnerability to sea level rise and other hazardous environmental forces.

15. **Enhanced rural development approach.** This approach differs from the BAU approach in that it entails implementing

*new policies, programs and interventions across all key sectors* in a concentrated effort to increase living standards and economic development in the region. The enhanced rural development approach involves the development of schools, public health centers and hospitals, and infrastructure (roads and railways), and implementing measures to attract businesses to settle in the area. While rural development initiatives would be expected to enhance, to some extent, human welfare in the short run, a major downside exists: economic development would most likely attract more people into the region, and this would place even greater populations at risk from natural hazards and lead to increased stress on an already fragile ecosystem that would be unable to sustain itself in the face of increasing demands on its resources. Increases in human vulnerability would be greater under this approach than under the BAU model.

16. **Long-term vulnerability reduction approach.** A long-term and gradual integration of the Sundarbans population into urban areas is the goal of this approach. This strategy reduces human vulnerability by educating residents on the dangers of living in the transition zone and aims to first improve health and educational standards so that, in the longer term, residents of the Sundarbans can successfully integrate themselves into cities away from the Sundarbans Reserve Forest. Evidence shows that, over multiple generations, the descendants of the rural poor who seek livelihood opportunities in urban areas are better off than they would have been if their families had remained rural residents (Glaeser 2011, p. 7; Ravallion 2007).<sup>37</sup> The de facto long-term result should be a significantly reduced population at risk in the transition zone, reduced morbidity and mortality, and improvements in livelihoods for the entire Sundarbans population.

<sup>37</sup>For analyses of the ways in which the lives of poor families shift over time, see also Narayan, Pritchett, and Kapoor 2009.



17. **Short-term migration approach.**<sup>38</sup> This approach, howsoever unlikely, centers on an out-migration process in which residents leave the Sundarbans in order to find safer places to live; this approach also has the effects of protecting biodiversity. To encourage outward migration, residents would be educated about the dangers of living in the area, and economic incentives (such as much improved social and economic infrastructure) for relocating to the safer places would be provided. The strategy would also restrict in-migration. As most of the population would be expected to migrate to urban areas, relinquished land would be converted into protected areas and mangrove forests. However, the focus on rapid migration out of the Sundarbans would likely result in increased social disruption. The overall potential outcome would be a population that does not have the adequate level of human capital and resources to live productive lives away from their original homes.

18. Based on an assessment of the different options (Table 2.1), the long-term vulnerability reduction approach provides the most appropriate opportunities for long-term poverty alleviation and biodiversity conservation, while protecting residents from natural disasters. The justification for this position is partly based on the extraordinary cost in both financial resources and loss of human life that would be associated with following strategies based on in situ economic development (the above-noted enhanced rural development approach) or the BAU approach. The long-term vulnerability reduction strategy recognizes that development in many areas of the Sundarbans transition zone would be likely to

result in an inefficient allocation of resources, as many islands are expected to become uninhabitable in the coming decades. Moreover, development of infrastructure in the very difficult geographic context of the Sundarbans, with its scattered populations and existing reliance on water transport, would be both challenging and expensive. In addition, investment associated with rural development strategies might lead to increased in-migration and settlement in the area, placing more pressure on the Sundarbans forest and more people at risk of negative consequences associated with sea level rise, cyclonic storms, soil and water salinization, and long-term changes in climate. The BAU and the enhanced rural development approaches would involve a continuing struggle against the forces of change and are not likely to lead to a successful long-term outcome. While the short-term migration approach acknowledges the risks of inhabiting the area, especially in the future, it is likely to result in major social disruption. The short-term nature of the approach would not allow sufficient time to properly equip residents of the Sundarbans for life in other areas, many of which would probably be urban.

19. The long-term vulnerability reduction approach presented herein contains elements that would make the region (possibly in the short and medium terms) attractive, and hence there is a risk of increased migration into the Sundarbans. Therefore, one of the key challenges associated with this strategy centers on arresting the tide of potential in-migration while making the area more habitable for current residents by means of interventions to accomplish the

**Table 2.1: Analysis of Alternative Approaches in the Sundarbans**

Pillar	BAU Approach	Enhanced Rural Development Approach	Long-term Vulnerability Reduction Approach	Short-term Migration Approach
Vulnerability reduction	No vulnerability reduction. Increase in loss of life, assets, and property	Vulnerability reduction is uncertain given that effects of disaster management efforts may be offset by increased in-migration	Vulnerability reduced but not as quickly as with the short-term migration approach	Vulnerability reduction as a result of risk communication in the short term to foster outward migration
Poverty reduction	Increased poverty	Reduced poverty only in the short term and possibly in the medium term	Reduced poverty in the short, medium, and long terms	Poverty not reduced – focus is not on enhancing health, education, and job skills
Biodiversity conservation	Mangrove forest degraded, not conserved	Mangrove conservation in the short term; potential mangrove degradation over the longer term	Mangrove conservation in the short, medium, and long terms	Mangrove conservation in the short, medium, and long terms
Institutional change	Continuation of inadequate institutional capacity and coordination	Partial institutional strengthening but no institutional coordination	Strengthened institutional capacity and coordination	No effort to strengthen institutional capacity and coordination

<sup>38</sup>The main goal of the short-term migration approach presented in this report is to encourage outward migration of the residents of the Sundarbans by educating them about the dangers of living in the area and providing them with incentives to migrate to other areas far from the Sundarbans Reserve Forest. However, those who choose not to migrate could continue to stay in the region. The approach described in this report does not provide educational human development services (health, education, and so on) in the short run. Moreover, institutional change is not feasible in the short-term migration approach. The financial compensation component in the approach and restriction of settlement and movement into the Sundarbans is based on the approach presented in Danda et al. 2011. Despite financial compensation, the population could continue to live at their current locations should they choose to do so.



following: creating effective disaster risk management programs, reducing mortality and morbidity associated with inadequate water supply and indoor air pollution, and implementing short- and medium-term measures to improve livelihood opportunities, for example via limited and sustainable ecotourism development. The implementation of this approach would require significant enhancements in the provision of information on risk to lives and assets associated with living in the transition zone. There are many details that remain to be sorted out regarding how this information would be organized and disseminated, but the underlying concept is that if current and potential new residents know well the high risks of mortality, morbidity, and loss of assets they will face in the future, they will find it attractive to consider alternative locations in which to reside. A key dimension of this approach is the uncertainty associated with the extent of in-migration; this is an issue that will require considerable attention.

## 2.2 Principles Supporting the Long-term Vulnerability Reduction Approach

20. A number of principles lend support to the recommended long-term vulnerability reduction approach, as outlined in the subsections below.

### A spatially oriented approach recognizes the different vulnerabilities of zones within the Sundarbans

21. The strategy employed in the long-term vulnerability reduction approach recommended by the NLTA involves a series of interventions at multiple levels and across different time frames, specifically targeting three planning “zones.” The zones are: (a) a densely populated *stable zone*, containing the peri-urban areas closer (and relatively well connected) to Kolkata and containing established settlements, such as Bakkhali, Canning, Jaynagar-Majilpur, Minakhan, Namkhana, and Tengrabichi; (b) a *transition zone* surrounding the forest and consisting primarily of rural communities with limited infrastructure and a high incidence of poverty; and (c) a *core zone*<sup>39</sup> that includes the legally protected areas (the National Park and the wildlife sanctuaries) as well as the Reserve Forest. The proposed long-term vulnerability reduction approach recognizes the specific

characteristics and needs of the three zones. There is, however, some emphasis on the transition zone, which includes an at-risk population of about 1.54 million people. Interventions within the three zones are different in scope and timing, but they are interrelated and include targeted instruments as well as broad policies. As an example of a broad-scale intervention, wide dissemination of information on risks involved in living in the transition zone is intended to discourage migration into the Sundarbans. At the broadest level, the recommended approach includes bilateral cooperation between the Governments of Bangladesh and India. The Sundarbans is a single ecological unit, and political borders are not meaningful from an ecosystem perspective. The long-term vulnerability reduction strategy also calls for extensive participation by the Government of India (GoI), GoWB and local-level governmental organizations, as well as coordinated participation among these institutions. In the long term, the sought-after result would be to have no people living in the high-risk portions of the transition zone (a belt on the periphery of the forest that includes areas impacted by Cyclone Aila),<sup>40</sup> a significantly reduced population at risk in the transition zone as a whole, and overall greater integration of all residents of the Sundarbans (in both stable and transition zones) into urban areas.

### A cross-sectoral approach allows for effective intervention and investment planning

22. The recommended development strategy for the Sundarbans is based on a cross-sectoral, spatially sensitive approach. This approach simultaneously considers multiple sectors – energy, water supply, education, health, and others – and highlights the possibilities for developing, in a single region, an overall program that integrates proposed interventions concerning four major issues: adaptation to resource degradation, vulnerability reduction, poverty alleviation, and biodiversity conservation. The cross-sectoral approach provides multiple benefits, including the opportunity to assess potential conflicts and trade-offs among different sectoral interventions. The overarching spatial strategy recognizes that interventions and investments will differ across different parts of the region as well as in the short, medium, and long terms. The approach also acknowledges that there are multiple stressors, some anthropogenic and some natural. An important finding of the NLTA is that climate change impacts are not the highest priority for intervention: past impacts of local (or “isostatic”) sea level rise,<sup>41</sup> cyclonic storms, salinization, and resource degradation from unsustainable or

<sup>39</sup>In the context of this report, the “core zone” refers to all the legally protected areas of the Sundarbans (the National Park, wildlife sanctuaries, and the Reserve Forest) and not just the National Park and Tiger Reserve. Roughly 40 percent of the Reserve Forest area has been brought under protected area status. For more information, see [http://www.sundarbanbiosphere.org/html\\_files/sunderban\\_biosphere\\_reserve.htm](http://www.sundarbanbiosphere.org/html_files/sunderban_biosphere_reserve.htm).

<sup>40</sup>In the Sundarbans, reference is sometimes made to a “high-risk zone,” which is an area that overlaps with both the core area and the transition zone. The high-risk zone includes all legally protected areas, the Reserve Forest, and the fringe area (a belt on the periphery of the forest and the area impacted by Cyclone Aila). Legally, there should be no residents of the core area. Thus the concern is with removing people from the parts of the transition zone impacted by Cyclone Aila.

<sup>41</sup>Scientists distinguish between isostatic and eustatic sea level rise. The term “eustatic” refers to a global rise in sea level (for example, an alteration to the global sea levels due to changes in the volume of water in the world oceans). The term “isostatic” refers to a sea level change that is localized, such as the change in the relative sea level caused by deltaic subsidence.

inappropriate land use pressures pose the most serious current threats. Predicted climate change impacts such as global sea level rise will only make an already bad situation worse.

## Spatially nuanced interventions are the backbone for improving living standards

23. The long-term success in helping prepare the underserved populations of the Sundarbans for economic opportunities hinges on three types of spatially nuanced interventions: spatially blind, spatially connective, and spatially targeted (World Bank 2009). These interventions are to be undertaken in the short and medium terms and address key issues. The population in the Sundarbans has been historically isolated and underserved by public services and infrastructure, particularly in the transition zone, and faces high levels of poverty, malnutrition, poor health, limited access to education, and high risks from natural disasters. In the short and medium terms, interventions should focus on a set of *spatially blind* investments (that is, investments made regardless of location within the Sundarbans) to meet the basic needs of residents with the underlying objective of building human capital. Investments in health (with particular emphasis on preventive healthcare), education, and job training are the central ingredients in building human capital. Postnatal care and nutrition and immunization programs for young children are among the steps that can be taken to improve early childhood development, which is well established as a basis of future learning and success in the labor market (World Bank 2010). Labor and vocational training programs are also needed as a way to improve the employment prospects of the Sundarbans residents in both the transition and stable zones, especially for those seeking employment opportunities in urban areas. Reductions of indoor air pollution and improved water and sanitation programs will improve human health, which is essential for building human capital: healthy students are better learners and healthy workers are more productive (Bloom and Canning 2005). Improvements in human capital will, in the long term, provide local populations with the skills and means necessary to pursue livelihood opportunities in lower-risk areas that provide employment opportunities.

24. Given the high population density and lack of livelihood opportunities in the Sundarbans, complementary *spatially connective* interventions, particularly transport infrastructure such as roads to connect the stable zone to outside urban markets, are essential. Spatially connective infrastructure removes barriers and addresses issues concerning access from the stable zone to urban areas. The overall objective of these investments is to facilitate market access to urban areas, which offer greater employment opportunities, higher wages, greater access to social services, and greater security, and thereby contribute to economic integration and convergence in living standards. In addition, a complementary set of *spatially targeted*

*interventions* is recommended for stimulating economic development in the stable zone, where livelihood clusters already exist and new clusters can be created. In the core zone, spatially targeted interventions take the form of strong conservation interventions.

## Spatially targeted approaches accommodate the differences in the three zones

25. In the transition zone, the recommended approach involves measures that address human capital, health, and safety needs, and enhance job opportunities and revenues, but with minimal negative social and environmental impacts. In the short term, interventions in this zone should focus on addressing critical health and welfare issues, particularly the provision of safe water supplies, less polluting fuel sources for cooking, and improved child and maternal healthcare, as well as introduction of disaster risk management measures. These interventions should recognize the medium- and long-term objective of reducing population pressures in the transition zone. In the medium term, meeting objectives for this zone would require introducing measures to: (a) reduce population pressures by providing incentives for residents of the Sundarbans to take advantage of employment opportunities in urban areas, with incentives based on schemes that would provide residents access to enhanced healthcare and education outside the transition zone; and (b) reduce perverse incentives (for example, those associated with the ration card system and the local implementation of health referrals)<sup>42</sup> that inadvertently decrease mobility and access to services (see Annex 6 for details about perverse incentives). In addition, measures should be taken to provide skill training that would allow residents to obtain the specialized knowledge base and skills needed for: (a) sustainable ecotourism consistent with the area's carrying capacity; (b) climate-resilient agriculture; and (c) modernized aquaculture that does not interfere with ecosystem integrity. Moreover, incentives should be introduced to encourage use of environmentally sensitive technologies, such as household-level solar energy systems.

26. In the stable zone (the densely populated areas far from the natural forest), the recommended approach centers on consolidating livelihood clusters and increasing human development by enhancing human capital, establishing vocational training and support services, and improving access to education and healthcare services.<sup>43</sup> Substantial livelihood clusters exist in the stable zone and have the potential to be further developed. Enhancing cluster development requires that economic incentives be provided to encourage firms to locate in clusters; examples of incentives include provision of basic infrastructure (especially electricity and water supply), and improved health and education facilities. In addition, stable zone residents will need training to fill jobs in that zone as well as in Kolkata and other

<sup>42</sup>Current referral systems for health services ignore the reality that the “nearest” medical care center may be impossible for many households in the Sundarbans to access because of the difficult geographic terrain or lack of transport. Many of the better facilities and their staff are outside the transition zone, but the referral system has been constrained to send people to closer services, which often lack capacity and are – in any event – often not accessible because of transportation issues.

<sup>43</sup>Recall from Table E.1 that the majority of residents of the Sundarbans live in the stable zone.

urban areas. This can be accomplished by creating demand-based technical and vocational training programs, including programs for people who would be willing to seek more lucrative employment in urban areas. More generally, educational and health interventions should be implemented in the stable zone to equip residents with the human capital needed to obtain better employment opportunities that offer higher wages in urban areas.

27. In the core area, the approach emphasizes modernized conservation policies, particularly a system of property rights allocation and co-management practices that gives local residents a financial stake in forest conservation. This area, a unique and fragile ecosystem, provides a rich sanctuary for numerous rare species. The singular nature of the Sundarbans provides the basis for creating a high-value niche ecotourism sector, with supportive infrastructure for supply chain management in both the stable and transition zones. Indirect impacts through multiplier effects and explicit revenue sharing would permit communities in the transition zone to benefit without having the forest degraded. Thus, conserving this forest area provides environmental benefits while also translating the area's natural capital into a tangible economic asset for residents of the transition area, and indeed for the entire state of West Bengal. The effective use of innovations in the use of property rights is perhaps the single most important aspect of this recommended approach.

### Elements of the forward-looking strategy are influenced by issues of practicability and scale

28. The chapters that follow contain a menu of possible interventions that collectively contribute to the overall goal of sustainable socioeconomic development. The selection of recommended interventions was influenced by considerations of practicability and scale. With regard to *practicability*, some courses of action are simply not feasible for one or more of the following reasons: they are inconsistent with local physical and biogeographic conditions, degradation has already progressed beyond irreversible tipping points, costs of remediation are prohibitive, or government constitutional requirements or international obligations are preventative. For example, it is not practical to try and reclaim inundated small islands and areas already designated as uninhabitable. As other examples, polderization as a practice used in the Sundarbans in Bangladesh and raising land are not feasible in the Indian Sundarbans given the sediment availability, timescales involved, and political difficulty of displacing residents involuntarily and compensating them in order to implement this technological intervention. Degazetting parts of the Sundarbans Reserve Forest is also inconsistent with policy. A practical consideration in the social services realm is that residents must have minimal lifeline services to which they are constitutionally entitled. Consideration is also given to issues related to *scale*. In the transition zone, the approaches suggested do not involve inadvertent “overbuilding” because that might contribute to further population

pressures and make the area more attractive to potential in-migrants. Many of the proposed interventions are separable and can be timed to satisfy priorities and meet budgetary constraints. In addition, most of the near-term basic interventions are associated with immediate requirements, such as embankment repair, emergency shelters and other disaster relief measures, social service lifelines, and enforcement of existing regulations to conserve biodiversity.

### The proposed strategy reinforces the adaptive capacity of residents and biophysical systems

29. The recommended interventions, based on the NLTA studies, are grouped under four interrelated pillars:

- **Vulnerability reduction.** Vulnerability of human settlements is reduced using measures that protect residents from expected future natural hazards and serve, among others, to reduce loss of lives and assets;
- **Poverty reduction.** This is accomplished by consolidating sustainable livelihood clusters and job training programs, and by providing improved access to health and education services;
- **Biodiversity conservation.** Conservation in the core forest area also contributes to socioeconomic development; and
- **Institutional change.** These measures complement all initiatives by supporting their effective implementation.

Interrelationships exist among the four pillars. For example, development of livelihood clusters and training programs far from the Sundarbans Reserve Forest will offer new employment opportunities to those currently dependent on illegal or dangerous forest-dependent livelihoods, and the subsequent reduction of pressure on the forest ecosystem will help conserve biodiversity. As another example of interrelationships, one set of recommended interventions requires realigning (and frequently retreating) embankments to ensure their future ability to protect the populations residing behind them; this relocation of embankments will provide new areas for mangrove restoration and growth, thereby enhancing forest conservation efforts and providing bioshields to decrease adverse effects of cyclonic storms. Taken together, these pillars provide a strategy for promoting growth in the stable zone, while building the resilience of populations in the transition zone. By improving conditions in the transition zone, residents will be empowered in the longer term to integrate themselves into economic growth nodes in or beyond the stable zone. The intended long-term result will be a net decrease in the poverty level of the population at risk in the transition zone, with a concomitant reduction in pressure on the Sundarbans Reserve Forest and an increase in forest coverage. To ensure this occurs effectively, changes in institutional arrangements will be required, and those changes are a critical element in the overall strategy.







# 3.

## PILLAR 1: VULNERABILITY REDUCTION



### Sustainable Socioeconomic Development

Pillar 1	Pillar 2	Pillar 3	Pillar 4
Vulnerability Reduction	Poverty Reduction	Biodiversity Conservation	Institutional Change
<ul style="list-style-type: none"> <li>■ Disaster risk management</li> <li>■ Estuary management via threat reduction investments</li> </ul>	<ul style="list-style-type: none"> <li>■ Stemming population pressures: capturing livelihood opportunities</li> <li>■ Human capital: health, education</li> <li>■ Basic physical infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>■ Incentive measures, property rights, and co-management</li> <li>■ Conservation partnerships</li> <li>■ Mangrove restoration and marine protection</li> </ul>	<ul style="list-style-type: none"> <li>■ Implementation functions</li> <li>■ Coordination functions</li> <li>■ Bilateral cooperation between the Governments of Bangladesh and India</li> </ul>

### Managing a complex system relies on building resilience

30. Building the resilience of individuals and communities currently at risk due to natural and anthropogenic system changes and uncertain future hazards is a cornerstone of the recommended vulnerability reduction strategy; the objective is to protect lives and assets while concurrently enhancing the adaptive capacity of residents. Since embankment construction, the inhabited areas of the Indian Sundarbans have been subject to a number of significant stresses, including sea level rise from deltaic subsidence, flooding, soil compaction, salinity intrusion, and embankment deterioration. These stresses have been building over long periods of time and will persist. Climate change forecasts suggest that future hazards associated with cyclonic storms and sea level rise will become even more severe.

31. The increased intensity of extreme weather events poses a significant challenge to the safety of the residents in the Sundarbans.

During the past three decades, roughly 7,000 people have been displaced from their homes as a result of flooding, sea level rise, storms, and coastal erosion (Panda et al. 2011). Moreover, matters are likely to deteriorate as a result of local human-induced changes, including alterations in fresh-water inflows to the delta and implementation of aquaculture methods that result in increased erosion of tidal creeks. The cumulative impacts of these hazards include embankment erosion and undercutting, embankment failure and overtopping, flooding of lands with reduced drainage capabilities, declines in land productivity, and losses of life and productive assets. These impacts are most pronounced within the transition zone, where they have become part of a poverty trap in which individuals remain vulnerable because of the physical hardships coupled with low levels of socioeconomic development. The concept of “building resilience” requires that the natural threats be addressed concurrently with attempts to improve the socioeconomic status of residents, all with the long-term intention of improving the welfare of current and future generations (see Annex 8).

32. Significant adaptation is necessary under current circumstances, and will be even more important in the future as climate change projections for the Sundarbans indicate that sea level rise will continue and the region is likely to experience cyclone and storm formations of greater intensity over the Bay of Bengal. Recognizing that the Sundarbans will continue to be home to many people, a program of adaptation to reduce the loss of life and property is essential. The recommendations below involve two types of short- and medium-term interventions: (a) disaster risk management measures that address immediate needs through the implementation of early warning systems, emergency preparedness, and construction of cyclone shelters; and (b) threat reduction investments, which include embankment realignment and upgrading, mangrove bioshield restoration, and salinity management investments (see Annexes 3, 4, and 5). Funding sources for these measures include conventional development assistance as well as climate change adaptation programs that have been created by multilateral and bilateral aid organizations.

## Disaster risk management is essential for saving lives and assets

33. Disaster risk management includes several elements, one of which is a system that provides residents of the Sundarbans with timely warnings of impending cyclones. Based on a 2010 Sundarbans household survey conducted as part of this NLTA (see Annex 1), roughly 82 percent of the 2,188 households surveyed reported that they were not prepared for another adverse natural event. The same survey found that nearly 94 percent of households had not recovered financially from the impact of Cyclone Aila. The need for disaster preparedness is pronounced, especially since recent projections by the Indian Network for Comprehensive Climate Change Assessment – a network of over 220 scientists and over 120 research institutions – point to the possibility of increasingly intense cyclonic events in the Sundarbans region. Investments should be made in mechanisms to *forecast* the location and intensity of cyclonic events in the Bay of Bengal 15 to 20 days in advance of their arrival (see Annex 3). With reasonably accurate forecasts, enormous savings in lives and assets can be achieved. In addition, an effective *early warning system* should be provided, one that reaches all segments of the population in a timely manner and clearly and explicitly describes the nature of the event and the expected landfall location (see Annexes 3 and 4). In this context, the Indian Sundarbans could benefit from the lessons learned with the comparatively more advanced early warning system of the Bangladesh Sundarbans.

34. Other elements of an effective disaster risk management approach include a detailed cyclone emergency response plan, well-distributed disaster relief services, and appropriately designed cyclone shelters. These elements are essential if the disastrous consequences of cyclones such as Cyclone Aila are to be avoided (Figure 3.1). A *cyclone emergency management plan* should be developed and publicized so that GoWB personnel at all relevant agencies and ministries, as well as NGOs and other key stakeholders, are aware of the plan

and relief coordination procedures to be used in response to cyclonic storm events. Communication and coordination among relief organizations is a huge problem during emergency relief efforts; coordination procedures should thus be a central element within emergency relief plans. In addition, residents need to be made aware of the existence of a plan and any of its elements that involve their direct participation and advance preparation. The planning process should consider measures to ensure that *disaster relief services* provide residents with access to adequate quantities of safe drinking water, appropriate sanitation facilities, and medical supplies during the emergency periods. In addition, the disaster relief plan must include backup systems that can handle multiple concurrent impacts, such as destruction of some of the infrastructure necessary to mobilize the disaster services. A network of multipurpose *cyclone shelters* should also be created. Shelters should have toilet facilities and levels of privacy that accommodate women's needs; surveys have shown that women frequently hesitate to go to shelters where such basic amenities are lacking. Shelters should have elevated space for livestock and overhead water storage. In times other than an emergency, a shelter can serve as a primary school or as office space. Based on studies done in Bangladesh, cyclone shelters can typically be built in six to nine months at a construction cost of about US \$ 100 per person accommodated in the shelter (see Annex 4 for further details on the construction of cyclone shelters).

35. An important way to prevent cyclone-related damages from escalating is to reduce in-migration to the region, and one means of accomplishing this is to implement a substantial program of risk communication so that potential migrants to the region are fully aware of the significant dangers to life and property from cyclonic storms and flooding in the transition zone. Climate change and associated increases in climate variability will likely exacerbate health problems in the Sundarbans. This is especially the case in high-risk areas, which are already suffering from a shortage of resources, loss of mangroves, high rates of disease, and overpopulation. Vector-borne diseases are expected to proliferate as a result of climate change, particularly among the many residents who already lack safe drinking water and sanitation and suffer from poor health. Having an effective risk communication program in place will be critical as a means: (a) to deter people from settling in the region; and (b) to educate current residents of the dangers of inhabiting the area. In general, an effective risk communication program based on best practices can help local populations integrate climate change considerations into their decision-making and planning processes.

36. The program of risk communication should be extended to those areas in Bangladesh and India from which people migrate to the Sundarbans. The 2010 survey of 2,188 households conducted as part of this NLTA provides initial guidance regarding locations where a risk communication program targeting incoming migrants is required (see Annex 1). The survey found that 27 percent of the respondents who could recall past residential locations had migrated to the Sundarbans from Midnapore, 4.7 percent had come from other locations in southern West Bengal, 17.4 percent said that they had come from Bangladesh, and 46 percent had lived earlier in a

**Figure 3.1: Cyclone Aila Path in 2009**



different location within the Sundarbans. About 14 percent of all respondents had come to the Sundarbans from outside, suggesting that the region still possesses the potential to attract migrants. While there can be no guarantee that in-migration will be eliminated or even substantially reduced by a program of risk communication, it is practically a certainty that more people will flood into the Sundarbans in the absence of an extensive risk communication program.

## Threat reduction should focus on estuary management

37. Policies need to ensure the creation of a new strategy for estuary management, one that includes the construction of new

embankments further from the tidal channels and at heights that can accommodate immediate needs and be raised periodically as sea level rises. The 2010 household survey found that 40 percent of the 2,188 surveyed households suffered from salinity intrusion when embankments were breached. The Irrigation and Waterways Department has already taken note of the recommendations herein in constructing new, stronger embankments in the areas affected by Aila.<sup>44</sup> An intensive process of embankment reconstruction is currently underway as part of an effort coordinated by the West Bengal Irrigation Department with a large grant from GoI. This process was originally focused on rehabilitating damage caused by Cyclone Aila, but has been expanded in consistence with the NLTA modeling study results indicating that managed realignment will be necessary to prevent channel bank erosion from undercutting

<sup>44</sup>Ghosh, S. (Government of West Bengal). Comments to the World Bank's NLTA on Sustainable Development of the Sundarbans Region, June 14, 2012.



embankments (see Annexes 4 and 5). The study results point to the need for a systematic retreat of many existing embankments by 100–500 m (or 50–250 m from each bank of a channel) over the next 20 years. For a given channel, required retreat distances decrease at upstream locations. During this 20-year period, the goal is to achieve embankment heights of 5.25 m above mean sea level in the near future and to increase the heights periodically as sea level rises.<sup>45</sup> For the next 20 years, the outer (existing) embankments will need to be maintained until the interior embankments are completed. For the remainder of the century, the height of the (new) interior embankments should be increased in a stepwise fashion to keep pace with sea level rise. The modeling study, along with other analytic work conducted as part of the NLTA, provides guidance concerning the locations of new embankments and their heights for different portions of the embankment system.

38. Modeling results indicate the need to implement additional adaptation strategies in the medium term: regulating recharge of aquaculture ponds, sluicing of smaller creeks or tributaries, and closing portions of channels. These measures can decrease the size of tidal prisms and thereby reduce erosion of tidal creeks, which continually threaten the integrity of embankments. Regulation of recharge of aquaculture ponds is called for because the construction of canals allowing estuarine waters to reach aquaculture ponds for recharge purposes have significantly worsened channel bank erosion problems in many locations. Efforts should also be made to control the location of aquaculture ponds and the timing of recharge activities so that erosion problems do not continue to be exacerbated. In addition, modeling results indicate that *sluicing of smaller creeks* or tributaries and *closing portions of channels* can also serve as viable measures to reduce the erosion of tidal creeks. Cutting off upstream portions of existing channels to create freshwater reservoirs provides a potentially effective erosion control strategy because such actions decrease the size of tidal prisms.

39. In retreating the embankments in danger of being undermined by erosion of tidal creeks, the land between old (abandoned) embankments and new (retreated) embankments will become unprotected.<sup>46</sup> Mangroves should be allowed to regenerate naturally in these areas to create a bioshield to attenuate wave energy. Where erosion is occurring, mangrove restoration can be an important component of a strategy of embankment retreat. Mangroves themselves will not prevent the erosion and undercutting that is threatening many of the embankments in the Sundarbans; however, restored mangrove habitat in the newly unprotected lands will contribute to long-term system stability and

help protect communities from the impacts of natural hazards. However, the embankment retreat distances and resultant sizes of these new mangrove areas should be carefully controlled. Excessive areas devoted to mangroves as a management technique may unnecessarily increase tidal prisms, thereby exacerbating difficulties associated with augmented channel velocities, which increase erosion. In areas of accretion, mangroves will tend to grow in any event (for further details, see Annexes 4 and 5).

## Integration of Sundarbans residents into areas of lower environmental risk and greater economic opportunities

40. A significant long-term multigenerational element of the recommended adaptation strategy involves integrating the population in the transition zone into areas with *lower risk* and greater economic opportunities, which include the stable portions of the Sundarbans as well as the urban areas outside the Sundarbans. The impact of increasingly intense cyclonic storms coupled with other natural threats will make it infeasible to support, in a sustainable way, the levels of population that currently exist in the transition zone. For this reason, encouraging transition zone residents to seek out opportunities in other areas and discouraging in-migration are feasible ways to reduce the numbers of people at risk of suffering from the extraordinary hazards associated with life in the transition zone. This recommendation should be considered in the broader context of urbanization in India. Based on population projections by the McKinsey Global Institute, the number of Indian cities with populations of more than 1 million will increase from 42 in 2008 to 68 by 2030. West Bengal will move from an urban population rate of 29 percent in 2008 to 40 percent in 2030. Moreover, the population of Kolkata agglomerate is projected to increase to roughly 23 million in 2030, with a total GDP of US\$169 billion (McKinsey Global Institute 2010)<sup>47</sup> (see Annex 10 for further details on spatial transformation and urbanization in India).

41. In addition to protecting transition zone residents from environmental hazards, integration of residents of the Sundarbans into the peri-urban and urban areas in and beyond the stable zone will reduce population pressure on the Sundarbans Reserve Forest. Endemic poverty in the transition zone, combined with the shortage of sustainable livelihood options, has forced residents of the zone to illegally exploit the forest's resources, with consequent adverse effects on biodiversity. As a result of their

<sup>45</sup>A maximum sea level rise of 3 m during this century was assumed in the analytic work.

<sup>46</sup>The area of land involved in the erosion is estimated to be approximately 15,000–25,000 ha; or a maximum area approximately equivalent to that of Sagar Island. This can potentially be offset by reclamation of lands under accretion or by channel closures that will also make available new land. The loss of significant areas of agricultural land points to the need for adopting some climate-resilient agricultural practices (for example, adoption of salt-resistant varieties) so that basic food needs can be met.

<sup>47</sup>For details on the positive associations between GDP per capita and urbanization levels, see World Bank 2009. As a further example, another study based on data for 180 countries revealed a positive cross-country relationship between the level of income and the urban population share in 2000 (Bloom, Canning, and Fin 2008).



limited education and job skills, lack of access to urban markets, and the existence of perverse incentives linked to ration cards and other social programs, many transition zone residents continue to be trapped in poverty which forces them to live in a context fraught with hazards. The discussion in the next chapter details recommendations intended to enable residents to make their way out of poverty.

## Summary of options for vulnerability reduction

42. A summary of the recommended measures that make up the vulnerability reduction strategy is provided in Table 3.1.

**Table 3.1: Pillar 1: Options for Vulnerability Reduction**

Time scale	Options for action
<b>Short term</b>	<ul style="list-style-type: none"> <li>Develop a forecasting system for extreme weather events (flood and storm forecasting)</li> <li>Implement an early warning and risk communication system</li> <li>Construct multipurpose cyclone shelters</li> <li>Retreat and realign embankments</li> <li>Allow for the natural regeneration of mangroves in areas between old and retreated embankments</li> </ul>
<b>Medium term</b>	<ul style="list-style-type: none"> <li>Continue systematic retreat of embankments by 100–500 m and increase embankment height to 5.25 m above mean sea level</li> <li>Allow mangrove regeneration between old and retreated embankments</li> <li>Introduce sluicing of smaller creeks</li> <li>Close portion of channels upstream</li> <li>Regulate location and recharge of aquaculture ponds</li> </ul>
<b>Long term</b>	<ul style="list-style-type: none"> <li>Increase height of (new) interior embankments in stepwise fashion</li> <li>Continue sluicing of small creeks</li> <li>Continue closing portions of channels</li> <li>Regulate recharge of agricultural ponds to adapt to sea level rise</li> <li>Declare entire transition zone as a protected area</li> </ul>



# 4.

## PILLAR 2:

### POVERTY REDUCTION



#### Sustainable Socioeconomic Development

Pillar 1	Pillar 2	Pillar 3	Pillar 4
Vulnerability Reduction	Poverty Reduction	Biodiversity Conservation	Institutional Change
<ul style="list-style-type: none"> <li>■ Disaster risk management</li> <li>■ Estuary management via threat reduction investments</li> </ul>	<ul style="list-style-type: none"> <li>■ <b>Stemming population pressures: capturing livelihood opportunities</b></li> <li>■ <b>Human capital: health, education</b></li> <li>■ <b>Basic physical infrastructure</b></li> </ul>	<ul style="list-style-type: none"> <li>■ Incentive measures, property rights, and co-management</li> <li>■ Conservation partnerships</li> <li>■ Mangrove restoration and marine protection</li> </ul>	<ul style="list-style-type: none"> <li>■ Implementation functions</li> <li>■ Coordination functions</li> <li>■ Bilateral cooperation between the Governments of Bangladesh and India</li> </ul>

#### Improved livelihoods go hand in hand with reduced population pressures

43. As mentioned, reducing population pressures in the transition zone of the Sundarbans must be a central element in a program for sustainable socioeconomic development; and expanding livelihood options in the stable zone provides one mechanism for reducing that pressure. A key approach to decreasing population pressures in the transition zone involves risk communication, which, in this context, entails making existing residents and potential migrants into the region aware of the likelihood that sea level will continue to rise and that climate change is expected to increase the intensity of future cyclonic storms. However, other strategies are needed, one of which concerns augmenting livelihood options in the stable zone. Employment opportunities in the stable zone must be expanded for two reasons: (a) the majority of residents of the Sundarbans live in the stable zone; and (b) expanding the number and types

of employment opportunities in the stable zone will make that zone attractive as an alternative location for transition zone residents who can choose to remove themselves from the hazardous living conditions that prevail in that zone.

44. In addition to expanding livelihood options in the stable zone, enhanced employment opportunities must be provided for the transition zone residents who choose to remain in the area, and those opportunities must be environmentally sustainable. The principal possibilities for improving livelihoods in the transition zone consist of opportunities in the following areas: sustainable ecotourism, agriculture and fisheries, and the limited harvesting of nontimber forest products. The discussion below concerning agriculture and fisheries is also relevant to the stable zone. The recommended actions to improve livelihoods would undoubtedly reduce pressure on the Sundarbans Reserve Forest because those now exploiting the forest would have more attractive livelihood options.<sup>48</sup> In addition to the provision of expanded livelihood

<sup>48</sup>Indeed, the aforementioned 2010 household survey found that 93 percent of 2,188 surveyed households reported that they would not be dependent on forest resources if there were other livelihood opportunities available.

opportunities, poverty reduction measures include actions to enhance human capital in ways that equip transition zone residents to pursue more attractive livelihood options in urban areas. The following are among the key measures to augment human capital: enhancing education and healthcare, reducing indoor air pollution, and providing safe water supplies, thereby cutting rates of morbidity and mortality (see Annexes 7 and 8 for assessments of health outcomes in the Sundarbans). Other key recommendations for reducing poverty involve provision of essential energy and transport infrastructure.

45. A strategy for poverty reduction based on *sustainable* livelihood opportunities requires eliminating all unsustainable income-generating activities currently taking place in the forest. These activities are illegal, but it is difficult to eliminate them using only regulation. Thus, it is recommended that regulatory strategies be supplemented by economic incentives that motivate residents to preserve the forest resources as a way of generating income for individuals and communities. This subject is examined in depth in Chapter 5 in the context of biodiversity conservation.

### **Livelihood clusters in the stable zone can become important sources of employment**

46. Opportunities exist to develop livelihood clusters in the stable zone, that is, the peri-urban areas closer (and relatively well-connected) to Kolkata and containing established settlements, such as Bakkhali, Canning, Jaynagar-Majilpur, Minakhan, Namkhana, and Tengrabichi. The employment growth envisioned for the stable zone would primarily be in value-added resource-based jobs, such as those linked to fisheries, but also including commercial or light industrial employment jobs in associated service sector activities that one would find in any urbanized economy (for example, trading, repairs, wholesale). Not all parts of the stable zone are suitable for cluster development, however, and thus care would need to be exercised so that clusters are located only in zones that will not be subjected to high risks from storms and sea level rise. In the context of the regional economic development theory, large agglomerations such as Kolkata are sometimes called “growth poles” (Dawkins 2003), and the suggested plan for the stable zone is the formation of secondary (or even tertiary) growth poles in an organized fashion, one that avoids cluster formation in areas that are likely to be unstable as a result of sea level rise and other hazards.

47. The livelihood clusters in the stable zone could be consolidated to provide job training and support services. These services can help promote the processing and allied services for local fruits, honey, vegetables, and medicinal plants, and production of durable or nondurable goods and local handicrafts. In addition, if the clusters included improved infrastructure for transport and storage of fish catches, they could promote and support sustainable fisheries. Industrial facilities in the peri-urban areas of Kolkata currently meet the outsourcing needs of firms in Kolkata. The infrastructure and services in the stable zone could be upgraded, particularly infrastructure for provision of reliable electricity and safe water supply and sanitation facilities. Labor and skill training programs for potential employees in the stable zone and those seeking economic opportunities in urban areas should also be provided. Investments in the stable zone should be made in ways that minimize negative impacts on the transition zone (see Annex 9 on enhancing livelihood opportunities).

### **Providing enhanced health and educational services in the stable zone is imperative for long-term economic success**

48. Providing educational and health services in the stable zone is needed to enhance human development capacity and to allow residents to pursue new livelihood opportunities created in the stable zone and in urban areas. Financial assistance for health and education (which are described below) could be offered to residents of the Sundarbans to promote improved health and schooling so that, in the long run, residents are equipped with the human capital necessary to pursue better paying jobs in the stable zone as well as in Kolkata and other urban areas<sup>49</sup> (see Annexes 8 and 9). Currently, Canning, Namkhana, and other clusters of livelihoods in the stable zone are relatively well connected to Kolkata and other major population centers by road, railroad, and sometimes by waterways, and they contain institutions meeting some of the health and educational needs of the hinterland.

49. The recommended strategy of this NLTA recognizes and capitalizes on the gradual increase in urbanization that India will experience in the coming decades. Given the abundant research showing the power of cities as engines of economic growth, increased urbanization can prove to be helpful in lifting many residents of the Sundarbans out of poverty. The role of urban areas in promoting economic growth is linked to “agglomeration economies.”<sup>50</sup> Agglomeration fosters industrial growth because it promotes: (a)

<sup>49</sup>There is much literature pointing to the strong positive association between education and income, for example, Sianesi and Reenan 2000, and Psacharopoulos 1985. There is a consensus in the existing literature that education is an important determinant of individual earnings in the long run as well as long-term economic growth.

<sup>50</sup>“Agglomeration economies” include within-industry and inter-industry economies. Within-industry economies arise when a large number of firms in the same industry locate in the same place. Locating near competitors allows firms to “stay abreast of market information in negotiating with customers and suppliers... [and] share a larger and more dependable pool of specialized labor.” Inter-industry economies occur when large numbers of *different* industries locate in the same area. This allows them to benefit from locating near large suppliers of complementary services usable by firms in different sectors, such as banking and legal services, and marketing and advertising agencies; they can also benefit from being near universities and vocational training centers. The quoted material is from World Bank 2009.



sharing of ideas, information, and knowledge among firms; (b) labor market pooling; and (c) input–output linkages among firms (Marshall 1890). Spatial proximity of firms also attracts suppliers and consumers to urbanized areas (Breschi and Lissoni 2003). The advantages of cities are not limited to greater employment opportunities. Education systems may be more effective in cities, given that schoolteachers are generally in greater supply there in comparison to rural areas. Moreover, cities have relatively large pools of healthcare workers, which can allow urban residents to readily access better healthcare services than their rural counterparts.

50. Findings from the NLTA highlight the importance of urban areas, such as Kolkata and its environs, in offering better living standards (including employment opportunities and education) compared to those offered in the Sundarbans. Evidence shows that, over multiple generations, the descendants of the rural poor who seek livelihood opportunities in urban areas are better off than they would have been if their families had remained rural residents (Glaeser 2011, p. 7; Ravallion 2007).<sup>51</sup> Moreover, urban economic growth can positively impact the living standards of those who remain in rural areas not only because of remittances sent back to them by family members, but also because fewer people are left in rural areas to compete for jobs.

## **Sustainable ecotourism – if pursued in a careful and limited way – can be a significant asset**

51. The portion of the transition area near the Sundarbans Reserve Forest can support a limited extent of *high-end, environmentally sustainable ecotourism*. The most important reasons for visitors traveling to the Sundarbans Tiger Reserve<sup>52</sup> and Sundarbans National Park<sup>53</sup> are the opportunity to see wildlife, particularly the elusive Royal Bengal tiger, and the natural mangrove scenery and landscape. For fragile ecosystems such as the Sundarbans, only limited, low-impact ecotourism, as opposed to mass tourism, is recommended. The spread of unregulated mass tourism<sup>54</sup> will degrade the natural resources of the Sundarbans to a point at which it will no longer have any value for local people or visitors. The

singular nature of the Sundarbans provides the basis to attract both domestic and international high-end and environmentally sensitive tourists, thereby increasing livelihood opportunities for communities in the transition zone without degrading the forest resources (Figure 4.1). A survey conducted as part of the analytic work for this NLTA showed that there is demand from high-end international and domestic travelers for nature- and ecotourism-based activities in the Sundarbans. In a sample of surveyed travelers<sup>55</sup> from more than 20 countries, English-speaking foreign tourists constituted the largest percentage (43.8 percent) of total visitors. This group comprised tourists from the United Kingdom (24 percent), the United States (9.4 percent), Australia (5.2 percent), Canada (4.2 percent), and New Zealand (1 percent). The other group of travelers of notable size was from Germany (11.5 percent). Together with France and Spain, these countries collectively constitute important and well-established tourist-generating markets. In addition, roughly 18 percent of the surveyed visitors were from India, which suggests that the domestic market can provide a solid base for initiating sustainable ecotourism development; this could be followed by the eventual expansion into the international market as the tourism product of the area improves. Interestingly, the survey also revealed that the majority of respondents (69 percent) were willing to pay more if the revenue generated as a result of the increase in the price was to be channeled toward the improvement of facilities and the preservation and conservation of the Sundarbans Tiger Reserve and National Park, rather than being used to finance the Forest Department's recurrent operating budget.

52. The tourism strategy for the region should be reviewed and modified to eliminate current unsustainable practices, which are tied to mass tourism. The spread of poorly regulated mass tourism will degrade the natural resources of the Sundarbans Reserve Forest and the transition zone to a point at which the area would have little value for high-end and environmentally friendly ecotourists, and the local environment would suffer badly. Tourism-related interventions should be based on internationally recognized guidelines for nature tourism, such as those advocated by the George Washington University and the Adventure Travel Trade Association.<sup>56</sup> The approach should be one that explicitly recognizes limits on the carrying capacity of the most fragile parts of the

<sup>51</sup>For analyses of the ways in which the lives of poor families shift over time, see also Narayan, Pritchett, and Kapoor 2009.

<sup>52</sup>The Sundarbans Tiger Reserve comprises a total area of 2,585 km<sup>2</sup> and constitutes a major part of the 4,260 km<sup>2</sup> Indian Sundarbans forested area. Situated in the West Bengal coastal district known as South 24 Parganas, it is one of the first of 27 tiger reserves established in 1973 by the Indian government as part of its globally renowned Project Tiger conservation efforts. See <http://projecttiger.nic.in/index.asp>.

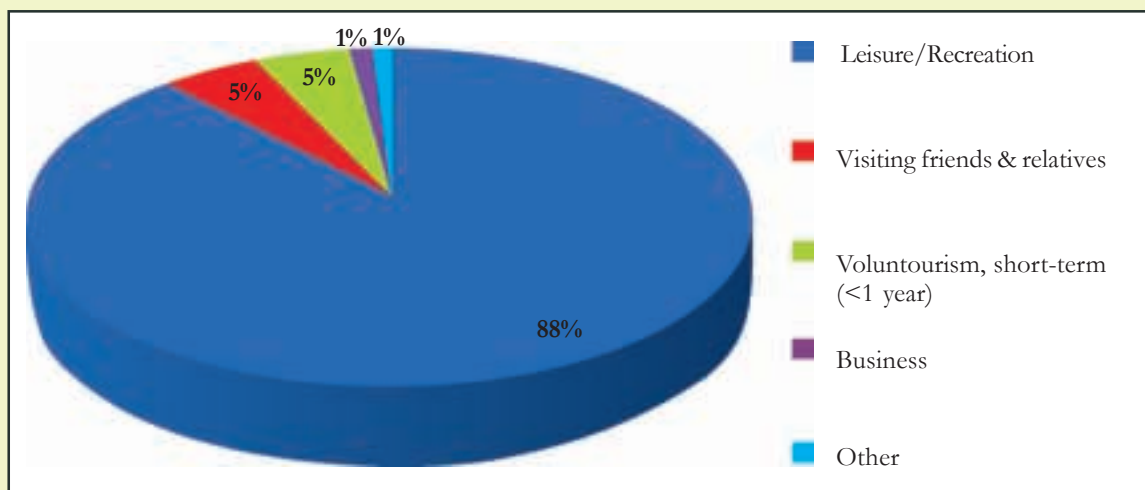
<sup>53</sup>The Sundarbans National Park is an area that is designated within the core area of the Sundarbans Tiger Reserve, where visitors are not allowed.

<sup>54</sup>Mass tourism has been shown to be not sustainable, as it rapidly degrades natural and cultural resources. Mass tourism approaches tourism as a commodity, and emphasizes marketing. Growth takes precedence over all other considerations, including the welfare of local people and environmental conservation. According to Seema et al. 2006: "Mainstream tourism is geared towards tourist satisfaction and sustainable ecotourism, on the other hand, has conservation (of nature and culture) and livelihoods (economic and educational benefits) as essential constituents." Understanding the results of mass tourism provides further support for adopting a high-end, environmentally sustainable ecotourism approach in the Sundarbans, an especially sensitive area with unique and precious assets.

<sup>55</sup>As part of the analytic work a total of 96 visitors were surveyed in three different locations: Sundarban Tiger Camp (private); Sajnekhali Tourist Lodge (government owned); and Sundarban Jungle Camp (private). The survey questionnaire contained 24 questions on visitors' demographics, perceptions about the location, suggestions for improvements, and other matters.

<sup>56</sup>See <http://www.gwutourism.org/iits/ATDI.htm> for more information.

**Figure 4.1: Visitor Travel Interest in the Sundarbans**



ecosystem. Areas outside the transition zone (such as Sagar Island) could potentially be considered as touristic areas that offer experiences appealing to relatively large numbers of middle-income domestic tourists.

53. Tourism in the Sundarbans must be promoted as a seasonal activity to minimize the risks associated with adverse natural events, such as cyclones. Nine of the 14 global tropical cyclones associated with the highest fatalities have occurred in the Bay of Bengal. Given the projected increases in the frequency and intensity of storms and cyclones in the region, the potential future impact on environmentally sustainable and high-end ecotourism hinges on the careful promotion of tourism during times in which storm surges and cyclones are minimal. The Bay of Bengal is subject to both types of storms during the spring and autumn. However, cyclones occur more frequently in the months of October–November, while most major convective storms cause impacts in the months of March–May. Environmental factors have been found to be important in determining the holiday destination for potential tourists (Braun et al. 1999, cited in Sookram S.). Storms and cyclones are likely to have negative impacts on the personal safety of tourists, and can deter potential tourists from visiting the Sundarbans. In addition, the government should devise detailed emergency response plans for tourists to ensure their safety during the course of an adverse natural event.

54. The ability to draw in high-end and environmentally sensitive ecotourists requires: (a) strict conservation within the forested areas, which are the zones attractive to ecotourists; and (b) development of near-zero environmental impact tourism infrastructure (for example, tented camps) within the transition area near the Sundarbans Reserve Forest. Transport with low environmental impact should be used to carry people to and from the Sundarbans

from entry points to the Sundarbans Reserve Forest (for example, Sonakhali via Canning or Bagna via Dhamakhali). Currently, most visitors come from these entry points on large tour buses, autos, and motorized boats, or a combination thereof. These transport modes have high impacts on the fragile environments being traversed. In-depth analyses and design exercises should be undertaken to identify ways to effectively regulate and mitigate air pollution and noise from the existing transport modes used in reaching the Sundarbans Tiger Reserve and National Park.

55. Environmentally sustainable ecotourism has the potential to offer livelihood opportunities for some of the transition zone residents who wish to remain in the region. A study in two villages in Gosaba concluded that tourism could be an effective driving force to reduce poverty by improving incomes of households that have relatively low human capital formation (Guha and Ghosh 2009).<sup>57</sup> The study examined living standards, as reflected by household monthly per capita expenditures, in Pakhiralay and Dulki villages. In comparison to Dulki (where households did not participate in tourism-related work), households engaged in tourism-related jobs in Pakhiralay had higher living standards, even though they had lower per capita landholdings and lower literacy and primary education completion rates. The tourism product now being offered in the area is not diverse and mature enough to increase the number and size of the local tourism businesses to the level that would provide full-time jobs. That would require an increase in the scale of sustainable ecotourism activities, but care must be taken to maintain a scale that does not exceed the area's carrying capacity for environmentally sustainable ecotourism. Scale could be increased via a marketing campaign to promote the attractions of the area for a number of other activities, such as birdwatching and guided programs run by trained local guides that take advantage of the extraordinary range of plants, birds, and

<sup>57</sup>In terms of a “trickle down [multiplier] effect”, the study revealed that the households that gained income from tourism did not contribute to the economic growth of the village economy. For the tourism multiplier to have a wider economic impact, more local jobs need to be created in the area to generate more intra-village tourism service transactions.

mammals that environmentally sensitive ecotourists would come to see. In addition, the villages of the transition zone could generate jobs and income by training tour guides, showcasing food and other aspects of the local culture, and creating and selling locally made handicraft items.

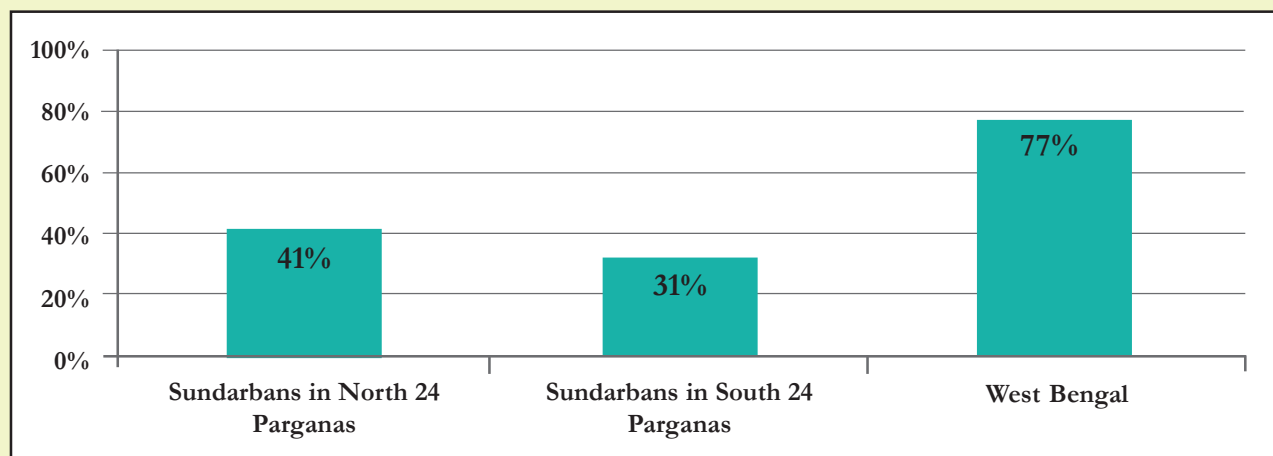
## Traditional pursuits of agriculture, fisheries, and forestry can continue to play key roles

56. Efforts should be made to improve the productivity of agriculture in a sustainable manner in the Sundarbans. Agriculture is an important source of livelihood in the Sundarbans economy. Nearly 60 percent of the total working population depends on agriculture as a primary occupation (see Annex 9). However, there is a high degree of risk associated with agriculture in the Sundarbans as a result of high salinity levels,<sup>58</sup> lack of fresh-water availability, and the small size and fragmentation of landholdings (the average landholding among cultivators is just 0.36 ha),<sup>59</sup> which together limit the long-term viability of agriculture in the region. Fresh-water aquifers are available, on average, only at depths of 160–400 m. An analysis<sup>60</sup> of more than 10,000 soil samples taken from eight blocks of the Sundarbans found that 32.4 percent of the samples have high salinity levels.<sup>61</sup> Low agricultural productivity is reflected in the poor levels of cropping intensity<sup>62</sup> in the Sundarbans (Figure 4.2). Improvements in agricultural productivity can be accomplished by placing more emphasis on climate-resilient agricultural practices, including adoption of salt-resistant paddy seeds. Improvements will also require programs of training and

dissemination of information regarding saline-resistant paddy varieties and organic farming practices, which are vital for maintaining soil fertility and ensuring sustainable levels of agricultural output. Farmers can be offered combination packages of services (for example, land and water testing and training) as part of the effort to improve agricultural sustainability (see Annex 9 for further details).

57. Development of modernized aquaculture should move in the direction of more semi-intensive and intensive operations, and the adverse environmental effects of current prawn seedling collection methods should be eliminated by the use of hatcheries. India is the second largest fish producer in the world, producing 2 million tons annually (FAO 2007). The state of West Bengal is the largest fish producer in India, which is dominated by production in North and South 24 Parganas. Based on the total production for 2007–08, West Bengal alone would be the 19th largest fish producer in the world. A separate study found that the estimated total number of inland fisher families in South and North 24 Parganas were 52,917 and 50,897, respectively (GoWB 2005). As is the case for agriculture and other actions that exploit natural resources, aquaculture operations involve some unavoidable and significant adverse effects. The overexploitation of shrimp fry severely limits the amount of adult shrimp available (Knowler et al. 2009). Moreover, the conversion of agricultural land into shrimp ponds by commercial shrimp aquaculture operators threatens the livelihoods of agricultural farmers. As another example, a major aquaculture-related problem in the Sundarbans concerns what is referred to as “by-catch,” the unintentional discarding of enormous numbers of juvenile finfish, shellfish, and other aquatic species that

**Figure 4.2: Cropping Intensity in the Sundarbans**



<sup>58</sup>Soil salinity in the Sundarbans results primarily from two factors: (a) inundation by tidal waters due to breach of embankment; and (b) capillary action of water in the soil bringing up salts from the layers below during the Rabi season. For further details, see Annex 9.

<sup>59</sup>Calculated as net cropped area in ha per number of cultivators.

<sup>60</sup>Analysis conducted by the agriculture cell at the Tagore Society for Rural Development, Rangabelia.

<sup>61</sup>Electrical conductivity of > 3 millimhos/centimeter.

<sup>62</sup>Cropping intensity represents the number of crops that are harvested in a year from a given piece of land and is calculated as the ratio of gross cropped area to net cropped area, expressed as a percentage. The higher the cropping intensity, the higher the returns to the farmer.

occurs during prawn seedling collection using fishing nets.

58. The use of hatcheries to obtain prawn seedlings, with appropriate codes of conduct, can minimize adverse environmental effects (particularly, the depletion of aquatic species) and realize gains from a modernized aquaculture sector. Implementing international standards for responsible fishing practices, such as the Code of Conduct for Responsible Fisheries, can help promote long-term sustainability in the aquaculture sector. Impediments to the creation of hatcheries in West Bengal include technical problems – mostly related to salinity conditions in West Bengal – and short-term market-related problems. However, some of these problems can be circumvented if there is a clear focus and understanding of the importance of the issue and if sufficient resources are dedicated to this task. Also, a program should be created to identify possible new commercially significant species (analogous to recent research into the potential for culture of cobia and pangasius fish species) that could prove successful under conditions found in the Sundarbans. In addition, postharvest losses can be reduced by providing improved infrastructure for the storage and transport of both aquaculture yields and fish catches using traditional methods. Facilities for refrigeration, in particular, are needed as a mechanism for reducing losses. Finally, an improved storm warning system should also include methods for ensuring that warnings are delivered to fishers so that their cyclone-related risks can be minimized.

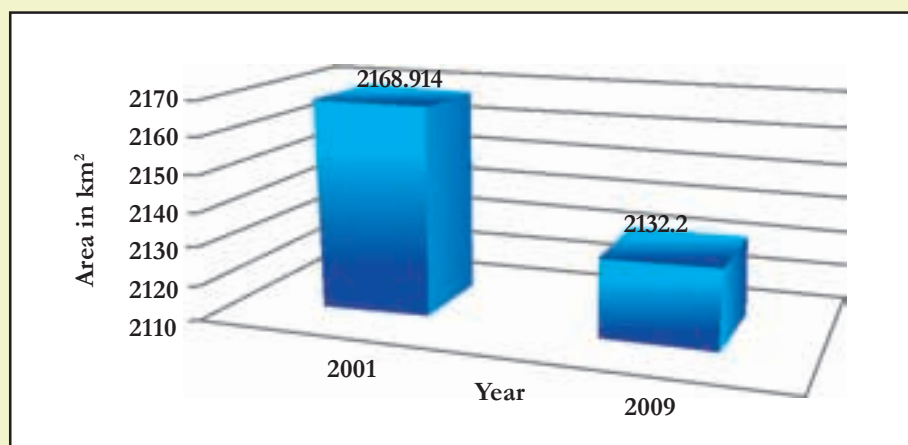
59. Forestry activities in the Sundarbans should be directed away from the Sundarbans Reserve Forest, where such activities are illegal, and toward naturally regenerated mangroves. At least 25 mangrove species in the Sundarbans are vulnerable to extinction, currently endangered, or critically endangered, according to the International Union for Conservation of Nature (IUCN) 2010 Red List of Threatened Species. Mangrove harvesting remains illegal throughout West Bengal. A near-term focus should, therefore, be on harvesting nontimber forest products, such as honey, fruits, or fishery products (see Annex 9 for further details). In the future, consideration should be given to providing incentives for sustainable harvesting of timber

and nontimber products in the context of managing a growing plantation supported by community-based revenue sharing. Revenue-generating activities based on nontimber forest products and sustainable harvesting of plantations can work in tandem with schemes to share revenues from carbon financing opportunities. As detailed in Chapter 5, the central idea is that providing opportunities for a community to share in revenues from sustainable forest management can motivate it to monitor and report activities that destroy the resource base on which community revenues depend.

60. Lack of skills and training, insufficient information about jobs, limited local income-generating opportunities, and sex trafficking networks are some of the factors that drive girls and women into sex work. Young girls (10 to 15 years old) from poor families are often sent to distant areas to earn income and many often wind up in the sex industry. The long distance and lack of communication with family makes girls easy prey for sex traffickers who convince parents that they will help them find jobs and spouses for their daughters. Adult women who migrate out primarily do so for domestic work and for sexual labor. Many women migrants not employed as domestic workers end up employed in the sex trade. Sex trafficking networks are active in even the most remote areas, and control by police and GPs has proven very difficult. Laws and systematic efforts for the protection of girls and women have not been effectively implemented. There have been no systematic efforts to identify focal transit points where sex trafficking of girls takes place, train enforcement personnel to conduct surveillance in those areas, or educate parents of the risks of trusting strangers with their children. There are only a few NGOs and local-level organizations that provide systematic interventions to protect girls from entering (or being forced into) sex work and underage marriages, as well as providing support to women in acquiring skills and training, and helping women identify employment opportunities outside the region.

61. A program to meet sustainable development objectives should include investments in special services for women and girls seeking employment opportunities in urban areas and interventions to protect

**Figure 4.3: Total Forest Cover Changes in the Indian Sundarbans**





them from harassment and abuse. Recommendations on these subjects are highlighted below. Additional interventions that support women and girls are discussed in subsequent recommendations concerning education and public health.

- **Information networks for women and girls leaving the Sundarbans.** Efforts should be channeled through new or existing organizations with rural–urban linkages to improve conditions for women and girls by means of: (a) providing information on available jobs and training; (b) offering financial and health services and information on work opportunities in destination areas; (c) issuing identification cards; and (d) establishing shelters on routes commonly taken by migrants. Organizations contributing to the safety and general welfare of women (including sex workers) who are vulnerable to physical and mental abuse should be supported financially as part of an effort to create a support network for women and children; and
- **Enforcement of laws protecting women and girls.** National laws protecting women and girls need to be effectively enforced in the Sundarbans. Efforts should also be made to educate parents on the risks of giving their children away to unknown individuals. There are related needs to identify focal transit points where sex trafficking takes place, and to train enforcement personnel to monitor those areas so that sex traffickers can be apprehended and punished. Additionally, increased job opportunities for women need to be created to keep them from resorting to or being forced into sex work to generate much-needed income. NGOs have been active in helping sex victims, and it is likely be cost-effective to work alongside NGOs to establish counseling services and temporary shelters that provide emotional support and medical assistance to abused victims.

## Access to education is a prerequisite for labor market success

62. Individuals must have sufficient education to be competitive in the workplace in the livelihood clusters created in the more densely populated stable zone of the Sundarbans and outside the region. However, there are numerous challenges to educating students in the transition zone. Poverty-stricken households have difficulties obtaining funds needed for school fees, books, uniforms, and transport. The lack of a reliable water-based transport system causes students to miss school regularly. In addition, boys often drop out of school to earn money, and girls are married off; the latter occurs partly because of social norms and partly to relieve financial burdens (see Annex 8). In terms of infrastructure, there are inadequate water supply and toilet facilities in primary and secondary schools. There has been a lack of emphasis on secondary education in the region. Indeed, research conducted

under this NLTA found a marked dropout rate by which the 90 percent enrollment at the primary level markedly declined with transition to higher levels of education. College and vocational education in the region is almost entirely nonexistent. The nonavailability of any formal training institutions for skill development prevents residents from securing employment in more technical fields. In addition, lack of English education in schools is a major barrier to employment.

63. The delivery of education to local residents in the Sundarbans must be reconsidered given the challenges in accessing schools and maintaining quality of service in the transition zone. Interviews<sup>63</sup> conducted on behalf of the NLTA with students and parents revealed two key findings: (a) parents expressed a strong understanding of the importance of education in securing employment; and (b) students showed a strong interest in pursuing higher education in order to secure employment in areas other than agriculture. An important finding from the 2010 Sundarbans household survey (conducted as part of the NLTA) revealed that roughly 85 percent of the surveyed 2,188 households would be willing to send all their children to schools in the stable zone or other parts of West Bengal, which indicates that many residents would find it attractive to have their children attend schools in urban areas.

64. Educational incentive programs, based on providing financial assistance in the form of scholarships for children to pursue their educational career, can be continued and strengthened to help address financial constraints that keep children from attending school.<sup>64</sup> Financial assistance should continue being offered to existing (not new) families in the transition and stable zones, but only on condition that their children enroll in schools in the relatively safer areas of the stable zone. In addition, financial assistance for post-secondary school training could cover a student's tuition and living expenses as well as provide money to families to help cover the income that would otherwise be earned if children did not extend their education beyond high school. The amount of the financial assistance could increase as the student progressed from one education level to the next, thus reducing dropout rates during transitions. Such programs have had broad success in Mexico, Brazil, Pakistan, and other countries (Soares et al. 2007; Chaudhury and Parajuli 2006). Pilot programs involving financial assistance for education should only be attempted in areas where the existing schools have proven to be effective in enhancing children's education. Moreover, parents can be further incentivized to send their children to school by expanding and intensifying national and state programs for improving the nutritional status of children in schools (such as the Mid-Day Meals Program); enhancing the quality of education in schools; and improving school water supply systems and latrines (especially for girls).

<sup>63</sup>A total of 34 focus group discussions were conducted on behalf of this NLTA, in which 24 were student focus group discussions and 10 were parent focus group discussions. Each group consisted of six members. Student focus groups were a mix of male and female members. Parent focus group discussions were conducted separately for fathers and mothers.

<sup>64</sup>Ghosh, S. (GoWB). Comments to the World Bank's NLTA on Sustainable Development of the Sundarbans Region, June 14, 2012.

65. Sundarbans residents in the transition and stable zones will need training to fill jobs offered in the livelihood clusters and peri-urban areas far from the Sundarbans Reserve Forest as well as in Kolkata and other urban areas. Demand-based technical and vocational training programs should therefore be created (outside the transition area), particularly for people from the transition area who would be willing to relocate to seek more lucrative employment. The 2010 Sundarbans household survey found that 78 percent of the 2,188 surveyed households supported the implementation of labor training programs in Kolkata and other areas of West Bengal. The World Bank experience with a conceptual framework known as “Stepping up skills – for more jobs and higher productivity” can provide a basis for thinking through alternative education program designs. The framework was developed to assist those designing education policies and programs to prepare individuals for employment. It includes five interlinked steps: (a) *getting children off to the right start* in early childhood, which in the case of the Sundarbans would involve both the home environment and primary school; (b) *ensuring that all students learn* by having well-trained teachers and adequate resources for schools; (c) *building job-relevant skills that employers demand*, which in the case of the Sundarbans would relate to jobs created in the new livelihood clusters as well as skill development to prepare individuals for work in tourism, agriculture, aquaculture, and fisheries; (d) *encouraging entrepreneurship and innovation* by developing appropriate incentives for both pre-employment and on-the-job training programs; and (e) *matching the supply of skills with the demand*, which would mean providing information and intermediation services for both residents of the transition zone seeking employment and firms in the various sectors looking for employees. In addition, intensifying national and state programs aimed at increasing the literacy and numerical skills of residents of the Sundarbans (aged 15 years and older) can help equip adult residents with basic skills needed for employment (see Annex 8 for further details on the recommendations for improving human capital).

## Access to quality health services is in critical demand

66. The principal health-related issues facing residents of the Sundarbans should be addressed in the short and medium terms. Residents of the Sundarbans face numerous health challenges, and the population’s health status is poorer than in other districts of West Bengal. In the rural areas of the Sundarbans (which constitute most blocks close to the forest), residents reported issues with airborne diseases, especially acute respiratory infections, which are common in many parts of rural India where households rely on traditional biomass-based cooking stoves. Respiratory illnesses show high relative prevalence in blocks such as Sandeshkhali I, Canning I, Canning II, and Kakdwip, with several blocks registering a rising trend. In addition, given the marshy and

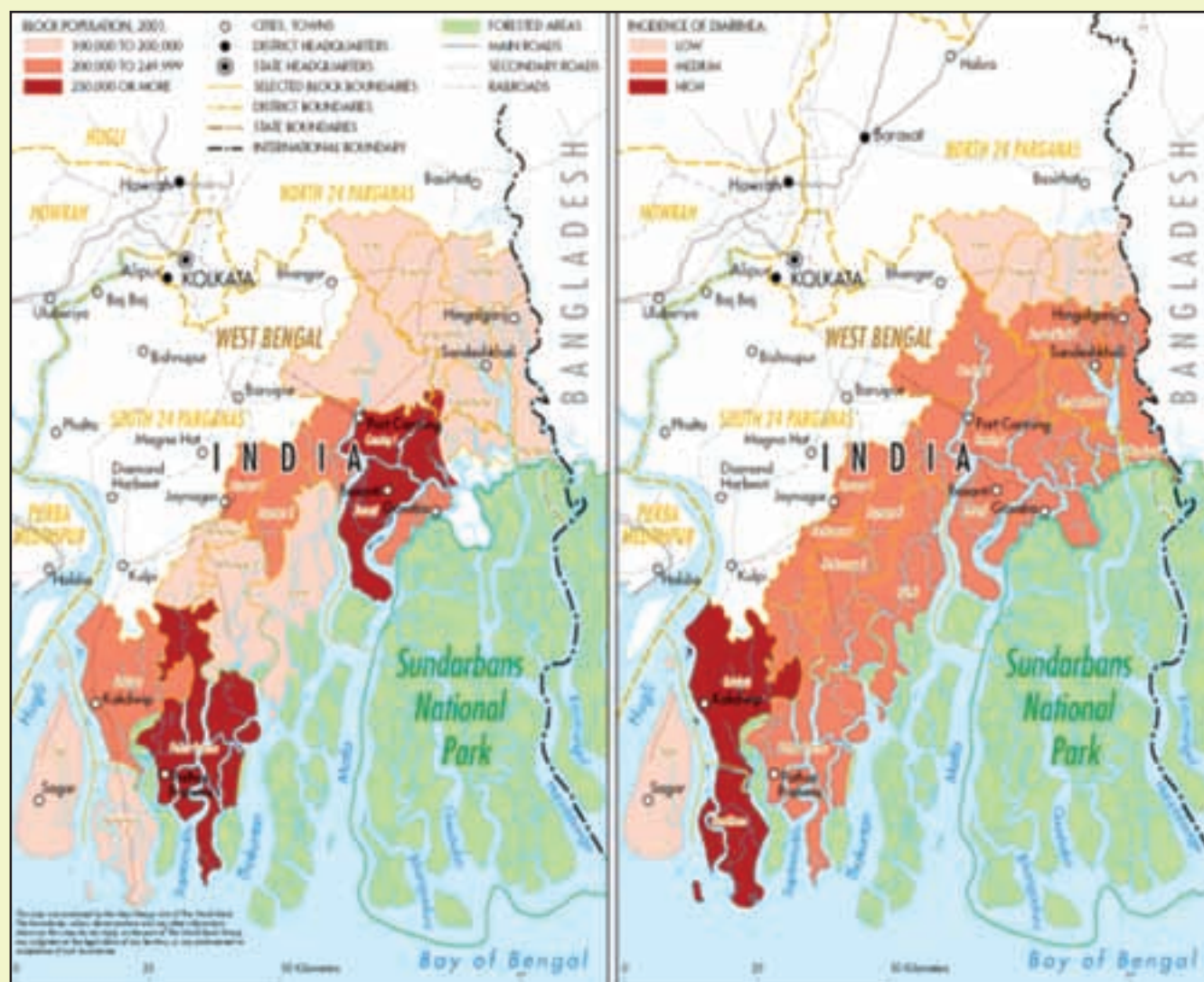
wet conditions of the Sundarbans, residents suffer from persistent gastrointestinal disorders (particularly diarrhea, as shown in Figure 4.4) and respiratory problems, as well as water- and vector-borne diseases. Pneumonia and sexually transmitted diseases are also prevalent, and people whose livelihoods depend on forest and river products are under constant threat of animal attacks (particularly from crocodiles and tigers) when they enter the forest. Compared with other districts in West Bengal and the national average in India, there is an inordinately high prevalence of mental health problems, and there is chronic malnutrition in about half of the number of children (below five years of age). Moreover, current referral systems for health services ignore the reality that the “nearest” medical care center may be impossible for many households to access because of the difficult geographic terrain or lack of transport. Many of the better facilities and their staff are located outside the transition zone, but the health referral system has been constrained to send people to services that often lack capacity and are – in any event – not accessible because of transportation issues.

67. Women and children face particularly high health risks for two reasons: environmental factors, and low levels of institutional healthcare delivery because of the challenging geographic terrain. Notwithstanding the increase in birth deliveries in medical institutions in 2008–10 in all blocks, institutional deliveries in the Sundarbans lag with a low average rate of 22 percent. Rates of dropout from the complete antenatal care cycle are high despite monetary incentives being provided through national programs. In addition, difficulties in accessing healthcare facilities are pervasive, both for patients and health workers. The immunization rate for the Sundarbans is 43 percent, against 88 percent in North 24 Parganas district as a whole, and 73 percent in South 24 Parganas district. The low immunization rates are due to low female literacy and lack of awareness, low availability of health personnel, and inadequate cold chain logistics.<sup>65</sup> Infant and maternal mortality rates reported for the Sundarbans are unusually low, but the official rates probably under-represent the reality because of irregular field visits by healthcare personnel due to difficult terrain and poor accessibility. Information collected as a part of this NLTA indicates that there is likely to be relatively high maternal mortality in the Sundarbans for several reasons: poor nutrition, prevalence of anemia among pregnant mothers,<sup>66</sup> and young age at marriage, which is associated with increased likelihood of infant mortality and morbidity. Children also have significantly lower health outcomes in the Sundarbans; for example, as pointed above, chronic malnutrition has been observed among children between the time of birth and age five. In the North 24 Parganas blocks of the Sundarbans, Grade I and Grade II category malnutrition surpasses that in the non-Sundarbans areas, while in South 24 Parganas the levels are equivalent. Malnutrition in the Sundarbans is the result of marginal dietary intake compounded by infection, low income, and lack of clean water (see Annexes 7 and 8 for further details on current health outcomes).

<sup>65</sup>Because most vaccines have specific temperature requirements, an effective cold chain and logistics management system prevent both excessive heat and cold from damaging the vaccines from the time of manufacture until they are used.

<sup>66</sup>Based on 2006–07 records, about 21 percent of the pregnant women in Sundarbans blocks of South 24 Parganas suffered from anemia.

**Figure 4.4: Incidence of Diarrhea in the Sundarbans**



68. Key public health issues will need to be addressed to build the human capital of the local population. At present, the residents of the Sundarbans face severe health risks that undermine health and well-being, and this makes it difficult to pursue socioeconomic development possibilities. About 1,700 children under five years of age died from inadequate provision of water supply and sanitation services in the Sundarbans in 2008 (Table 4.1). This represented 29 percent of total under-five child mortality, of which about 40 percent was from diarrheal mortality and 60 percent from the effects of diarrhea on child nutritional status and consequent increase in mortality from infectious diseases. Water supplies contaminated with arsenic are common in some blocks; for example, groundwater is heavily contaminated in the Hasnabad block in North 24 Parganas,

with arsenic concentrations greater than 50 milligrams per liter (mg/L), and there have been several recorded cases of arsenic poisoning. Malaria is endemic in the Sundarbans, and the annual parasite incidence<sup>67</sup> has shown a rising trend, particularly in the post-Aila period. High prevalence of *Plasmodium falciparum*, the most dangerous type of malarial infection, has been reported in a number of Sundarbans blocks. Leishmaniasis (kala-azar) is another vector-borne disease prevalent in some blocks of the Sundarbans; causes include poor socioeconomic status, inadequate sanitation, unsafe water supply, and poor housing facilities. Tuberculosis continues to be a major health problem in the Sundarbans and, as in all of India, it is the main cause of death for adults who die of infectious diseases. Pulmonary tuberculosis accounts for about 85 percent of all new

<sup>67</sup>Annual parasitic incidence refers to the number of blood smear tests found positive for the malaria parasite in a year per 1,000 population.



**Table 4.1: Estimated Annual Child Mortality from Inadequate Water Supply, Sanitation, and Hygiene (WSH) in the Sundarbans, 2008**

	Annual Mortality among Children under 5 Years	Attributable Fraction from WSH	Annual Mortality from WSH	Years of Life Lost from WSH
Diarrheal diseases	771	88%	679	23,081
Acute lower respiratory infections	1,205	42%	502	17,052
Measles	261	34%	89	3,024
Other infectious and parasitic diseases	1,009	43%	433	14,711
Other causes	2,688	0%	0	0
<b>Total</b>	<b>5,934</b>	<b>29%</b>	<b>1,702</b>	<b>57,868</b>

tuberculosis cases. Canning I and Canning II have the highest endemicity of tuberculosis, and it is linked directly with poverty and the sociocultural context. In addition, the threat of animal bites (from tigers, crocodiles, and dogs) is grave, especially among those who frequent the swamps and waterways of the Sundarbans for fishing and collecting forest products. Incidences of snakebites are historically high in the South 24 Parganas because of its low-lying nature.

69. In the short term, it is critical to place emphasis on preventive healthcare to reduce the incidence of diseases. Examples of preventive healthcare services include provision of health and hygiene education, physical examinations and screenings, immunizations, and vaccinations. Moreover, existing health initiatives<sup>68</sup> implemented by the Department of Health and Family Welfare need to be strengthened with the aim of: (a) improving and expanding these programs in hard-to-reach places, most of which are located in the high-risk area of the Sundarbans; and (b) placing additional emphasis on illness prevalent in the region. Under the Revised National Tuberculosis Program, the cure rate for tuberculosis has improved; however, detection rates are low due to low rates of surveillance. Both the National Anti-Malaria Program and the Integrated Child Development Services Program<sup>69</sup> suffer from a shortage of qualified health staff. Reduction in illnesses can only be attained with continued improvement in existing public health services provided under the national health and state programs for nutrition and reproductive and child health, and also under the disease-related programs, including those targeting tuberculosis, HIV/AIDS, vector control, leprosy, and polio. Additional emphasis should be placed on specific illnesses and vulnerable groups. Wild animal attacks, as

well as high diarrhea incidence linked to salinity intrusion,<sup>70</sup> are two examples of situations that are specific to the Sundarbans and require both appropriate preventive and response interventions to reduce incidence and impacts.

70. Other health-related recommendations concern ways of decreasing morbidity and mortality by reducing indoor air pollution and improving WSH. These environmental risk factors were responsible for nearly 3,800 deaths and 1.9 million cases of illness in 2008 that placed significant economic burdens on families and the economy (Figure 4.5). Premature deaths from inadequate WSH were overwhelmingly among children under five, and over 70 percent of premature deaths from respiratory diseases arising from household use of wood and other biomass involved adult women. These deaths represent over 30 percent of all deaths among children under five, and 11 percent of all deaths among women over 30 in the Sundarbans. Over 90,000 years of life are lost from these deaths annually, of which 83 percent are among children under five (see Annex 7 for further details on health risks).

## Water and sanitation services are a cornerstone of sustainable development

71. A range of interventions could be implemented in the Sundarbans to mitigate the severe health consequences of environmental risks. A study conducted as part of this NLTA evaluated the costs and benefits that would result from alternative measures that have a demonstrated effect in reducing respiratory and waterborne diseases caused by environmental risks in the Sundarbans. As shown in Table 4.2, the benefits of several

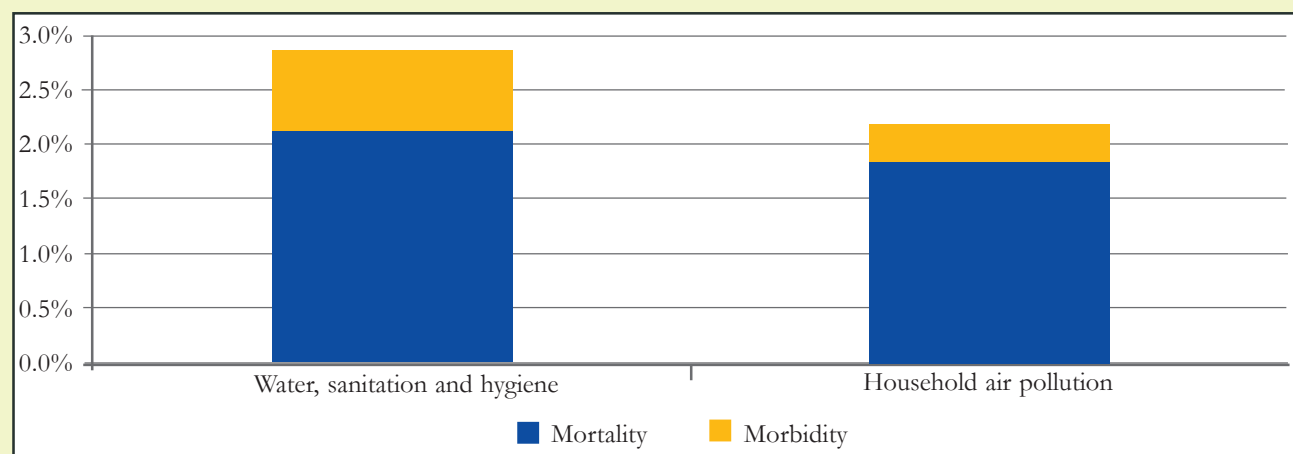
<sup>68</sup>These programs include the Reproductive and Child Health Program, National Anti-Malaria and HIV/AIDS Control Programs, and Revised National Tuberculosis Program.

<sup>69</sup>The Integrated Child Development Services Program is committed to improving the welfare of pregnant/lactating women and children under six years of age in India. The primary objective of the program is to improve the nutritional status of children less than three years of age. The major focus is on children with Grade I and II category malnutrition, who constitute more than 50 percent of children enrolled under this scheme.

<sup>70</sup>Sea level rise could increase the incidence of diarrhea by decreasing the amount of available “sweet” groundwater, thereby reducing the supply of potentially potable water.



**Figure 4.5: Annual Cost of Health Effects (Percentage of GDP, 2007–08)**



**Table 4.2: Summary of Benefit–Cost Ratios of Environmental Health Interventions**

Interventions	By Valuation Method of Health Benefits		
	Primary Beneficiaries	Low	High
<i>Household air pollution control</i>			
Improved wood/biomass stove (switching from <i>unimproved</i> wood/biomass stove)	Children & adults	10.7–12.7	13.7–18.7
Liquid petroleum gas stove (switching from <i>unimproved</i> wood/biomass stove)	Children & adults	1.0–1.2	1.3–1.8
Liquid petroleum gas stove (switching from <i>improved</i> wood/biomass stove)	Children & adults	0.5–0.6	0.6–0.9
<i>Handwashing</i>			
For health protection of young children	Children < 5 years	1.9–5.1	2.1–5.5
For health protection of older children and adults	Population 5+ years	0.1	0.3
<i>Household drinking water treatment</i>			
For health protection of young children	Children < 5 years	1.7–8.5	1.8–9.3
For health protection of older children and adults	Population 5+ years	0.2	0.4
<i>Improved water supply and sanitation</i>			
Piped water supply (low capital cost)	Children & adults	1.3	1.6
Piped water supply (high capital cost)	Children & adults	0.7	0.8
Improved household toilet facility	Children & adults	3.6	4.3

interventions significantly outweigh their costs, particularly of the following: installing improved cooking stoves to reduce household air pollution, conducting handwashing campaigns and disinfecting household drinking water to protect young children, and supplying households with improved toilet facilities. A benefit–cost ratio greater than 1 indicates that the benefits of the intervention outweigh the

costs. The robustness of the analysis was assessed by using different methodologies, some of which provide higher values than others. The results show that the benefits of interventions such as handwashing for children and installing improved cooking stoves outweigh their costs regardless of the methodology chosen.

72. An assessment of water supply problems in the Sundarbans highlighted several key issues: the scarcity of aquifers containing nonsaline (“sweet”) water, remoteness of the area, and absence of electricity in many locations. Priority water supply problems in the Sundarbans islands include:

- Scarcity of sweet water in surface sources due to saline intrusion into surface water (ponds and rivers) and limited availability of sweet water aquifers: salinity is more than 1,000 mg/L even beyond depths of 300 m, and sweet water is available only at 1,000 m depth, and even that does not include all habitations;
- The sand of aquifers bearing sweet water is very fine, which reduces the yield of tubewells;
- There is a shortage of land for excavating new ponds for storing rainwater and providing barriers to prevent saline water from entering ponds during floods;
- Water sources are submerged during floods, with consequent disruptions in service;
- Many villages have no source of electricity and thus groundwater pumping is not a viable option in these cases;
- Habitations without either sweet water aquifers or ponds as sources can only rely on desalination, which is very costly; and
- In remote locations, there is difficulty in maintaining regular supply of good-quality bleaching powder for disinfection.

73. Several options could be considered for increasing access to water supply in the Sundarbans but, before deciding on options, GoWB’s PHED should update the status of water supply in the Sundarbans and identify the number of households requiring provision of safe water. The following are among the options that can be considered:

- In areas in which water supplies are highly saline, PHED should consider the establishment of drinking water desalination plants that are provided with a pretreatment phase and ultraviolet radiation for disinfection. Solar power (as opposed to diesel generator sets) could be used to run desalination facilities;
- Ponds that collect rainwater can be used to provide safe water. However, bunds must be provided around ponds to prevent entry of saline water during cyclones, and the water should be treated using pressure filters; disinfection via hypo solution can be fed through handpumps, but this option should first be piloted;<sup>71</sup>
- Fresh-water storage capacity can be augmented by closing some creeks (as discussed in Chapter 3);
- Tubewell maintenance should be carried out on a regular basis; and
- The following medium-term, cost-effective remedial actions to existing infrastructure can be undertaken: raising existing tubewells at spot sources of supply by 3–4 m, elevating floors of pump

assemblies that would otherwise be submerged during flooding, and enhancing protection of fresh-water ponds by raising their encircling bunds.

The PHED can enlist the services of NGOs in disseminating information regarding the availability of handpump mechanics and banks of spare parts, and to ensure the participation of the community in the operation and maintenance of water supply schemes. However, a caveat is in order: in some cases, it is clear that significant investment in physical infrastructure would yield marginal benefits, as the affected areas will likely be inundated in the next 50 years. In other cases, investment might lead to increased settlement in the area, putting more pressure on the Sundarbans forest and placing more people at risk of negative consequences associated with climate change. Thus, investments should be made in ways that are sensitive to the increased risks due to more intense cyclonic storms. More generally, increased levels of salinity may also cause major threats to the habitability of some areas.

74. A key approach to improving sanitation in the Sundarbans involves strengthening the implementation of the government-led Total Sanitation Campaign (now called the Nirmal Bharat Abhiyan), which is a comprehensive program implemented at the district level to improve sanitation facilities in rural areas with a broader goal of eradicating the practice of open defecation. Under this program, a nominal subsidy is given to poor rural households for construction of toilets. It emphasizes information dissemination, education and communication, capacity building, and hygiene education in order to effect behavior change. The approach involves participation by local government institutions and civil society organizations. Key intervention areas include individual household latrines, school sanitation and hygiene education, community sanitary complexes, and *anganwadi* toilets.

75. Particular problems within the Sundarbans involve the adverse effects of cyclonic storms on toilet facilities and shortfalls in maintenance of community-level toilet facilities. To deal with these issues, local governments should enlist the cooperation of NGOs or the private sector in carrying out the following:

- Repairing or relocating toilets that were damaged in floods;
- Streamlining the maintenance of school toilet facilities and community sanitary complexes; and
- Redesigning toilets to reduce their cost and enhance the ability of toilets to withstand the effects of cyclonic storms.

76. Priority should be given to improving water supplies and latrines in schools. This issue deserves priority because of the central importance of education to long-term human development as well as employment prospects. Drinking water, toilets, and separate spaces are present in only about 60 percent of the schools, and the problem is particularly notable in primary schools. Girls are especially disadvantaged when schools do not have water supplies and separate latrines.

<sup>71</sup>A number of pond-based surface water systems were adversely affected by saline water intrusion linked to flooding that accompanied Cyclone Aila; these systems also suffered from inadequate drainage because land behind embankments was below mean sea level.

77. Campaigns for hygiene education should be conducted to encourage handwashing and to improve household sanitation in food handling and preparation, and treatment of domestic drinking water. Since people's motivation to improve hygienic practices hinges on their ability to understand the linkages between disease and hygiene, instruction on these linkages should be a part of any campaign. Interventions to improve domestic hygiene could help to reduce significantly high childhood morbidity and mortality. One study conducted as part of this NLTA showed that less than 10 percent of 313 surveyed households in eight blocks in the Sundarbans used appropriate drinking water treatment methods, such as boiling or filtering. Nearly 20 percent strained water through a cloth, only 8 percent boiled water, and 72 percent did not treat water at all prior to drinking. Several studies have demonstrated that appropriate handwashing can, in addition to reducing gastrointestinal diseases, reduce upper respiratory illness, especially among children. Promoting the use of footwear can decrease morbidity among children by drastically reducing worm infestation. Interventions should be undertaken to help educate women on the positive health impacts of boiling water, value of employing safe cooking methods, and use of effective household hygiene practices in reducing disease, especially among young children. Women should be targeted because they are typically in charge of domestic water supply, food preparation, and hygiene issues.

## Energy services can rely on both traditional and modern sustainable alternatives

78. Cooking stoves that burn biomass (vegetable matter such as straw, shrubs, or grass, agricultural crop residues, and animal dung) should be replaced by alternative cooking devices, such as biogas cooking stoves and smokeless *chulas*. Replacement of biomass-based cooking stoves will yield significant decreases in household air pollution with consequent reductions in morbidity and mortality. Combustion of biomass tends to generate the most smoke, followed by wood, then coal or charcoal. Household air pollution from the use of solid fuels – biomass, wood, and charcoal – for cooking and other purposes causes substantial adverse health effects, particularly among young children and adult women, as these groups tend to spend the most time in household environments. The main strategy for cooking should focus on improved cooking stoves (for example, biogas cooking stoves and smokeless *chulas*), which decrease indoor air pollution and provide energy services at higher efficiencies than traditional biomass-based cooking stoves. Biogas, which is largely methane, is a low-cost form of energy derived from renewable sources, such as animal manure, agricultural residues, human waste, and other organic materials.

79. Reliable access to energy supplies should be provided for all households and commercial establishments. GoWB intends to extend the state grid to all villages in the Sundarbans by 2015. However, a customized strategy that relies on market segmentation, based on proximity to the Sundarbans Reserve Forest and its transition zone, could speed the provision of energy to households.

For lighting and other home appliances, all households in or near the transition area could make greater use of technologies with low environmental impact and decentralized renewable sources of energy, such as solar energy. Households outside the forest fringe or near the mainland, areas with light commercial activities in livelihood clusters, and tourist facilities outside the transition area could rely more on decentralized systems connected to small local power plants using appropriate technologies in locally connected grids. The wood fuel-based power plant run by the Gosaba Rural Energy Cooperative Society, which is generating grid-quality electricity, could be used as a model. For livelihood clusters and households located in relatively well-populated areas far from the transition zone or near the mainland, priority should be given to connecting all households and commercial activities to the existing electric power grid to encourage clustering of population and development of new livelihood opportunities. In all cases, use of energy-efficient techniques that contribute to demand reduction (such as use of compact fluorescent lighting) should be encouraged (Annex 11 provides detailed recommendations on the spatially based approach for the provision of energy services in the Sundarbans).

80. West Bengal is in a power deficit situation, and the absence of dependable electric power for commercial and industrial loads in the stable zone leaves the population in a less advantageous position in terms of energy supply, and thus increased attention should be given to nonconventional sources. The quality of electricity supply is likely to be poor in the near and medium term, and thus reliance on nonconventional sources of electricity may be needed. In all cases, energy-efficient techniques that contribute to demand reduction should be encouraged. Reliance on environmentally sensitive applications such as solar water heaters, solar home lighting systems, solar parabolic cookers, and solar streetlights will help reduce environmental impacts and decrease health-related hazards.

## Upgrade to sustainable means of transportation

81. Given that the development of transport infrastructure may facilitate access into the Sundarbans and, hence, place greater stress on the fragile ecosystem, the transport infrastructure needs to be planned in ways that promote the integration of residents into the relatively safer stable zone and peri-urban areas located more inland. Hence, developing and improving road infrastructure between the stable zone and urban areas can encourage residents residing in the more environmentally dangerous areas of the transition zone to take advantage of the road network in the stable zone that can be used to access urban markets. Based on an examination of transportation in the Sundarbans, it is recommended that improved railway and highway connections be made between the more densely populated stable zone and peri-urban areas and urban markets outside the Sundarbans. This would facilitate the movement of goods and people, offer improved connections to urban markets, and allow firms to take advantage of agglomeration economies. It would also help to overcome the limitations of geographic isolation. All households in or near the transition zone should maximize the

use of transportation with near-zero environmental impacts, such as nonmotorized vehicles. In locations where the tops of embankments are flat and wide enough for walking or nonmotorized vehicles, households might use the crests of embankments as a medium for transportation (see Annex 11 for further details).

82. Promoting inland water transport away from the transition area toward urban areas should be a priority. Inland water transport is an essential mode of transportation in the Sundarbans, and it is often the only transport mode in the transition zone. Based on studies conducted for this NLTA, it is recommended that the relative neglect of inland water transport be reversed, and that investments to promote and develop such transport be prioritized to help facilitate the movement of people from the transition zone to the more densely populated stable zone and peri-urban areas. In particular, for the main rivers with high passenger traffic, it is recommended that investments be made to modernize and upgrade jetties and

landing stations. These investments should also include adequate facilities for female travelers.

83. Safety issues related to road and inland water transport are major concerns for residents of the Sundarbans, and interventions to improve safety are urgently needed. Installation of adequate traffic signs, including regulatory, warning, and route information signs, is recommended. The safety of inland water transport is a particularly important issue for the people of the region, and related safety standards should be reviewed, improved, and more rigorously enforced, with special emphasis on avoiding the overloading of launches (passenger ferries) and country boats.

## Summary of options for poverty reduction

84. A summary of the recommended poverty reduction measures is provided in Table 4.3.

**Table 4.3: Pillar 2: Options for Poverty Reduction**

Targets	Options for action
<b>Interventions in the stable zone and peri-urban areas</b>	<p>Improve railway and highway connections between the more densely populated stable zone and peri-urban areas and urban markets outside the Sundarbans</p> <p>Connect all households and commercial activities to the existing electric power grid to encourage clustering of population and development of new livelihood opportunities</p> <p>Develop water supply infrastructure, extend health and educational services, and implement labor training programs</p>
<b>Interventions for promoting women and child protection</b>	<p>Promote stricter enforcement of laws protecting women and children from abuse (for example, training enforcement personnel to conduct surveillance at focal points of sex trafficking)</p> <p>Educate parents on the risks of giving up their children to unknown individuals</p> <p>Introduce counseling services for women and girls who migrate out of the Sundarbans in search of work</p> <p>Develop information networks for women and girls leaving the Sundarbans (including information on jobs)</p> <p>Provide financial and health services for female migrants</p> <p>Provide identification cards for women</p> <p>Establish shelters on routes commonly used by women migrants</p>
<b>Measures for enhancing education in the stable zone</b>	<p>Continue offering financial assistance in the form of scholarships to families who send their children to schools in the stable zone</p> <p>Implement technical and labor training programs in the stable zone</p> <p>Expand and intensify national and state programs aimed at improving the nutritional status of children in schools, for example, provision of micronutrient packets to students under the Mid-Day Meals Program</p> <p>Expand and intensify national and state programs aimed at: (a) increasing the literacy and numerical skills of adults (aged 15 and above); (b) providing quality education in schools (including English education)</p> <p>Install latrines in schools in the stable zone, especially for girls</p>



**Table 4.3 (continued): Pillar 2: Options for Poverty Reduction**

Targets	Options for action
<b>Interventions for enhancing health outcomes in transition and stable zones</b>	<p>Continue and intensify public health services under the national health and state programs for nutrition, reproductive and child health, and disease and mental health programs, with increased mobile health services</p> <p>Reform the Department of Health and Family Welfare's referral and logistics system to provide better access to appropriate health facilities</p> <p>Place greater emphasis on preventive healthcare, for example, through providing health and hygiene education, physical examinations and screenings, immunizations, and vaccinations</p> <p>Develop a financial assistance program for healthcare</p>
<b>Measures for improving</b>	<p>Continue the implementation of programs such as the Nirmal Bharat Abhiyan</p> <p>Improve water supply and install latrines in schools</p> <p>Relocate toilets damaged by floods and redesign toilets to withstand cyclonic storm impacts</p> <p>Introduce in situ disinfection of drinking water to curb waterborne infectious diseases</p> <p>Regulate aquaculture practices to reduce salinity intrusion</p> <p>Close tidal creeks to improve fresh-water storage</p> <p>Raise existing tubewell sources at spot sources of water supply by 3–4 m</p> <p>Raise floors of pump assemblies</p> <p>Develop ponds to collect rainwater and protect fresh-water ponds by raising their encircling bunds</p>
<b>Interventions for improving</b>	<p>Install alternative cooking devices, for example, biogas stoves and smokeless <i>chulas</i></p> <p>Implement low environmental impact technologies and decentralized renewable sources of energy, such as biogas plants and solar energy</p>
<b>Measures for improving transportation in the</b>	<p>Provide investments to enhance the capacity of transport agencies to effectively gather data, manage information, and conduct analyses of demand and environmental and social impacts</p> <p>Develop inland water transport to enable residents from the transition zone to travel to the stable zone</p> <p>Upgrade and modernize jetties and landing stations in the transition zone</p> <p>Develop adequate facilities for female travelers</p> <p>Implement road and inland water transport safety measures</p>



# 5.

## PILLAR 3:

### BIODIVERSITY CONSERVATION



#### Sustainable Socioeconomic Development

Pillar 1	Pillar 2	Pillar 3	Pillar 4
Vulnerability Reduction	Poverty Reduction	Biodiversity Conservation	Institutional Change
<ul style="list-style-type: none"> <li>■ Disaster risk management</li> <li>■ Estuary management via threat reduction investments</li> </ul>	<ul style="list-style-type: none"> <li>■ Stemming population pressures: capturing livelihood opportunities</li> <li>■ Human capital: health, education</li> <li>■ Basic physical infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>■ Incentive measures, property rights, and co-management</li> <li>■ Conservation partnerships</li> <li>■ Mangrove restoration and marine protection</li> </ul>	<ul style="list-style-type: none"> <li>■ Implementation functions</li> <li>■ Coordination functions</li> <li>■ Bilateral cooperation between the Governments of Bangladesh and India</li> </ul>

#### Supporting and synergizing current GoWB efforts in conservation of the Sundarbans

85. GoWB has been providing substantial allocations for the protection of the Sundarbans Biosphere Reserve. It has undertaken successful ventures in the Sundarbans aimed at biodiversity conservation while, simultaneously, providing local communities with alternative livelihoods in areas further away from the core in order to prevent further biodiversity degradation. For example, in 2009-2010, the Ministry of Environment and Forests (MoEF) provided a total of INR 11 million under the Biosphere

Protection and Management Scheme, which was used primarily to relocate people from the core area of the Biosphere Reserve and to develop alternative means of livelihoods.<sup>72</sup>

86. There are numerous important Action Plans implemented with grants from the state and union governments that are aimed at biodiversity conservation in the Sundarbans Biosphere Reserve. They are: (i) the Annual Management Action Plan; (ii) Conservation and Management of Mangroves; (iii) Conservation and Management of Sundarban Wetland; and (iv) surveillance and patrolling activities for the protected areas. A description of the key schemes as well as relevant funding is provided in Box 5.1 and Table 5.1.

<sup>72</sup>MoEF, January 10, 2010. "Ministry of Forest and Environment Visit Sundarbans. Ministry to Enhance Focus. Press release, available at: [http://moef.nic.in/downloads/public-information/Sunderbans\\_press\\_release.pdf](http://moef.nic.in/downloads/public-information/Sunderbans_press_release.pdf).

### Box 5.1: Government Schemes Implemented for Biodiversity Protection in the Sundarbans

**Conservation and Management of Sundarban Biosphere Reserve:** The scheme primarily focuses on the afforestation of the Sundarbans with nonmangrove species. It also implements education programs to raise awareness of conservation efforts in the region. Eco-development, and training and capacity building activities have also been conducted under this program.

**Conservation and Management of Sundarban Mangroves:** Given the important productive and protective functions of mangroves, GoWB has made significant strides in promoting mangrove development. MoEF has been releasing funds for intensive mangrove conservation and management in the Sundarbans. Decline in mangrove cover had been stopped by 1990s, and between 1997 and 2007, the mangrove coverage in West Bengal, almost entirely in the Sundarbans, increased from 2,123 km<sup>2</sup> to 2,152 km<sup>2</sup>, an increase of 29 km<sup>2</sup>, according to the India State of Forest Report prepared by the Forest Survey of India.

**Conservation and Management of Sundarban Wetland:** The Sundarbans wetland is one of the identified wetlands under the National Wetland Conservation Program. The Sundarbans wetland serves as a breeding ground and nursery for a large number of aquatic species. However, the wetland is threatened due to overexploitation, uncontrolled fishing, pollution, and unregulated tourism. To date, an amount of INR 87.7 million has been allocated to the GoWB for conservation and management of the Sundarbans wetland. This amount includes a sum of INR 9.25 million released during 2012-13. The funds have been provided for activities such as wetland mapping, habitat improvement, restocking of aquatic fauna,

development of alternative livelihoods, public awareness, and monitoring and research.

**Project Tiger:** This initiative helped increase the tiger population in the “tiger reserve” areas from 268 tigers in nine reserves in 1972 to 1,576 tigers in 27 reserves in 2003. The project has also been successful in eliminating exploitation of natural resources by humans in the specially constituted tiger reserves areas. Currently, wireless communication systems and patrol camps have been developed in the tiger reserves and, as a result, poaching has been reduced significantly. Voluntary village relocation, especially from the core areas, has also been carried out in many reserves. To reduce population pressures on forests, villages were provided with alternative agricultural lands and other benefits to relocate away from the tiger reserves.

**Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA):** This major government program, launched in 2005, aims at enhancing the livelihood security of people in rural areas by guaranteeing 100 days of wage employment in a financial year to each rural household whose adult members demand work. The employment work under this program gives priority to the following activities: water harvesting, groundwater recharge, and drought proofing. In the pre-Aila period, most activities under this scheme were directed toward irrigation activities and water conservation for improving agricultural production. However, Cyclone Aila damaged nearly 1,000 km of embankments, and salinity intrusion inflicted substantial economic losses. As a result, program activities were then directed at embankment rehabilitation (Sharkhel 2013).

**Table 5.1: Funding Details of Key Schemes Implemented in the Sundarbans**

Name of Scheme	Source	Estimated Annual Budget (in million INR)
Conservation and Management of Sundarban Mangroves	GoI	15
Conservation and Management of Sundarban Biosphere Reserve	GoI	11
Conservation and Management of Sundarban Wetland	GoI	26
Project Tiger	GoI	44.5
State Plan (Annual Plan)	GoWB	42
Intensification of Forest Management	GoWB	0.4
13th Finance Commission	GoWB	7.8
Rashtriya Krishi Bikash Yojana	GoWB	16.8
Rural Infrastructure Development Fund	GoI	28
Mahatma Gandhi National Rural Employment Guarantee Act	GoI	22.5
<b>Total</b>		<b>214</b>

Source: India's Periodic Review, 2011, Report of Sunderban Biosphere Reserve.



87. Given the various policies and agencies working to promote biodiversity conservation in the region, institutional synergy is needed which requires greater collaboration between agencies, including coordination amongst agencies to prevent agencies from working at cross-purposes and to promote the efficient usage of funds channeled towards biodiversity conservation from the central to the local levels (further details in following chapter).<sup>73,74</sup>

## One ecosystem shared by two countries

88. Although this NLTA concerns the Indian portion of the Sundarbans, it recognizes that the ecosystem would be managed more effectively if both Bangladesh and India created an integrated policy for conservation and development, or at least adopted a harmonized policy that could be implemented by each country individually; this would prevent the countries from inadvertently acting at cross-purposes. The Sundarbans is a single ecosystem, and the Indian and Bangladeshi portions have a number of common attributes. Both sides have high levels of poverty and limited livelihood opportunities, and households on both sides suffer from lack of safe drinking water, high levels of indoor air pollution, restricted access to health services, and inadequate knowledge of proper sanitation practices. Moreover, the expansion of aquaculture has proceeded in an unregulated fashion on both sides of the border.<sup>75</sup> In addition, both the Indian and Bangladeshi portions of the Sundarbans have been subject to similar natural hazards in the form of cyclones and sea level rise. Resource management challenges remain significant in both countries, while the information base for

managing key problems (for example, salinity intrusion) is inadequate.

89. While similarities between the Indian and Bangladeshi Sundarbans exist, there are also notable differences that are relevant to disaster risk management and planning for socioeconomic development; the existence of differences in experience provides the basis for mutually beneficial exchanges. In comparison to the Sundarbans region in West Bengal, the information base relating to physical and socioeconomic conditions is more developed in Bangladesh. The planning basis for development is also more clearly established in Bangladesh, where there is a distinct separation of the protected area of the Sundarbans Reserve Forest and the inhabited area of the Sundarbans Impact Zone. Larger-scale industrial development and private investment is also more pervasive in the Bangladeshi Sundarbans; for example, a port and export development zones have been created within the Sundarbans Impact Zone. Aquaculture in the Bangladeshi portion of the Sundarbans is based more on value-added, locally manufactured inputs while traditional methods remain more pervasive in the Indian Sundarbans. Influences of fresh-water rivers on the hydrodynamics of the delta are more significant in Bangladesh than they are in India. Moreover, the polder<sup>76</sup> system in Bangladesh is of more recent construction (1960s and later) than is the embankment system in West Bengal (mid-19th century). In the Indian portion of the Sundarbans, the expansion of inland aquaculture coupled with historical deltaic subsidence has contributed to extensive erosion problems and embankment failures; this is a pressing management issue that has

<sup>73</sup>In the Sundarban Biosphere Reserve, several other projects and schemes aiming at biodiversity conservation and livelihood improvement had been implemented earlier including UNDP financed “Strengthening sustainable livelihood for biodiversity conservation in Sundarban” during 2003-04. MoEF (2013).

<sup>74</sup>According to MoEF (2013), as far as legal protection of the Sundarbans area is concerned, GoI notified the Wetland (Conservation Management) Rules-2010 vide notification no. GSR-951 (E), dated December 4, 2010. Sundarban has not yet been notified under the said rules, but options exist to notify Sundarban under this specific rule. As per the Wetlands Rules, some activities are prohibited in the notified wetlands and some are allowed with the approval of the Central Wetland Regulatory Authority (CWRA) which need to be taken into account while synergizing activities in the area; details of prohibited activities and those with approval of CWRA are:

### *Prohibited Activities:*

Reclamation of wetlands; Setting up of new industries and expansion of existing industries; Manufacture or handling or storage or disposal of hazardous substances; Solid waste dumping; existing practices to be phased out within a period not exceeding six months; Discharge of untreated wastes and effluents from industries, cities or towns and other human settlements; prevailing practices to be phased out within a period not exceeding one year; Any construction of a permanent nature, except for boat jetties, within 50 m from the mean high flood level observed in the past 10 years, calculated from the date of commencement of these rules; and Any other activity likely to have an adverse impact on the wetland to be specified in writing by the Authority.

### *Activities with Approval of CWRA:*

Withdrawal, impoundment, diversion or interruption of water sources; Harvesting of living and nonliving resources; Grazing to the level not to have an adverse effect; Treated effluent discharges from industries, cities or towns, human settlements and agricultural fields falling within the limits laid down by the Central Pollution Control Board/State Pollution Control Boards; Plying of motorized boat not detrimental to the nature and character of the biotic community; Dredging only in areas impacted by siltation; Construction of boat jetties; Activities that may directly affect the ecological character of the wetland; Aquaculture, agriculture, horticulture activities within the wetland; Repair of existing buildings or infrastructure; and Any other activity to be identified by the Authority

- Notwithstanding anything in sub-rule (1) or sub-rule (2), the Central Government may permit any of the prohibited activities or nonwetland use in the protected wetland on the recommendation of the Authority.
- No wetland to be converted to nonwetland use without the approval of the central authority.

<sup>75</sup>The problem of unregulated aquaculture in the Sundarbans is described in GoWB. 2009 (Chapter 7). See also Knowler et al. 2009. For evidence of unregulated shrimp aquaculture on the Bangladeshi side of the Sundarbans, see Sarwar 2005.

<sup>76</sup>Bangladesh relies extensively on the use of polders, which are protected by embankments (also referred to as dykes). Although construction of embankments in Bangladesh has a history that extends over centuries, that activity increased during the latter half of the 20th century.

led to extensive new work on embankments. In the Bangladeshi portion, recent polderization and modification of fresh-water river flows make saline intrusion and estuary sedimentation the most immediate management issues. Policy prescriptions for West Bengal (for example, embankment retreat and reduction of population pressures in the transition zone) are thus not likely to be necessary in the Bangladeshi portion at the same scale; in contrast, polder strengthening is an issue of concern on the Bangladeshi side. In comparison to West Bengal, disaster management and relief systems in Bangladesh are more comprehensive, both in terms of monitoring systems and in infrastructure development, and Bangladesh has had some successes with the use of tidal basin management to control sediments, thereby contributing to improved drainage and land productivity. The use of carbon financing is at different stages of development in the two countries. For example, Bangladesh is somewhat more advanced in tapping the potential of revenues linked to the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN REDD), given that the country has initiated inventory work and circulated preliminary REDD proposals.

90. A Memorandum of Understanding<sup>77</sup> between the two countries was signed on September 6, 2011 in which both countries recognize that the Sundarbans represent “a single ecosystem divided between the two countries.” Specifically, both countries recognize the need to: (i) monitor and conserve the Sundarbans; (ii) adopt appropriate joint management and joint monitoring systems; (iii) explore the possibility of implementing conservation and protection efforts; (iv) develop a long-term strategy for ecotourism opportunities; (v) better understand the relationship between human settlements and the ecosystem; (vi) identify opportunities for livelihood generation that do not adversely affect the ecosystem; (vii) identify and catalog the diversity of flora and fauna; (viii) carry out research to develop a common understanding of the impacts of climate change and to determine appropriate climate change adaptation strategies; and (ix) share relevant information and technical knowledge.

91. GoWB has made significant strides in providing legal protection to the Sundarbans. As for legal protection of the Sundarbans forest, the entire Sundarbans has been declared a ‘Reserve Forest’ long ago under the provisions of the Indian Forest Act, 1927. An area of 1,700 km<sup>2</sup> has been declared as ‘Critical Wildlife Habitat’. An area of 2,585 km<sup>2</sup> was declared as a ‘Tiger Reserve’ in the year 1973. Important steps toward bilateral cooperation on biodiversity conservation have already been taken on several fronts. For example, the Governments of India and Bangladesh have initiated the Ecosystem Forum on the Sundarbans.<sup>78</sup> The Forum embraces the idea that effective biodiversity conservation should employ a range of management approaches (for example, economic

incentives, community co-management, and conservation partnerships with the private sector and communities) to attain the goals of restoring and managing the Sundarbans ecosystem. The biodiversity conservation pillar of the approach recommended herein reflects all of these management elements and goals. The Governments of India and Bangladesh created the Ecosystem Forum to facilitate research and promote coordinated planning and enhanced protection of the region’s biodiversity. A key goal of this Forum is to avoid having the two countries implement national-level plans that act at cross-purposes. The platform created by the Forum can also facilitate bilateral collaboration on other Sundarbans-related management issues. For example, the Forum can be used to: (a) assess the advantages to India of adapting Bangladesh’s sustainable ecosystem management policies; (b) explore opportunities to improve regulation and control of legal timber harvesting and other resource extraction in the forest and to prevent illegal resource extraction activities; and (c) initiate bilateral efforts to deal with the prawn seedling by-catch problem by considering increased use of hatcheries and improved methods of prawn seedling collection during the interim period in which hatcheries are established. In addition, an international group of experts in conservation biology has been formed as part of this NLTA and has produced a volume that contains inventories of species and analyses of the structure and function of the Sundarbans (in both India and Bangladesh) as a unique ecosystem (see Annex 12). Moreover, Bangladesh and India have already signed a Protocol on conservation of the Royal Bengal Tiger of the Sundarbans in September 2011.<sup>79</sup>

92. Continuing bilateral cooperation can further strengthen the management of the Sundarbans. Future programs for bilateral collaboration can yield significant benefits in the form of information exchanges and coordinated programs for patrolling the border and conducting tiger census work. The following are examples of activities for which collaboration can strengthen both countries’ abilities to conserve the biological integrity of the Sundarbans: (a) improving information-sharing mechanisms between forest offices in India and Bangladesh, thereby allowing for the interchange of ideas on strategies for managing, conserving, and developing the Sundarbans; and (b) exchanging technical information and knowledge on conservation and management of mangrove forests and biodiversity.

## Economic incentives are important complements to regulation

93. The use of economic incentives funded by revenues from climate change mitigation programs can play an important role in enhancing the effectiveness of regulatory enforcement in the near term. Although still at a pilot stage, emerging climate change mitigation programs (for example, carbon financing) provide a basis

<sup>77</sup>The Memorandum of Understanding between India and Bangladesh on Conservation of the Sundarbans, September 6, 2011, can be accessed at <http://www.hcidhaka.org/pdf/5.MOU%20between%20India%20and%20Bangladesh%20on%20Conservation%20of%20the%20Sundarban.pdf>.

<sup>78</sup>The website for the Forum’s Internet information portal – the Sundarbans Pavilion – is at <http://www.sundarbanspavilion.org/>.

<sup>79</sup>GoWB. 2012. Comments of GoWB on the Draft Final Report under the NLTA by the World Bank on Sustainable Development of the Sundarbans Region. Communication of the Chief Secretary, West Bengal, Shri Samar Ghosh, to the Acting Country Director of the World Bank. Kolkata. June 14, 2012.

for generating revenues that can be shared at the community level or throughout West Bengal. Sustainable forestry practices provide a basis for accessing these funds because of their ability to conserve biodiversity and prevent deforestation, thereby retaining forests for sequestering atmospheric carbon. By preserving the forest, it will be possible to take advantage of funding opportunities that have been (and will be) created in the context of carbon reduction efforts under the Kyoto Protocol's Clean Development Mechanism; voluntary carbon markets; and the UN-REDD program. Under UN-REDD, a native forest will be eligible for carbon credits once it can be demonstrated that the forest would have been degraded or deforested in the absence of targeted interventions. Funds generated in the Sundarbans via UN-REDD and various other carbon financing schemes can be used to support a number of initiatives aimed at enhancing biodiversity by reducing the pressure that residents near the Sundarbans Reserve Forest are placing on forest resources.

94. A number of additional revenue streams, such as the Climate Investment Funds, can also be explored as sources of funding. The Climate Investment Funds have a Pilot Program for Climate Resilience,<sup>80</sup> which is a potential funding source for biodiversity conservation and climate change adaptation measures. A number of climate resilience pilots are being supported by these funds, including a pilot program in Bangladesh, of which a large part involves the Bangladesh side of the Sundarbans. Assuming the Climate Investment Funds are replenished, they could serve as new and additional sources of funding for biodiversity conservation as well as climate change adaptation within the Indian portion of the Sundarbans. Moreover, GoI may have opportunities to access a number of other sources of global climate finance for the Sundarbans, such as the Green Fund being developed under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), and the Special Climate Change Fund (which could be a source of co-financing and leveraging). Other climate-related funding sources include programs developed by bilateral and multilateral aid institutions.

95. Climate-related revenues are not the only potential new funding sources. The Sundarbans regions could possibly benefit from creating Payment for Ecosystem Services (PES) programs, which have become popular around the world. Countries such as Brazil, Costa Rica, Lesotho, Mexico, and Nigeria have established mechanisms through which landowners and municipalities can receive financial compensation by adopting sound management practices that deliver ecosystem services. The specific services that have been recognized by PES programs include maintaining water quality for consumption; climate change mitigation; catchment-area services (for example, reducing sedimentation, and preventing floods and landslides); and forest conservation. As an example, a PES mechanism could be established so that entities such as the central government, or Kolkata and other urban areas, pay for the conservation of wetland forests in the Sundarbans, which have notable effects in reducing vulnerability to extreme weather events (see Annex 12).

## Property rights innovations can pave the way for improved conservation practices

96. An innovative approach for generating revenue that should be further explored involves creating property rights on forest resources in ways that yield funds for programs benefiting individuals in the transition zone, thereby giving them incentives to conserve forest resources. The potential revenue streams are linked to sustainable uses (for example, honey collection and fruit harvesting) as well as those associated with nonextractive use functions (for example, tiger viewing and carbon sequestration, both of which generate revenues that can be shared with local communities). In broad terms, the central idea is to create new revenue streams from previously nonmonetized products or services tied to the forest, and to allow local communities and individuals to benefit from these new revenues. According to GoWB (2012), revenues could fund existing programs that provide financial assistance in the form of scholarships that allow weaker sections, living on the edge of the forest, to send their members to vocational training programs in the stable zone (or in Kolkata). This use of innovative property rights would create incentives for residents of communities near the forest to become custodians and co-managers of the forest, thereby decreasing direct pressures on the forest and reducing the need to spend scarce public resources on enforcement.

## Mangrove restoration efforts are an economically efficient investment

97. Although the Forest Department has traditionally focused on small-scale monospecific plantations, future efforts can rely more on promoting growth through a combination of planting and natural regeneration of a diversity of species, which can self-select and adapt to changes in salinity. For example, in natural systems, monitoring undertaken as part of this NLTA demonstrated that areas of *Rhizophora apiculata* are giving way to *Rhizophora mucronata*, which is a more salt tolerant species. Efforts to promote mangrove restoration are expected to focus initially on some 15,000–25,000 ha of degraded land in areas of embankment realignment, but restoration efforts can also target areas of accretion and emergent shoals. This effort will require an important change from historical practice in that greater coordination will be required between the Forestry and Irrigation Departments than has occurred in the past. Currently, local communities receive financial assistance as direct payments from both the central and state governments in return for engaging in activities that include raising nurseries, planting mangroves, maintaining old plantations, among others.<sup>81</sup>

## Interventions can be phased to support socioeconomic development efforts

98. Livelihood opportunities created to serve transition zone residents who continue to live near the forest should be consistent

<sup>80</sup>The Pilot Program for Climate Resilience aims to identify ways to mainstream climate resilience considerations into national development planning. For more information, see <http://www.climateinvestmentfunds.org/cif/ppcr>.

<sup>81</sup>India's Periodic Review, 2011, Report of Sunderban Biosphere Reserve.



with efforts to conserve the forest. In any efforts to enhance livelihood opportunities in the transition zone, care must be taken to avoid making the area attractive to potential migrants from outside the transition zone. In-migration would undermine conservation efforts and put more people in the path of the natural disasters commonly experienced in the zone. In enhancing livelihood opportunities linked to tourism, for example, the current tourism policy should be altered in the near term to include provisions for environmentally sustainable ecotourism at levels strictly limited by the ecosystem's carrying capacity. Mass tourism in the transition zone should be eliminated entirely as it will degrade the natural resources of the Sundarbans Reserve Forest and the local environment to a point at which the area would have little value for high-end, environmentally sensitive ecotourists.

## Medium-term measures include a focus on co-management with partners

99. **Private sector partners.** The establishment of privately funded hatcheries in the prawn aquaculture sector can help avoid environmental degradation, particularly the by-catch problem. In the interim, while hatcheries are being developed, prawn seedling collection methods must be improved. Current prawn seed collection methods represent a serious threat to biodiversity and long-term sustainability. The establishment of hatcheries has proven effective in other Indian states, as well as in Bangladesh and other countries. Hatcheries can produce a steady supply of good quality postlarvae, essential for shrimp aquaculture. There are challenges in establishing hatcheries in West Bengal due to salinity conditions and market-related problems, but these difficulties are resolvable. The development will depend on creating an investment climate to foster private sector investment in state-of-the-art shrimp hatcheries.

100. **Transition zone community partners.** Mangrove restoration is an integral part of the adaptation strategy for the Sundarbans. In retreating embankments to protect coastal communities from erosion

and climatic events, the areas between old (abandoned) and new (retreated) embankments will become unprotected. Mangroves should be allowed to naturally regenerate in these areas to create a bioshield to attenuate wave energy. Mangrove forests are effective bioshields in the event of a cyclone, and they can serve to protect populations that have withdrawn further inland. Mangrove restoration offers livelihood opportunities and also allows for local communities to become involved in conservation, sustainable management, and ecosystem restoration operations (see Annex 9). As carbon financing opportunities develop, existing and new mangrove forests could provide an important revenue stream to fund investments or programs for residents of the Sundarbans, including programs to equip Sundarbans residents with the necessary means to access employment opportunities in the stable zone and outside the region. As new mangroves are regenerated, it is recommended that these be designated as *community reserves*<sup>82</sup> or *conservation reserves*<sup>83</sup> in order to shift the focus from exploitation of forest resources to management based on sustainability considerations. According to MoEF, private sector involvement may be helpful in the coastal zone for promoting employment opportunities linked to conservation and management of coastal resources.<sup>84</sup>

101. **Transboundary partners.** Because the Sundarbans region includes both India and Bangladesh, a mechanism of bilateral cooperation on Sundarbans biodiversity research should be established. It is recommended that MoEF and GoWB take the initiative by designing a mechanism for cooperative research and work, and additional information sharing to obtain a bilateral agreement on an implementable system. An effective approach to bilateral research and additional information exchange would allow for enhanced cooperation between the two countries on a host of important issues, such as women's empowerment, management of forested areas, and ecotourism aimed at zero environmental impact. It can also facilitate trust building and sharing of lessons and experiences that can benefit the Sundarbans

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<sup>82</sup>Under the amended Wildlife (Protection) Act, 2002, "the State Government may, where the community or an individual has volunteered to conserve wild life and its habitat, declare any private or community land not comprised within a National Park, sanctuary or a conservation reserve, as a community reserve, for protecting fauna, flora and traditional or cultural conservation values and practices." Once such a reserve is declared, its land use cannot be changed, except in accordance with a resolution passed by the management committee and its approval by the state government. A community reserve management committee is constituted by the state government, which shall be the authority responsible for conserving, maintaining, and managing the community reserve. This committee has five representatives nominated by the Village Panchayat (institution of local self-governance) or, where such a Panchayat does not exist, by the members of the Gram Sabha (village assembly) and one representative of the state forest or wildlife department under whose jurisdiction the community reserve is located. This committee is the competent authority to prepare and implement the management plan for the community reserve and to take steps to ensure the protection of wildlife and its habitat in the reserve. Source: Wildlife (Protection) Act, 1972, as amended in 2002.

<sup>83</sup>"The state government may, after having consultations with the local communities, declare any area owned by the government, particularly the areas adjacent to National Parks and sanctuaries and those areas which link one protected area with another, as a conservation reserve for protecting landscapes, seascapes, flora and fauna and their habitat, provided that where the conservation reserve includes any land owned by the central government, its prior concurrence shall be obtained before making such declaration." A conservation reserve management committee is constituted by the state government to advise the chief wildlife warden to conserve, manage, and maintain the conservation reserve. This committee consists of a representative of the forest or wildlife department, who shall be the member secretary of the committee, one representative of each Village Panchayat in whose jurisdiction the reserve is located, three representatives of NGOs working in the field of wildlife conservation, and one representative each from the Department of Agriculture and Animal Husbandry. Source: Wildlife (Protection) Act, 1972, as amended in 2002.

<sup>84</sup>MoEF. 2013.



ecosystem as a whole.<sup>85</sup> The previously mentioned Ecosystem Forum on the Sundarbans provides a solid foundation for further cooperation.

**102. Scientific community partners.** Conservation efforts in the Sundarbans should be driven by research and development, and it is recommended that a research center be established, tasked formally with conducting research to inform and advise policymakers on the Sundarbans. This research center should be administratively separate from the Department of Sundarban Affairs (DSA), and the sole mandate of the center should be to conduct research that fits into and informs the planning process for the Sundarbans. The studies conducted under this NLTA can serve as background papers or baselines for this institute, particularly for biodiversity, as a comprehensive state-of-the-art report was prepared based on information collected concerning all species in the Sundarbans. Such a research institute could collaborate with Bangladesh on similar research efforts to ensure an overall and comprehensive view of the Sundarbans.

### **Forest regulations need to be enforced effectively and the existing Sundarbans Reserve Forest should be designated for conservation**

**103.** Regulatory instruments that must be enforced are already in place, but new market-based incentive mechanisms could improve regulatory efficiency and help realize positive biodiversity conservation outcomes. Illegal poaching of tigers, clearing of mangroves, and settlement in protected areas are still prevalent activities, and all must be tackled through traditional enforcement approaches. The interventions for traditional enforcement approaches further support GoWB's efforts to strengthen legal protection of the Sundarbans. For instance, forest regulations suggested by this NLTA are expected to foster tiger conservation in the core area and complement the ongoing Centrally Sponsored Scheme of Project Tiger (CSS-PT).<sup>86</sup> For the core area, the main goal should center on eliminating the illegal harvesting that is currently taking place in the forest. To reduce population pressures on the forest, the Forest Department is implementing a permit allocation system to control entry into the forest. Forest entry permits could be reissued annually or biannually. To ensure transparency, details of the permit system should be publicly disclosed. A near-term focus should be on harvesting nontimber forest products, such as honey, fruits, or fishery products. As a short-term measure, the present Sundarbans Reserve Forest should be given a higher level of protection by defining it as a combination of areas legally protected for conservation (wildlife sanctuaries and national parks). In that context, all economic activity

in the existing Reserve Forest should be gradually reduced (see Annex 12).

### **Long-term measures should focus on increasing the extent of protected forest area in the transition zone and creating a marine reserve**

**104.** Designating the existing Sundarbans Reserve Forest for conservation protection is a measure that should be complemented by a long-term, gradual transformation in which increasing portions of the transition zone are designated as protected and reserve forest areas. As mentioned earlier, short-term improvements in livelihood options and disaster management in the transition zone, combined with opportunities created to generate revenue streams from the forest over a longer period, may encourage potential migrants to enter the transition zone. This would increase pressures on the forest, thereby undermining conservation efforts, and subjecting more people to loss of life and assets due to cyclonic storms and floods. To reduce these risks and further protect the forest ecosystem, it is recommended that GoWB continue to focus its efforts on developing alternative livelihoods in the stable zone and more peri-urban areas as an incentive for residents to integrate themselves with the relatively safer areas. This long-term transformation, which would be accompanied by a gradual decrease in the population size of the transition zone, will further reduce population pressures on the fragile ecosystem and lead to a smaller number of people living under threat of suffering the ravages of cyclonic storms and floods.

**105.** In the long run, the bilateral cooperation between India and Bangladesh should be expanded to include the co-management of a marine reserve area to protect the coastal and inland areas of the Sundarbans in both countries. It is recommended that, on the West Bengal side, the reserve should include the following: the Sundarbans National Park in the southern part of the Sundarbans, and the delta area and parts of the Bay of Bengal. As with other marine reserves in India, this would be managed by MoEF. As the process unfolds, a bilateral agreement should be sought with Bangladesh, leading eventually to a marine reserve involving both countries. The marine reserve will allow for the preservation of diverse aquatic species, including whales and dolphins.

### **Summary of options for biodiversity conservation**

**106.** A summary of the recommended biodiversity conservation measures, both national and transboundary, is provided in Table 5.2.

<sup>85</sup>Other potential partners include Nepal and Bhutan, to the extent that catchment area and river basin management efforts with these countries could also impact sediment and fresh-water flows into the Bay of Bengal and Sundarbans delta.

<sup>86</sup>MoEF. 2013.

**Table 5.2: Pillar 3: Options for Biodiversity Conservation**

Time Scale	Options for Action
<b>Short term</b>	<p>Continue and intensify bilateral cooperation between India and Bangladesh for conservation in order to: (a) improve information-sharing mechanisms between forest offices in India and Bangladesh; (b) exchange technical information and knowledge on conservation and management of mangrove forests and biodiversity; (c) plan joint tiger census operations; (d) coordinate patrol operations in the border areas; (e) assess the advantages of Bangladesh's sustainable ecosystem management strategy; and (f) explore ways to deal with the by-catch problem</p> <p>Improve forest regulation (enhance border patrol and strengthen the permit allocation system to control forest entry)</p> <p>Redevelop the current tourism policy to include provisions for environmentally sensitive ecotourism at levels strictly limited by the ecosystem's carrying capacity</p> <p>Define the Sundarbans Reserve Forest as a combination of areas legally protected for conservation (wildlife sanctuaries and national parks)</p>
<b>Medium term</b>	<p>Establish property rights on forest resources</p> <p>Introduce mangrove restoration schemes based on carbon financing</p> <p>Introduce PES programs</p> <p>Designate portions of the transition zone as protected and reserve forest areas</p> <p>Designate areas around mangrove plantations as community or conservation reserves</p> <p>Establish a research institute on biodiversity</p> <p>Establish and regulate state-of-the-art hatcheries</p>
<b>Long term</b>	<p>Create a new marine reserve to be co-managed by India and Bangladesh</p> <p>Declare the entire transition zone as a restricted area in which privately-held land could only be sold to GoWB for conservation purposes; all land sales should be at fair market value and all sales strictly on a voluntary basis</p>

# 6.

## PILLAR 4: INSTITUTIONAL CHANGE



### Sustainable Socioeconomic Development

Pillar 1	Pillar 2	Pillar 3	Pillar 4
Vulnerability Reduction	Poverty Reduction	Biodiversity Conservation	Institutional Change
<ul style="list-style-type: none"> <li>■ Disaster risk management</li> <li>■ Estuary management via threat reduction investments</li> </ul>	<ul style="list-style-type: none"> <li>■ Stemming population pressures: capturing livelihood opportunities</li> <li>■ Human capital: health, education</li> <li>■ Basic physical infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>■ Incentive measures, property rights, and co-management</li> <li>■ Conservation partnerships</li> <li>■ Mangrove restoration and marine protection</li> </ul>	<ul style="list-style-type: none"> <li>■ Implementation functions</li> <li>■ Coordination functions</li> <li>■ Bilateral cooperation between the Governments of Bangladesh and India</li> </ul>

### Institutional reforms must focus on implementation, coordination, and cooperation

107. Numerous national and state-level agencies and ministries are active in the Sundarbans. The region contains a national park and multiple zones with associated statutory conservation and development requirements, and thus there are numerous central agencies present with mandates and activities concerning matters ranging from coastal issues to earmarked funding via centralized schemes for socioeconomic development. In addition, there are 19 different GoWB agencies that have formal mandates to implement one or more programs in the Sundarbans (Table 6.1). Of these, only DSA has a specific policy that recognizes the region's terrain, poverty, and accessibility issues. DSA is the only organization with a special mandate to address the region's

challenges. The Sundarban Development Board (SDB), created under the Development and Planning Department of the state in 1973, was entrusted with "the planning and co-ordination of development activities in the backward region."<sup>87</sup> SDB was brought under DSA, which functions as a distinct development agency guided by the Board members.<sup>88</sup> Even though DSA was created in response to a clear and specific need, its actions have been constrained by a number of factors, including the following:

108. The scope of work of SDB and later DSA has been limited only to socioeconomic development of the inhabited parts in the Sundarbans. In addition, other relevant departments, such as those with responsibility for forests, irrigation and waterways, health, and education, continued to independently plan and execute sectoral schemes in the Sundarbans, which defeats the purpose of creating DSA as a coordination agency.

<sup>87</sup>Department of Sundarban Affairs website: <http://www.sadepartmentwb.org/>.

<sup>88</sup>The Board includes elected representatives, district magistrates of North and South 24 Parganas districts (in which 19 blocks of the Sundarbans area fall), and representatives from NGOs and social groups.

**Table 6.1** Role of State-level Agencies in the Sundarbans

Name of Government Organization	Functions	Current Role in the Sundarbans
<b>DSA (with SDB and Sundarban Infrastructure Development Corporation)</b>	Implementation of Special Area Development Plan Coordination and integration of plans Performance assessment and monitoring	Responsible for socioeconomic development of the inhabited part of the Sundarbans. Greatly constrained in playing the role of the coordinator. Implements programs in several sectors, including rainwater harvesting, agriculture, and construction of tubewells, bridges, and jetties. DSA has four divisions: agriculture, fisheries, social forestry, and engineering, with deputed staff from the respective departments
<b>Department of Forests</b>	Enforces Indian Forest Act (1927), Forest (Conservation) Act (1980), and Wildlife Protection Act (1972), among other responsibilities  Developmental role for soil conservation, nonsocial forestry, and timber yield	In charge of the National Park, Reserve Forest and sanctuaries, and wildlife. Oversees joint forest management initiatives and shares forest products with communities in a co-management framework.
<b>Department of Irrigation and Waterways</b>	Flood control through protection of embankments in Sundarbans  Drainage	Constructs embankments in the Sundarbans. Also provides clearance for bridges
<b>Department of Water Investigation and Development</b>	Tubewells Licensing for groundwater extraction	Manages groundwater extraction in the Sundarbans. DSA implements boring of tubewells directly
<b>Department of Environment</b>	Enforcement of environmental regulations, mostly through the State Pollution Control Board  Lead agency for state's Biodiversity Strategy and Action Plan	Designs and implements Biodiversity Strategy and Action Plan for West Bengal
<b>Department of Fisheries and Aquaculture</b>	Responsible for conservation of fish species, creation of infrastructure for fishing activities (including jetties), surveying, undertaking programs of skill upgrading, and livelihoods	Fish farming technical support, prawn cultivation, distribution of fingerlings, etc. Apparent duplication in efforts in distribution of fingerlings
<b>Department of Agriculture</b>	Provides information on agriculture, schematic implementation at grassroots level, soil analysis, pest management, seed firms in districts and blocks, etc.	Rainwater harvesting, providing seedlings, and mini-kit supplies
<b>Department of Panchayat and Rural Development</b>	Social forestry Administers the three-tier local government at district, block, and village levels Supports local governments with appropriate budget, technical support, and policies	Construction of boreholes for wells, obtaining land for school buildings, and all work at local levels are done through the involvement of the three-tier local government. Areas of work include agriculture, health, education, and other socioeconomic activities
<b>Department of Animal Husbandry</b>	Provides support, inputs, and guidance for improving livestock	Provides extensions services for improving livestock
<b>Department of Nonconventional Energy</b>	Awareness programs for nongrid power Implementation of nongrid power projects	Implementation of nongrid power projects



**Table 6.1 (continued): Role of State-level Agencies in the Sundarbans**

Name of Government Organization	Functions	Current Role in the Sundarbans
<b>Department of Scheduled Castes and Scheduled Tribes</b>	Development and improvement of sociocultural and livelihood aspects of scheduled caste and scheduled tribe populations Provides financial assistance and implements employment generation schemes for scheduled castes and scheduled tribes	Implements employment generation schemes for scheduled castes and scheduled tribes
<b>Department of Tourism</b>	Promotion and development of tourism Administers conducted tours Developes properties for tourism purposes	Promotion and development of tourism
<b>Department of Home (Police)</b>	Implementation of law and order through upkeep of legal provisions of various departments	Works in collaboration with forest agencies, district administration, coastguard, navy
<b>Department of Disaster Management</b>	The State Disaster Management Authority is responsible for planning and implementation of disaster management schemes and coordinating relief and rehabilitation	Relief for disasters (e.g., Cyclone Aila) was routed to different departments through Department of Disaster Management. Also provides funds for cyclone shelters
<b>Department of Health and Family Welfare</b>	Protects health of people through preventive, promotive, and curative measures.	Mobile ambulance scheme support
<b>Department of Education (school, higher secondary, tertiary, and vocational)</b>	All three departments of education are active across the state	Provides primary, secondary, tertiary education, and vocational training
<b>Department of Self-Help Groups</b>	Support to self-help groups at the community level	Support to self-help groups at the community level
<b>Department of Public Health Engineering</b>	Piped water supply Construction of tubewells Certifying quality of water Investigation for water sources	Design, construction, and management of water supply and sanitation systems
<b>Public Works Department</b>	Responsible for infrastructure and construction-related works through its own human resources	Building and maintenance of road infrastructure in the Sundarbans

109. DSA has a formal mandate and structure to plan, monitor, and evaluate activities conducted by other agencies in the region. While these functions are carried out periodically, they have no clear influence on the allocation of resources or the improvement of schemes. For example, DSA publishes annual work plans as well as yearly targets and achievements. However, there is no evidence of cross-sectoral coordination or alignment with a longer-term plan for the region. Thus, the schemes pursued are often at

cross-purposes. Also, results are reported by sectoral divisions and independent impact evaluations are not carried out systematically.

110. The power and influence of DSA are not significant compared to its larger counterparts for several reasons, including its limited budget compared to other departments; political economy issues related to decisions on investments or expenditures

in the area; and a comparatively small spatial domain that is largely underdeveloped and vulnerable.

111. SDB has four divisions – agriculture, engineering, fisheries, and social forestry – and it is staffed by officials deputed from the respective departments into DSA. The interests and incentives of such officials are more clearly aligned with their parent departments than with those of DSA. The four divisions of the SDB duplicate the work of other agencies, including fisheries, agriculture, and forests. Areas of research and planning, responsibilities that the SDB was mandated to conduct, have not been made priorities.<sup>89</sup>

112. Having a geographic and multisectoral mandate, DSA is required to look at complex and broad-ranging issues such as climate change, environment, forests, and agriculture. However, the staff, with the technical capacity to oversee these areas, is mostly located within line agencies working in those sectors.

113. In line with its mandate, DSA implements a number of socioeconomic development schemes, some of which are duplicated by sectoral departments. A few areas of duplications in work between DSA and other state departments are shown in Figure 6.1. Another review<sup>90</sup> of the institutional framework deployed in the Sundarbans further highlights the duplication problem in the region. The review finds that SDB presently implements small-scale development projects such as construction of brick-paved roads, jetties, bridges, culverts and sinking of tubewells, which duplicates the activities of the Public Works Department and PHED.

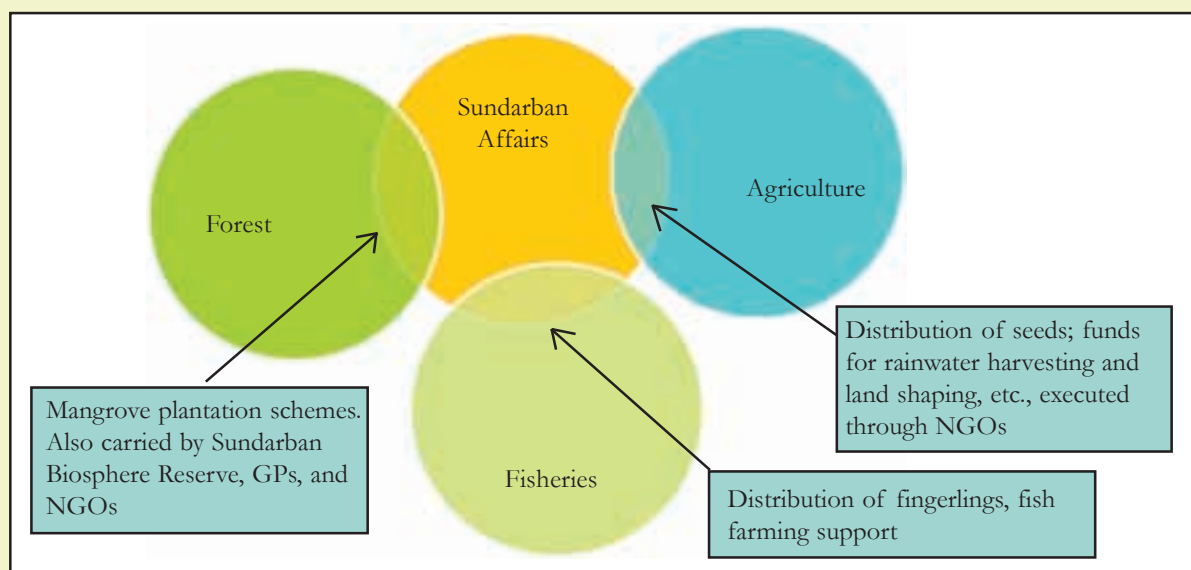
114. Apart from the deficiencies within the DSA and SDB, the state's departments in charge of agriculture, forests, fisheries, and irrigation, among others, are working at cross-purposes in the

region. Numerous examples exist of how sectors working at cross purposes affect socioeconomic conditions and biodiversity conservation: (a) aquaculture development undermines embankment stability; (b) complete bans on mangrove cutting reduce incentives for communities to manage them well and have, in fact, turned pursuit of some potentially sustainable uses into a crime; (c) ration cards intended to improve livelihood security keep people trapped in poverty by discouraging them from integrating themselves into areas of lower risk and greater economic opportunities; and (d) referral systems for health services ignore the reality that the “nearest” medical care center may, in fact, be impossible to reach because of the difficult geographic terrain or lack of appropriate transport.

115. Moreover, there is no nodal agency that coordinates all of the government work in the Sundarbans. The presence of numerous governmental organizations with overlapping authorities and responsibilities gives rise to duplication of efforts, especially in terms of socioeconomic development, and monitoring of outcomes is limited (see Annex 13 for further details on institutions in the Sundarbans).

116. Each of the several types of specially designated reserve areas in the Sundarbans has its own distinct level of protection and is managed by a different governmental department. In 1970, MoEF (within GoI) declared the entire 9,630 km<sup>2</sup> of the Sundarbans as the Sundarbans Biosphere Reserve. This includes approximately 4,260 km<sup>2</sup> of reserve forests, of which around 40 percent has been declared protected areas, including about 1,330 km<sup>2</sup> as a national park, and around 406 km<sup>2</sup> as wildlife sanctuaries. The most stringent levels of protection are those established by the Constitution and through legislation on national parks and wildlife

**Figure 6.1: Overlaps in Functioning between State Government Departments**



<sup>89</sup>See the Center for Science and Environment. 2012.

<sup>90</sup>Center for Science and Environment. 2012.

sanctuaries, with wildlife sanctuaries having slightly lower protection levels than national parks. The Forest Department of GoWB consists of a Forest Directorate with three wings: wildlife; forests; and research, monitoring, and development. Each wing is headed by a principal chief conservator. The wildlife wing is responsible for protection and conservation of the wildlife in the forests of the state, including those in the Sundarbans Biosphere Reserve. The forest wing's focus is on preventing the exploitation of forest resources for economic gain. This emphasis on preventing exploitation is now lower than it once was, and the department does allow for some economic activity to continue based on a lease and permitting system. The Forest Department's focus centers on "preserving the forest," which means exploiting its resources in a sustainably way, rather than restricting exploitation entirely. (In contrast, usage of the word "conservation" is highly constrained, as illustrated by the restrictions imposed on activities in the National Park and wildlife sanctuaries in the Sundarbans.) In addition to the above-mentioned areas, GoI has declared about 2,585 km<sup>2</sup> of the Sundarbans Biosphere Reserve as a Tiger Reserve – which includes the Sundarban National Park and the Sajnekhali Wildlife Sanctuary – in order to protect the Royal Bengal tiger. Tiger reserves have an ambiguous legal status, and are supported by MoEF at the national level. Interestingly, the 2010 household survey found that 93 percent of 2,188 surveyed households would agree if the government were to restrict human access to the forest *completely* in order to protect the Bengal tiger. While the survey item was purely hypothetical, nearly 25 percent of the surveyed households indicated that they would, without qualification, give up 1 percent of their household income to protect the Bengal tiger.

117. While considerable institutional capacity exists on paper, there is inadequate capacity to effectively implement strategic interventions in the Sundarbans. Existing institutions are frequently hobbled by lack of resources. The availability of adequately trained staff remains a constraint in many organizations: doctors, teachers, and other technical professionals have no incentives to work in an environment with risks as high as they are in the Sundarbans. Outdated technical approaches continue to be used: examples include prevalence of monospecific forestry, overreliance on excessively restrictive and unenforceable conservation regulations, and lack of modernized systems to handle isolated communities in need of basic social services. There are no incentives to cooperate or coordinate programs, and this is apparent from the number of contradictory and maladapted initiatives that have been adopted over the past decades. Numerous examples exist, as illustrated above. Such perverse incentives and maladaptations point to the need for changing the BAU way of doing things; institutions need to change in order to effectively and efficiently address the key problems in the Sundarbans (see Annexes 6 and 12 for further details).

## Implementation capacity needs to be strengthened in line institutions

118. Recommended measures can only be implemented effectively if adequate implementation capacity exists, and a first step is to strengthen technical implementation capacity within key institutions. The strengthening cannot be arbitrary and must be done with a view to better address the unique circumstances existing in the Sundarbans. Many of the institutions active in the Sundarbans are also active statewide, with general mandates that do not necessarily mesh well with the on-the-ground realities or challenges of the Sundarbans region. One reason for this is that institutional mandates are often the same for the Sundarbans as they are for the mountainous parts of West Bengal far to the north. In many situations, this is not an issue: all citizens are entitled constitutionally to certain service standards, and all parts of India face similar constraints, for example, shortages of doctors. Moreover, this NLTA cannot address nationwide problems or make proposals to strengthen the capacity to implement measures that are contingent on reforms beyond the scope or control of institutions operating in the Sundarbans. However, many of the capacity-related issues are local, and they call for local solutions. The focus herein is on two types of local solutions to enhance the implementation of recommended measures: (a) those that involve strengthening existing single institutions; and (b) those that involve the cooperation of two (or at most three) key institutions working in tandem. The following discussions highlight the priority areas and institutions for which important changes can be made effectively.

119. Examples of interventions within specific sector agencies include the following:

- In the transportation sector, investments are needed to build the capacity in agencies planning transport interventions in the region so that they can effectively gather data, manage information, and conduct analyses of transportation demand and assessments of environmental and social impacts of proposed actions. The analytic work conducted as part of this NLTA determined that units planning transport systems in the area are lagging behind in terms of information management and various analysis methods and procedures. It is, therefore, recommended that appropriate investments be made in data collection, data management systems, and capacity building, and that interagency coordination related to transport systems be enhanced;
- In the short term, it is critical to place emphasis on preventive healthcare to reduce the incidence of diseases. Examples of preventive healthcare services include provision of health and hygiene education, physical examinations and screenings, immunizations, and vaccinations. Moreover, existing health initiatives<sup>91</sup> implemented by the Department of Health and

<sup>91</sup>These programs include the Reproductive and Child Health Program, Revised National Tuberculosis Program, and National Anti-Malaria and HIV/AIDS Control Programs.

Family Welfare need to be strengthened with the aim of: (a) improving and expanding these programs in hard-to-reach places, most of which are located in the high-risk area of the Sundarbans; and (b) placing additional emphasis on illnesses prevalent in the region. Wild animal attacks as well as high diarrhea incidence linked to salinity intrusion,<sup>92</sup> are two examples of situations that are specific to the Sundarbans and require appropriate preventative and response interventions to reduce incidence and impacts; and

- In terms of energy services, the focus has traditionally been on providing grid power, but there should be an increased emphasis on appropriate local-scale alternatives. Many renewable alternatives have been identified, but capacity to manage these within a broader integrated network is still lacking. Additional training, especially in repair of systems through local or small-scale private businesses, could be facilitated by the Department of Power.

### Paired cooperation and coordination efforts are a near-term priority

120. Although DSA is mandated to coordinate all efforts in the Sundarbans, many near-term implementation efforts to tackle high-priority issues could be achieved by improving cooperation and coordination of selected pairs of responsible institutions, and at times coordination between pairs and other interested parties. Examples of such pairings to address specific issues include:

- **Irrigation and forestry.** Cooperation between these departments has been lacking but is essential, given the current and future needs to encourage mangrove growth along areas that become available for restoration as a result of embankment retreat and realignment. A third party to such cooperation is the Department of Panchayat and Rural Development, given its capacity to improve community efforts in social forestry;
- **Health and transport.** Many of the health-related access constraints relate, in some manner, to transportation issues. The Department of Health and Family Welfare's referral system should be reformed to provide better access to appropriate facilities. Many of the better facilities and their staff are located outside the transition zone, but the referral system has been constrained to send people to services that often lack capacity and are, in any event, not accessible because of transportation challenges. Increased coordination between the two departments can improve service delivery and access;
- **Irrigation and aquaculture.** The Department of Fisheries and Aquaculture should modernize aquaculture practices in ways that do not have a negative impact on investments undertaken by the Irrigation Department. Much of the current embankment erosion in the eastern delta is related to unsustainable aquaculture.

Cooperation and awareness building between these two departments is called for to reduce the negative side effects associated with both the location and operation of aquaculture; and

- **Health and forestry.** Greater coordination is required to handle emergency medical cases in the high-risk area in the transition and core zones. The first steps could involve the establishment of protocols relating to medical emergencies (such as animal attacks), and subsequent work could involve coordination in the context of evacuation and treatment.

### Monitoring and evaluation efforts should be vested in an impartial entity to influence funding allocations

121. To promote increased interagency coordination and a more efficient allocation of public resources, the monitoring and evaluation role of DSA in the region should be strengthened. An important purpose of this monitoring would be to assist in evaluation of the effectiveness of funding allocations to state agencies. DSA has a formal mandate and structure to plan, monitor, and evaluate activities conducted by other agencies in the region. The recommended scheme is one in which each of the state agencies operating in the Sundarbans would adopt annual goals that address one or more of the region's development priorities. Progress toward meeting those goals and budget expenditures would be assessed and reported periodically to top officials of GoWB and disclosed to the public. At the end of a yearly budget cycle, DSA would systematically evaluate how effectively each agency's funding allocation was used. GoWB's Finance Department would allocate the budget that can be spent in the Sundarbans during the next budget cycle based in part on DSA's evaluations of performance, with increased funding directed to agencies that achieved good results and decreased funding for agencies that performed poorly.

### Regulatory functions should be strengthened in an emerging entity: West Bengal Coastal Zone Management Authority

122. The previous version of the coastal zone regulatory framework has been updated in response to India's Coastal Zone Notification of 2011. The new version requires classification of "sensitive" and "hazardous" coastal areas into categories, and explicitly designates the Sundarbans as an area requiring special consideration and, more specifically, as a critical vulnerable coastal area. Under the Notification, the Sundarbans region is subject to restrictions in the nature and scale of development. The

<sup>92</sup>Sea level rise could increase the incidence of diarrhea by decreasing the amount of available "sweet" groundwater, thereby reducing the supply of potentially potable water.



Notification includes the following Coastal Regulation Zone (CRZ) classifications: CRZ-I, ecologically sensitive areas; CRZ-II, built-up municipal areas; CRZ-III, rural areas; CRZ-IV, aquatic areas; and a separate category for areas requiring special consideration. According to the 2011 Notification, the entire Sundarbans region falls under category CRZ-I (ecologically sensitive areas),<sup>93</sup> which implies that the region must adopt very strict controls on construction and development activities. Under the Notification, critical vulnerable coastal areas are required to have integrated management plans to ensure conservation and management of mangroves and to consider the “needs of local communities” for development of school, transport, water supply, sanitation, and other facilities.

123. It is recommended that an emerging entity within the context of the Coastal Zone Notification’s regulatory framework – the West Bengal Coastal Zone Management Authority – be made responsible for enforcing and overseeing (within the Sundarbans) the national regulations, which are established through MoEF and are to be enforced nationally and through the state coastal zone management authorities. In West Bengal, the Coastal Zone Management Authority is “emergent” in the sense that its functions have only been vested recently and are now being strengthened through the World Bank’s Integrated Coastal Zone Management Project. Within the next five years, West Bengal and two other pilot states (Gujarat and Odisha) will have effective institutions in place under the support of this project; all coastal states in India are expected to form such entities over a similar timeframe.

### **Consideration should be given to vesting coordination and implementation responsibilities in a Steering Committee at the state level<sup>94</sup>**

Complex problems with multiple sectoral and spatial dimensions and linkages often call for new solutions, and this is the case for the Sundarbans. DSA had been created exclusively to look after the socioeconomic and developmental needs of the region. SDB, now under DSA, has also been in place since 1973. DSA may have been originally conceived with these functions in mind, but the

current challenges in the region far exceed the mandate and capacity of that agency. However, GoWB can create a high-level Steering Committee at the state level to coordinate developmental activities and to enforce various regulations related to the region. Moreover, DSA can play a more effective role by carrying out the above-mentioned monitoring and evaluation functions to guide the budget allocations of the Finance Department of GoWB for work within the Sundarbans. The West Bengal Coastal Zone Management Authority could also potentially carry out the necessary priority setting and interagency coordination functions, but its mandate includes the entire coastal margin of the state and – more significantly – the range of issues involved is well beyond that contemplated for the Coastal Zone Management Authority.

124. Although no equivalents exist elsewhere, a potential model for the Sundarbans Steering Committee is the Delta Committee, established in the Netherlands in 2007 to move forward the process of managing the transition of a degrading estuary system dependent on rural agriculture into a sustainable area that supports socioeconomic development, while also promoting the conservation of regionally important wetlands. While numerous differences exist between the Netherlands and West Bengal, the Delta Committee also embraced the idea of building resilience and supporting the capacity to adapt in the face of a resource base that had been degraded as a result of earlier interventions. The Committee also considered the future threats of climate change in carrying out its work.<sup>95</sup> If similar ideas were adopted in creating the Sundarbans Steering Committee, the institution would be given responsibility for anticipatory planning and selection of effective interventions, along with a coordinating role which ensured that various sectoral agencies were doing their part. The working approach of the Delta Committee is “Faster and Better,” which was interpreted operationally as a way to speed up decision-making.<sup>96</sup> If adopted for the Sundarbans, this approach could overcome potential stagnation resulting from existing processes and institutional norms. To provide a foundation for further considering the idea of creating a Sundarbans Steering Committee as a new entity, it is recommended, as a first step, that a series of study tours be organized for officials in the Sundarbans to see how related institutions in the Netherlands, and potentially in other jurisdictions, are pursuing estuary management.<sup>97</sup> The experience

<sup>93</sup>The CRZ-I designation is for “areas that are ecologically sensitive and the geomorphological features which play a role in maintaining the integrity of the coast”, and are located between the low tide line and the high tide line. CRZ-I includes areas containing mangroves, national parks, sanctuaries, reserve forests, wildlife habitats, and biosphere reserves, all of which exist in the forested part of the Sundarbans.

<sup>94</sup>GoWB. 2012.

<sup>95</sup>In 2008, the Delta Committee completed its report, with proposals for long-term planning (Delta Committee 2008). The report called for an increasing reliance on natural systems (dunes, tidal dynamics, bioshields) to protect high-value areas while abandoning some productive but lower-value areas; it also identified an extensive set of enabling laws and regulations that would need to be implemented to realize this vision. A related report also promoted a “Faster and Better” principle as a means to address the problem that “the need in our consensus-based culture to unite the virtually irreconcilable in many cases [...] does not advance because of the administrative and political incapacity to take decisions or, once a decision has been taken, to actually implement it” (Elverding et al. 2008).

<sup>96</sup>Deelstra et al. (2009) observe that rather than postponing decisions until negotiated alternatives have been elaborated and evaluated, the approach involves identifying and exploring strategic alternatives early on and then selecting one to be advanced on a fast track. See also Werners, van de Sandt, and Jaspers 2009.

and knowledge gained from those visits could then drive the discussion of whether and how a Sundarbans Steering Committee could be created.

## **Institutional change is inevitable and should focus on near-term implementation needs**

125. The reform and realignment of existing organizations is not simple and, in many cases, will need to be accomplished using extensive participatory processes. Most of the recommended near-term interventions are urgently needed because ongoing and future degradation places large numbers of people in the transition zone at significant risk. In addition, many of the recommended high-priority actions (for example, improved disaster risk management systems) could be implemented without foreclosing any future options. Moreover, many recommendations for action are accompanied by actions that should *not* be taken, such as encouraging mass tourism, reinforcing existing embankments without considering the need for embankment realignment and retreat, and investing in costly transportation infrastructure in the transition zone, given that the zone will gradually have a reduced population as residents take advantage of job opportunities in the stable zone and elsewhere.

## **Mainstreaming of climate change in relevant institutions**

126. The impacts of climate change are highly local, and the effective means to adapt depend on local institutions in addressing climate change concerns. The typical rationale for local governments in helping regions adapt to climate change is as follows. Since environmental problems are typically felt locally, local governments are often in a better position to understand climate change concerns in their respective jurisdictions, and thus would achieve superior outcomes if given the freedom to choose the most appropriate policies, and programs. However, adapting to climate change requires the participation of local populations, both in planning

and implementation, as the majority of climatic events (sea level rise and storms) are mostly experienced by residents living in high exposure areas such as the Sundarbans.

127. Given that climate change is expected to cast a long shadow in the region, efforts to mainstream climate change considerations in all relevant institutions operating in the Sundarbans, as well as local governments, should be a priority over the medium term. Enhancing knowledge on climate change issues must be a continual process to eliminate the lack of relevant expertise in operating institutions, particularly at the local level. Currently, there are no formal mechanisms in place to identify priorities using analytical work and incorporate them in multi-year planning processes. Also missing are mechanisms to incorporate the concerns of groups (particularly women and children) most severely affected by climate change into local government and local institutions' planning processes.

128. The institutional capacity of the Nodal Agency for Climate Change located in MoEF should be strengthened to better address climate change impacts in the region.<sup>98</sup> The Climate Change Division of MoEF is India's nodal agency for climate change, dealing with climate change issues at both domestic and global levels. It is also the nodal unit for coordinating the National Action Plan on Climate Change.<sup>99</sup> The capacity of the agency should, therefore, be augmented by increasing the number of staff as well as their level of expertise on climate change. Furthermore, the West Bengal State Action Plan on Climate Change has a sectoral approach and its implementation could be hampered by the lack of cross-sectoral coordination discussed above. GoWB will prepare a specific strategy for the Sundarbans. This opens a window of opportunity to implement climate change responses through the coordinated efforts recommended by this report. Funding will also be needed to augment the agency's capacity to conduct analytic work related to climate change, and to identify possible measures for climate change mitigation and adaptation in the Sundarbans. The Nodal Agency should undertake work on climate change in consultation with the Department of Environment, with both units collaborating with one another to develop the State Action Plan on Climate Change.<sup>100</sup>

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<sup>97</sup>As part of the NLTA, a study tour was organized in 2010 for GoWB officials to visit the area affected by Hurricane Katrina in the United States; participants met in New Orleans with experts from the U.S. Army Corps of Engineers and other organizations engaged in post-Katrina follow-up work. Participants in the study tour learned about the use of storm prediction systems and disaster management response methods, as well as measures to expand protection against hurricanes and associated floods. Participants found the tour informative. Some of the risk management systems that were discussed have been considered as potential candidates for future use in West Bengal.

<sup>98</sup>MoEF. 2013.

<sup>99</sup><http://envfor.nic.in/public-information/climate-change>.

<sup>100</sup>MoEF. 2013.

## Summary of options for institutional change

A summary of the recommended measures for institutional change is provided in Table 6.2.

**Table 6.2: Pillar 4: Options for Institutional Change**

Time Scale	Options for Action
<b>Short term</b>	<p>Strengthen the capacity and effectiveness of state institutions to better address problems in the Sundarbans (for example, Department of Health and Family Welfare to focus on preventing and treating illnesses prevalent in the region)</p> <p>Initiate paired cooperation and coordination efforts among lead institutions, particularly those in the following sectors: irrigation and forestry; health and transport; irrigation and aquaculture; and health and forestry</p>
<b>Medium term</b>	<p>Task DSA to monitor and evaluate sectoral agency activities; GoWB's Finance Department would allocate the budget that can be spent in the Sundarbans during the next cycle based in part on DSA's evaluations of performance, with increased funding directed to agencies that achieved good results and decreased funding for agencies that performed poorly</p> <p>Task the West Bengal Coastal Zone Management Authority to enforce and oversee national coastal zone management requirements in the Sundarbans</p> <p>Strengthen the technical expertise of agencies and local governments to better understand how climate change impacts their jurisdictions</p> <p>Enhance the institutional capacity of the Nodal Agency for Climate Change of the MoEF to better mainstream climate change concerns in policymaking</p>
<b>Long term</b>	<p>Create a new institutional authority called the Sundarbans Steering Committee to set implementation priorities and facilitate coordination efforts</p>







## 7. NEXT STEPS



This study is the culmination of two years of active engagement and research but, in most respects, the real work has not yet begun. The next steps will need to focus on working to achieve consensus regarding key elements of the recommended development strategy. The NLTA has already built significant capacity locally to move forward with many of the recommended actions. Researchers in West Bengal have been involved in all 21 background studies to varying degrees, and the resulting consultants' reports represent objective resource materials for decisionmakers and policymakers. Moreover, some of the proposed actions are already being pursued and others have been mandated by national policy initiatives. As an example, actions have already been initiated in response to India's 2011 Coastal Zone Notification. As another example, the West Bengal Irrigation Department has begun to realign damaged embankments in the transition zone; the approach adopted by the Irrigation Department includes rehabilitation and resettlement procedures that are similar to best international practices. As other examples, cyclone shelters are being financed by NGOs in threatened areas and private sector actors are engaging in mangrove planting to earn carbon credits under the Clean Development Mechanism of UNFCCC.<sup>101</sup> These activities have relied directly or indirectly on local capacity, which has been informed or strengthened by the NLTA. In addition, the NLTA facilitated the establishment of the Ecosystem Forum on the Sundarbans to establish a dialog between India and Bangladesh on issues of common regional concern.

### Accepting the reality of a degraded and poverty-stricken area

129. The Sundarbans mangrove forest is surrounded by 19 blocks in the districts of North 24 Parganas and South 24 Parganas with a population of over 4.4 million, including some of India's poorest and most vulnerable people. A high percentage of the households in these blocks live below the poverty line. Per capita income in the region is about 50 cents (US\$) per day, which is half

of the commonly used indicator of extreme poverty. Along with abject poverty, there is a lack of basic food security; around 6 percent of all households reported that they consumed less than one square meal a day, with around 19 percent consuming only one meal a day. All 19 blocks of the Sundarbans region have more poor households than the corresponding averages for India and West Bengal, and the percentage of BPL households ranges from 31 percent to 65 percent in these blocks.<sup>102</sup>

130. The physiography of the Sundarbans region currently poses risks to the lives and assets of the local population, and numerous factors will increase those risks over the next several decades. The Sundarbans contains a challenging terrain for residents; high levels of poverty and dependence on the forest and natural resources are leading to degradation of the resource base upon which much of the population depends. This problem is further compounded by past human interventions and ongoing geomorphological shifts. Moreover, climate change is expected to exacerbate impacts of sea level rise and intensify cyclonic storms in the future. As a result, within the next few generations, the demands placed upon the region will far exceed its carrying capacity, leading to a deteriorating situation for the local population. Under the circumstances, there is an urgent need for intervention.

131. To provide a diagnostic and priority-setting framework, this report adopted an approach centering on three geographic zones – stable, transition, and core – to identify key areas of intervention over different time frames. Recognizing the high spatial diversity within the Sundarbans, the NLTA distinguishes three different zones: a relatively densely populated stable zone far from the Sundarbans Reserve Forest, a transition zone that is between the stable zone and the protected forest area, and a core zone consisting of a reserve forest and legally protected areas. The transition zone surrounds the forest and contains primarily rural communities, historically underserved by infrastructure and public services. The transition zone gives way to the stable zone, which consists of peri- and semi-urban areas closer (and relatively well connected) to

<sup>101</sup>For more information, see <http://cdm.unfccc.int/>.

<sup>102</sup>Figures in this paragraph are based on the findings of the household survey conducted as part of this NLTA.

Kolkata. In comparison to residents of the transition zone, inhabitants of the stable zone do not suffer to the same extent from the ongoing effects of geomorphological shifts and natural disasters. In the Sundarbans, reference is sometimes made to a “high-risk zone,” which is an area that overlaps with both the core area and the transition zone. The high-risk zone includes all legally protected areas, the Reserve Forest and the fringe area (a belt on the periphery of the forest and the area impacted by Cyclone Aila). The short-term focus is on meeting the basic needs of residents and building human capital to enable residents to enhance their skills and otherwise become equipped to take advantage of more lucrative livelihood options in less physically hazardous settings. The longer-term emphasis is on adopting mechanisms to use the rich natural capital in the Sundarbans to generate a stream of revenues that can support adaptation, socioeconomic development, and biodiversity conservation.

## Near-term acceptance of the long-term needs and opportunities

132. Four key areas of intervention are identified below, and collectively they contribute to meeting the long-term goals of decreasing vulnerability, reducing poverty, and enhancing biodiversity conservation. When coupled with requisite institutional reforms, the measures summarized below are expected to contribute to overall socioeconomic development for residents of the Sundarbans while, at the same time, conserving biodiversity. In the near term, a program to communicate these ideas widely is called for so that all concerned parties can be made aware of the following key themes.

133. **Employment and economic opportunities.** In the long term, the most effective poverty alleviation strategies will be those that empower and equip residents of the Sundarbans with the means necessary to seek greater economic opportunities in lower environmental risk areas that provide improved access to employment, health, education, and safety. To realize this long-term objective, it is essential to implement measures to incentivize parents to send their children to school and obtain medical services that are accessible and affordable. Indeed local populations, particularly in the high-risk area, face disproportionately lower health and well-being outcomes than in West Bengal as a whole. A number of investments can be made to improve health: placing greater emphasis on preventive healthcare; enhancing water supply, sanitation, and hygiene services, for example, by means of in situ disinfection of drinking water to curb waterborne infectious diseases; curbing indoor air pollution through the promotion of more efficient cooking stoves; improving transportation networks and routes to existing health facilities; and providing specific health services to address human–wildlife conflicts, most notably snake or tiger bites. Short-term priorities for the provision of healthcare should center on addressing critical primary health issues in the hard-to-reach areas of the transition zone, and particularly on improving child and maternal healthcare. Enhancing health and

educational outcomes for transition zone residents will allow them to be more mobile and, thus, more able to take advantage of the fuller range of economic opportunities in urban areas in the long term. It will also be necessary to implement job training programs in the stable zone to prepare residents for employment opportunities in the livelihood clusters in that zone as well as economic opportunities in Kolkata and other urban areas. However, the need for these measures is not limited to transition zone residents. Interventions to enhance human capital by improving health, education, and job skills are also needed in the stable zone to allow those residents to obtain better employment options in livelihood clusters in the stable zone as well as in Kolkata and other cities. This is a process that can unfold gradually over time.

134. **Biodiversity conservation.** Key approaches for conserving biodiversity include enhancing levels of conservation protection of the forests, restoring mangrove forests, and reducing pressure on the forests by providing transition zone residents with livelihood options that are sustainable. The existing Sundarbans Reserve Forest should be legally protected for conservation by designating it as a combination of wildlife sanctuaries and national parks, and this should be complemented by a long-term, gradual transformation in which increasing portions of the transition zone are designated as protected and reserve forest areas. Mangrove restoration in the core zone and in the high-risk sections of the transition zone will serve multiple purposes. Mangrove forests provide effective bioshields in the event of a cyclone, and thus they can serve to protect populations in the Sundarbans as well as in Kolkata. In addition, mangrove forests sequester carbon emissions and, as carbon financing opportunities develop, existing and new mangrove forests could provide an important revenue stream to fund measures that benefit residents of the Sundarbans, including incentive programs allowing residents to access improved healthcare, education, and job training programs. As new mangroves are regenerated, it is recommended that these be designated as *community reserves* or *conservation reserves* in order to shift the focus from exploitation of forest resources to management based on sustainability considerations.

135. **Revenue generation options.** New revenue generation schemes can be created to fund programs that prepare residents to pursue improved employment opportunities in urban areas. At the same time, these revenue generation options can provide incentives to residents near the forests to assist in forest preservation efforts. Continuing and intensifying current financial assistance programs for transition and stable zone residents can improve their access to healthcare and education as well as to obtain job training within the stable area and in peri-urban and urban areas outside the Sundarbans. Revenues to support programs providing financial assistance for education and health could come from normal state budgets augmented by new sources, such as: (a) carbon financing, as illustrated by the UN-REDD and REDD-plus programs and grant programs that have been promoted by the World Bank and other development assistance organizations;

(b) schemes based on PES; and (c) innovations in the creation of property rights based on the assets within the Sundarbans Reserve Forest. Residents who own forested land can take advantage of some of these financing opportunities, such as PES programs, to receive compensation for preventing forest destruction and maintaining biodiversity. Some of these revenue streams, involving grant financing provided by international aid organizations, will be relatively straightforward in both design and implementation. However, others will require additional analytic work because they are relatively new (as is the case for carbon financing programs under REDD-plus) or they have proven challenging to design in other settings (as is the case for PES). The general notion of creating property rights on forest resources is based on creating revenue streams linked to sustainable uses (for example, honey collection, fruit harvesting) and associated with nonextractive use functions (for example, tiger viewing or carbon sequestration). Each of the revenue streams above – carbon financing, PES, and innovative property rights – would involve forest preservation and thus create incentives for residents of communities living near the forest to become custodians and co-managers of the forest.

**136. Disaster relief and livelihood options.** Key changes recommended for the transition zone involve new disaster relief measures, enhanced provision of basic services, and new, sustainable livelihood options. Many residents of the transition zone will remain in that area, especially in the near term, and thus there is a need for improved disaster risk management, basic service provision, and employment options that protect the resource base. Improved disaster risk management requires multiple measures, such as improved warning systems and well-coordinated relief services. Basic service provision is also multifaceted, involving, among other things, water supply and sanitation and infrastructure for transport and energy. Several approaches can be used to augment sustainable livelihood options in the transition area; examples include developing a limited program for high-end and environmentally sustainable ecotourism, modernizing the aquaculture industry, and enhancing the sustainability of agriculture.

## Spatially blind policies to meet basic needs and manage risks of natural disasters are immediate priorities for meeting long-term goals

**137.** Short- and medium-term interventions should focus on disaster risk management and meeting basic needs of residents, but actions should be consistent with the overall recommendations for meeting objectives linked to biodiversity conservation and long-term socioeconomic development. The following three sets of recommendations for the short and medium terms are “spatially blind” in the sense that they apply for all residents of the Sundarbans.

**138. Embankment reconstruction and retreat.** In areas in which existing embankments are (or will be) undercut by tidal creek erosion, a program of embankment reconstruction and embankment retreat needs to be continued; in addition, crest heights for *all* embankments should be raised. Tidal creek erosion has radically undermined the stability of many parts of the embankment system in the Sundarbans, and such embankment systems should typically be retreated between 100 and 500 m. Crest heights for all embankments will need to be raised to accommodate both local and global sea level rise and expected increases in storm intensity. In many of the spaces between retreated embankments and old embankments, mangrove forests should be planted or encouraged to regenerate naturally; these will act as bioshields in the event of disasters and they may also be a source of revenues based on carbon financing.

**139. Disaster risk management.** Given the immediate risks from natural disasters, a well-designed program of disaster risk management should be implemented. Residents of the Sundarbans are at a high risk from cyclones and tropical storms, and climate change is expected to increase the intensity of such disasters in the coming years. In the near term, efforts should be made to develop *disaster risk management strategies* to reduce the threat to the lives and assets of the local population. These interventions should include improvements in the forecasting and early warning systems for local populations; construction of multipurpose cyclone shelters and access roads, with a particular focus on separate facilities for women and children; and community-level communications and training programs to develop local-level evacuation plans and warning systems.

**140. Improved education and health.** Mobility can be improved by enhancing education and health. A key priority for both the transition and stable zones is the removal of restrictions on mobility by improving health, education, and job training outcomes for residents. Doing so will allow residents to take advantage of better employment opportunities located in urban settings. Interventions for education and healthcare can take the form of incentives to help residents improve living standards and become more eligible for improved employment opportunities. Measures to improve health outcomes, including placing additional emphasis on preventive healthcare and diseases prevalent in the Sundarbans, were summarized above. According to GoWB (2012) in terms of education, intensifying current financial assistance programs providing scholarships<sup>103</sup> could reduce financial constraints that cause some families to remove students from school. Financial assistance could be offered to residents of the Sundarbans, but only on the condition that their children attend school in the stable zone or more urban areas. Financial assistance for post-secondary school training could cover a student’s tuition and living expenses, as well as provide money to families to help cover the income that would otherwise be earned if children did not extend their educations beyond high school. The amount of the cash transfer

<sup>103</sup>Students from weaker sections are eligible to get financial assistance in the form of scholarships from the government in order to pursue their education. Source: GoWB. 2012.



should increase as the student progresses from one education level to the next, thus reducing dropout rates during transitions. According to GoWB (2012) financial assistance programs for education should continue to target primarily vulnerable groups that have limited access to health and education services, such as minority groups, women, and the elderly. These programs could also be designed to make it easier for residents to access vocational training programs.

## **Investments and policies that enhance spatial connectivity can help to improve mobility and provide access to better opportunities**

141. Transport infrastructure can help provide access to employment opportunities and improve linkages between the stable zone and Kolkata and other urban markets. Railways and highways connected to the stable zone would reduce access barriers and allow more movement of goods (and people) between that zone and Kolkata. More generally, improved transport from the stable zone and peri-urban area to Kolkata would allow residents to access jobs in urban areas and increase the likelihood of being lifted out of poverty.

## **Spatially targeted interventions can promote economic growth and enhance forest resources**

142. Spatially focused measures in the stable zone can expand employment opportunities, improve access to public services, and provide training and support services. Economic incentives could be provided to attract new firms to existing and new livelihood clusters. These incentives can include improvements in infrastructure (roads, energy supply, water supply and sanitation, schools, and hospitals). Measures should also be implemented to support transition zone residents who choose to integrate themselves into the stable zone in order to enhance their job prospects. Such measures could include support services in the stable zone such as temporary housing, skills development programs, and job placement services. More generally, spatially targeted investments in the stable zone could lay a foundation for residents of the Sundarbans to become integrated into relatively better economic opportunities in more urban contexts.

143. Special attention should be focused on using risk communication and a government-run land transaction program as measures to reduce the number of people exposed to risk associated with flooding, sea level rise, cyclonic storms, and other hazards in the transition zone. The risk communication program could be used to discourage in-migration into the area and to encourage residents of the Sundarbans to integrate themselves into areas of lower environmental risk, particularly residents now living in the high-risk portions of the transition zone (areas originally

covered by mangrove forest and those impacted by Cyclone Aila). Current demographic shifts in the Sundarbans include out-migration (both temporary and permanent) of workers going to larger cities, mostly Kolkata; and in-migration of workers coming to the Sundarbans from parts of West Bengal, other parts of India, and neighboring Bangladesh.

144. Levels of protection against exploitation of core zone areas should be enhanced. As a short-term measure, the present Sundarbans Reserve Forest should be provided a higher level of protection by defining it as a combination of areas legally protected for conservation (as wildlife sanctuaries and national parks). In that context, all economic activity in the existing Reserve Forest should be gradually reduced.

145. Other measures to conserve biodiversity in the core zone include enhanced enforcement of existing regulations supplemented by market-based incentives that promote attainment of biodiversity conservation goals. Regulatory instruments that must be enforced are already in place, but new market-based incentive mechanisms could improve regulatory efficiency and help realize positive biodiversity conservation outcomes. An important goal for the core area is elimination of illegal poaching of tigers, clearing of mangroves, and settlement in protected areas. There are regulations on these activities but they can be updated (for example, a requirement for forest entry permits to be reissued annually or biannually) to more effectively reduce the extent of such activities. In addition, new revenue generation activities, based on ecosystem services, could provide residents on the fringe of the core zone with economic incentives to monitor and report illegal exploitation of the forest. The recommended development approach involves making efforts to use the natural capital found in the rich ecosystem of the Sundarbans to create revenue streams in a variety of ways, including carbon financing, PES programs, and support from multilateral and bilateral aid institutions. The resulting revenue streams could provide funds both to support biodiversity conservation efforts and improve socioeconomic development for Sundarbans residents. Since revenue generation would be contingent on meeting conservation performance goals, the use of revenues to support the needs of residents would motivate them to play an active role in ensuring that conservation targets are met.

## **Complementary initiatives for institutional change**

146. The ability to capture monetary values of ecosystem services could be enhanced by building capacity in research, monitoring, and evaluation, and by establishing institutions to assist in taking advantage of international financing opportunities. It is recommended that a research organization be established in West Bengal to provide a focus on the Sundarbans, which would include monitoring the ecosystem and estimating the monetary values of ecosystem services provided by the Sundarbans. The research unit could also monitor the state of biodiversity and ecological structure



and function of the forest. Such a research-oriented organization could build upon the findings from the studies conducted as part of this NLTA. The research unit could also coordinate and collaborate with analogous research-oriented entities in India and Bangladesh to promote transparent and shared information on the Sundarbans. A related recommendation is to create an institutional structure to take better advantage of international and domestic financing opportunities for global public goods; this would involve creating systems to organize funding applications, registration processes, and other types of preparation needed to obtain carbon financing. Some of this effort can be organized in cooperation with Bangladesh.

147. Successfully implementing recommendations presented in this report will only be possible in an institutional environment that supports the overarching strategy of promoting socioeconomic development and biodiversity conservation while adapting to climate change. At present, the institutional arrangements for management and development of the Sundarbans are complex, with multiple agencies and departments working primarily within their sectoral mandates. Given the difficult terrain of the Sundarbans and the multitude of development challenges, it is recommended that existing institutional arrangements be realigned to embrace a spatial planning approach that better accounts for the unique features of the Sundarbans. Several institutional changes should be considered:

- A spatially-oriented planning approach to the Sundarbans is recommended (in contrast to traditional sectoral planning). The overarching strategy in this report is founded on the premise that the geography of the Sundarbans merits a strategy that distinguishes among spatially defined zones and plans for them in a unified way instead of relying on a BAU approach based upon sectors and line departments. It is also recommended that all planning and policy making should draw on work performed by the above-mentioned research unit;
- Consideration should be given to creating an entirely new entity – a Sundarbans Steering Committee – to handle the significant near-term coordination and management requirements of a proposed investment program over the next decades. This unit would be unique in its structure and function. However, there are existing institutions that may serve as models for selected activities of the Sundarbans Steering Committee, such as the Delta Committee in the Netherlands and the Federal Emergency Management Agency in the United States;

- Budgets for GoWB departments working in the Sundarbans should be allocated based on performance in meeting predetermined performance targets (based on indicators). Performance would be assessed by DSA, which would have a focus on monitoring and evaluation of agency performance. The West Bengal Finance Department should make its budget allocations based on the assessments of DSA. To enhance the legitimacy of the process, there should be public disclosure of all DSA performance assessments and Finance Department budget allocations for GoWB agency work in the Sundarbans;
- As mentioned, the entire Sundarbans Reserve Forest should be given legal protection so that conservation efforts can be applied throughout the entire reserve. Only a portion of the Sundarbans Reserve Forest has protected area status: the Sundarbans National Park and the three wildlife reserves. The remaining portions of the current reserve forest should be integrated into the wildlife sanctuaries and Sundarbans National Park, given that the sanctuaries and park have strong legal mandates for conservation. It is also recommended that a new biological marine reserve be created, which could eventually be managed in conjunction with the Government of Bangladesh; and
- The Sundarbans Reserve Forest should be gradually expanded to take better advantage of growing carbon financing opportunities. In the immediate future, it is envisioned that many sections of the embankment system will likely be retreated between 100 and 500 m to avoid embankment failures due to undercutting via tidal creek erosion, among other things. In the space between retreated embankments and the old embankments, mangrove forests should be restored as bioshields. These new areas should be designated as community reserves, with economic activity regulated to ensure the forest's sustainability and its availability for carbon sequestration. Efforts to promote biodiversity conservation and socioeconomic development will be most effective through the combined and coordinated efforts of both India and Bangladesh. The ongoing efforts to develop bilateral cooperative agreements between the Governments of India and Bangladesh, concerning various matters related to the Sundarbans, should be continued and strengthened.

148. Table 7.1 presents a matrix showing priority issues and related interventions, and provides a starting point for understanding the timing, location, and nature of some of the key initiatives.

**Table 7.1:**<sup>104</sup> Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans

Short Term (5–10 years)		
Source	Condition/Pressure	Interventions
<i>Anthropogenic factors</i>	Overexploitation of forest resources in the core zone	Forest regulation (for example, annual or biannual allocation of permits); emphasis on harvesting nontimber forest products, such as honey, fruits, or fish; risk communication to reduce forest pressure in the core zone
	Unregulated tourism in the core zone	Development of high-end and environmentally sustainable ecotourism for the core zone, including altering the current tourism policy to eliminate mass tourism
	Low agricultural productivity in the transition zone	Improvement in agricultural productivity in the transition zone (emphasis on climate-resilient agricultural practices, including adoption of salt-resistant varieties); regulation and modernization of aquaculture practices
	Embankment erosion from inappropriate location and operating characteristics of tidal aquaculture in stable and transition zones	Regulation and modernization of aquaculture practices in the stable zone; regulation of timing of recharge and location of ponds, especially strict limitations on tidal aquaculture in the transition zone
	Biodiversity loss from harmful fishing and prawn seed collection practices in the transition/core zone	Regulation and modernization of aquaculture practices in the transition zone, for example, implementation of state-of-the-art hatcheries
	Poor human development outcomes in transition and stable zones	Implementation of spatially blind policies (improving health and education facilities; enhancing water supply, sanitation, and hygiene; continue offering financial assistance for education to families in the transition and stable zones)
	Lack of employment opportunities in the transition zone	Promoting high-end and environmentally sustainable ecotourism, modernized aquaculture, sustainable agriculture, and harvesting of nontimber forest products; continue offering financial assistance for education to increase employment prospects and incomes in the long run
<i>Geomorphological processes</i>	Embankment erosion and failure from historical processes in the transition zone and parts of the stable zone	Systematic retreat of embankments by 100–500 m over the next 20 years and an increase in embankment heights to 5.25 m above mean sea level; outer (existing) embankments will need to be maintained until the interior embankments are completed
	Salinization of soil water sources and soil from sea level rise, reduction in fresh-water inflows to the delta, and flooding in transition zone and parts of the stable zone	Upgrading of fresh-water point sources; changing agricultural practices to respond to salinization of soils
<i>Climate change</i>	Anticipated increases in storm intensity, local and global sea level rise, and salinization	Disaster risk management, including risk communication to reduce population pressure in the area, development of improved warning systems, development of cyclone emergency response plan and services, provision of an adequate supply of cyclone shelters; relocation and elevation of embankments

<sup>104</sup>Table 7.1 applies a stress–response organizing framework, and highlights the differences between anthropogenic and natural stresses. The table is organized around three different time frames; short term (5 to 10 years); medium term (10 to 30 years); and long term (more than 30 years). For each time frame, pressures are grouped under categories: anthropogenic, geophysical, and climate change.

**Table 7.1 (continued): Framework for Assessing Priority Issues and Identifying Policy Options in the Sundarbans**

Medium Term (10–30 years)		
Source	Condition/Pressure	Interventions
<i>Anthropogenic factors</i>	Potential reduction in pressure on the forest as a result of a decrease in population in the transition zone, and forest regulation	Community-based mangrove restoration and forest protection schemes based on carbon financing; development of high-end and environmentally sustainable ecotourism sector in the transition zone
<i>Geomorphological processes</i>	Persistent erosion stresses from subsidence and sea level rise	Continue systematic retreat of embankments by 100–500 m and increase embankment heights to 5.25 m above mean sea level; maintain outer embankments; mangrove plantation in the area between old and retreated embankments; sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds
<i>Climate change</i>	Potential reduction of fresh-water flows in the delta from changes in monsoon pattern	Closure of tidal creeks to improve fresh-water storage capacity; raising existing tubewell sources at spot water supply sources by 3–4 m; raising floors of pump assemblies; protecting fresh-water ponds by raising their encircling bunds
	Increase in intensity of storms/cyclones and sea level rise	Continue systematic retreat of embankments by 100–500 m and increase embankment heights to 5.25 m above mean sea level; community mangrove restoration and conservation programs based on carbon financing; sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds
Long Term (30+ years)		
Source	Condition/Pressure	Interventions
<i>Anthropogenic factors</i>	Potential increase in urbanization in the stable zone, reduced population pressure in the transition zone	Implement job training programs in stable zone; upgrade and extend health/education/infrastructure services in stable zone; create a new marine reserve to be co-managed by India and Bangladesh; declare entire transition zone a restricted area in which privately held land could only be sold to GoWB for conservation purposes
	Increased sedimentation in some areas of the transition and core zones from upland closure of tributaries	Restoration of protective mangrove bioshields in the transition zone; encouragement of natural regeneration of mangroves in the core zone
<i>Geomorphological processes/ climate change</i>	Increased salinity in the transition zone and parts of the stable zone as a result of sea level rise	Embankment realignment and retreat
	Increased sea level rise	Height of (new) interior embankments should be increased in a stepwise fashion to keep ahead of sea level rise
<i>Climate change</i>	Increase in intensity of storms/cyclones and sea level rise	Sluicing of smaller creeks, closing portions of channels, regulating recharge of aquaculture ponds to adapt to sea level rise; the height of (new) interior embankments should be increased in a stepwise fashion
	Catastrophic flooding of some smaller embanked areas from storms in the transition zone	Effective early warning system in place with contingency plans to evacuate residents







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# Annex 1.

## Historical Overview and Current Trends in Development in the Sundarbans<sup>1</sup>



### Abstract

The inhabited areas of India's Sundarbans are characterized by severe poverty, which both contributes to and arises from the vulnerability of its population to a growing range of natural hazards. The riverine terrain of the Sundarbans, combined with its exposure to natural hazards, makes it a difficult place to survive in. However, the Sundarbans are also densely populated, and people continue to live there despite the growing environmental risks that they face. In order to better understand the Sundarbans, a comprehensive household survey was undertaken to address key data gaps. The findings of the survey show that over half of the households in the Sundarbans are classified as poor and over half are from historically marginalized social groups. Two-thirds of households are prone to the impacts of natural disasters, which pose a constant threat to agriculture. Households are typically engaged in multiple livelihood strategies that are dominated by agriculture (cultivation of own land or that of others) and complemented by strategies such as trading, fishing, forest-dependent livelihoods, and, increasingly, migration out of the Sundarbans to seek possible livelihoods elsewhere. Spatial transformation of the Sundarbans will require that shortcomings in human development are addressed to better link the local populations to alternative livelihoods to mitigate the growing risks in the region.

### 1.1 Introduction

The inhabited areas of the Indian Sundarbans are characterized by high poverty, low service delivery, and social exclusion. Of the over 4.4 million inhabitants of the Sundarbans blocks, half live below the official poverty line,<sup>2</sup> 70 percent do not have access to safe water, and only 17 percent of households have grid access. The region is also characterized by a high number of historically marginalized populations; Scheduled Caste (SC) and Scheduled Tribe (ST) populations make up around 60 percent of the population. The people and the productivity of their

holdings are under increased threats from deltaic subsidence, salinity intrusion, sealevel rise, and increased cyclone intensity as climate change and decay of a 19th-century 3,500-kilometer (km) system of embankments take their toll.

Despite these dismal conditions and endemic poverty, the population is growing and exerting even greater pressure on fragile and recovering natural systems. Nearly 80 percent of the households pursue livelihood options that involve inefficient production methods in agriculture, fishing, and aquaculture. Impacts of environmental damage and health effects are estimated as equivalent to 10 percent of the Sundarbans gross domestic product (GDP) in 2009,<sup>3</sup> and an appropriate response strategy is required for such a large population to escape from conditions of poverty under the growing threat of a changing climate.

### 1.2. History of the Sundarbans

The Sundarbans have been inhabited for thousands of years, as is proved by artifacts dating back to before the Mauryan era (4th–2nd centuries BC). Much of the early history is based on archeological evidence (Mandal 2003). From about 750 AD to approximately 1200 AD, West Bengal was ruled by the Palas, followers of Mahayana Buddhism. Many of those occupying the Sundarbans made their livelihood by fishing. The Palas were eventually driven from power by the invasion of Turkish-speaking groups from Central Asia. University of Arizona Professor Richard Eaton explains the historical significance of this Turko-Mongol conquest:

Bengal's historical experience was extraordinary not only in its widespread reception of Islam but also in its frontier character.... For several centuries before and after the Mongol irruption into West Asia, newly Islamicized Turks from Central Asia and the Iranian Plateau provided a ready supply of soldiers, both as slaves and as free men, for commanders such as Muhammad Bakhtiyar. Once within Bengal's fertile delta, these

<sup>1</sup>This Annex was prepared by Ernesto Sánchez-Triana and Anna O'Donnell based on the various background reports and analyses.

<sup>2</sup>As measured by whether the household has a below the poverty line (BPL) card.

<sup>3</sup>See Annex 7: Environmental Risks and Measures to Reduce their Costs.

men pushed on until stopped only by geographical barriers. Surrounded on the north and east by mountains, and to the south by the sea, Bengal was the terminus of a continent-wide process of Turko-Mongol conquest and migration. It was, in short, a frontier zone (Eaton 1993).

In describing the period from 1204 until 1575, during which the Muslim Indo-Turkish sultans ruled, Eaton points to some fundamental changes that take place in this period: “Muslim pioneers ... not only established the Islamic religion in much of South and Eastern Bengal, but also played important roles in the intensification of wet rice agriculture, established new modes of property rights, and contributed to a fundamental altering of a natural, forested ecosystem” (Eaton 1990). During this period, the Muslim preference for farming over fishing affected the outlook of Hindus in the Sundarbans. Farming became preferred to fishing as an occupation (Danda 2007, p. 29).

In the late 16th century, another important change took place. Bengal was annexed by Chaghatai Turks, commonly known as the Mughals, a dynasty that had already established a vast empire in other parts of India. Mughal rule extended from about 1575 until the early 1700s (Eaton 1993).

Although the British East India Company had been establishing trading outposts in India since the 1600s, a singular event occurred in 1717: the Mughal Emperor exempted the Company from the payment of custom duties in Bengal (Lal 2008). By about 1760, the Company acquired the right to collect revenues on behalf of the Mughal Emperor, and, by 1773, India was under the rule of a Governor-General appointed by the British. Less than a hundred years later, in 1858, the rule was transferred from the East India Company to the Crown, and the British Government assumed direct responsibility for the administration of India. The British had a key influence on land use change in the Sundarbans. In 1793, the British East India Company gave the *zamindars* rights to own land in exchange for paying annual land taxes to the Company.<sup>4</sup> Thus, both the *zamindars* and the Company had financial incentives to bring new lands in the Sundarbans under cultivation, and this was accomplished by means of extensive forest clearing and an elaborate system of embankments (Danda 2007, p. 30–31).

The Sundarbans forests, however, were recognized by the British for potential exploitation of wood, bamboo, and other forest produce, which led to extensive surveying of the forest areas by the Forest Service, established in 1865. The Sundarbans came under Act VII of 1878, which defined “reserved” and “protected” forests for every province in British India, to be

administered by the Forest Service. The area classified as protected forest stayed relatively constant from 1890 through the 1930s at between 4,400 and 4,500 square kilometer (km<sup>2</sup>), placing about 60 percent of the Sundarbans area under the administration of the Forest Service. In the history of the Sundarbans, the period of British occupation is also notable for the Indian National Parks Act of 1934, which provided the basis for creating the Sundarbans National Park in 1984 (Danda 2007, p. 31–35).

With the establishment of the reserve forests and protected areas, there was renewed interest in settling land outside these areas. Between 1878 and 1915, further reclamation of the Sundarbans districts was promulgated, and blocks of 200 acres or more were leased for 40 years to large capitalists (*zamindars*) for development. The government reserved for itself all rights to mineral resources.

Observations on the land reclamation process by Mitra (2000) are instructive. After describing the revered status of Mubarra Ghazi and other Muslims engaged in the clearing of forests as holymen and “patron saints of the land clearing process,” Mitra characterizes the evolving process of land clearance as follows:

Often the Hindu *zamindars* utilized the services of Muslim saints to further the task [of land reclamation] with the peasantry, providing a moral authority and backing to that of the *zamindar*. Some such saints went into the process of extending the frontiers of cultivation on their own behalf and not that of the *zamindars*. They patronized particular areas leading to the Islamitization of the population and emerging in later generations as local *taluqdars* and *zamindars*.<sup>5</sup>

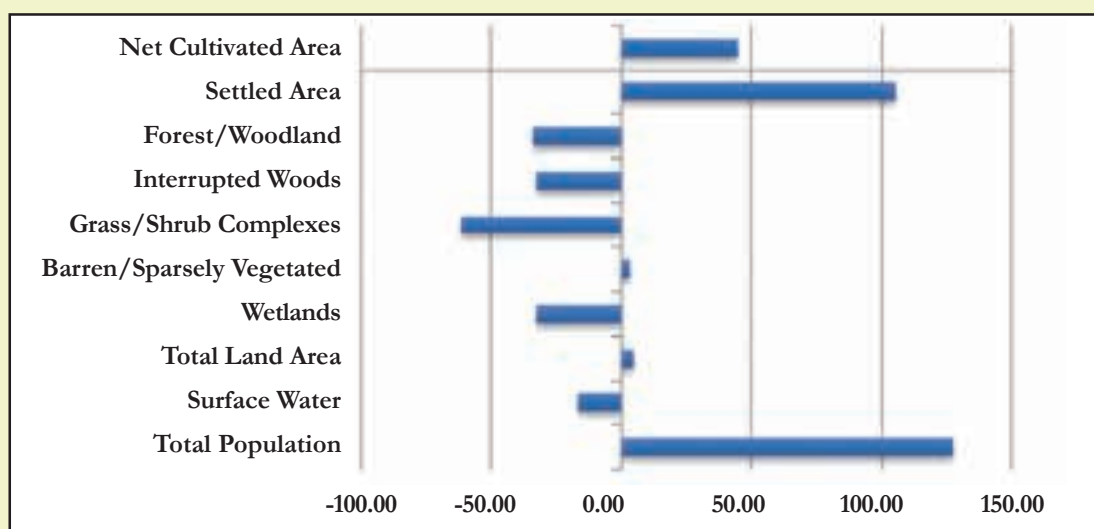
By 1903, because of abandonment of land and large-scale fiscal losses to the government, the system of leasing to large-scale capitalists had been abolished in favor of *ryotwari* (peasant-wise) leases and taxation systems whereby between 10 and 75 *bighas* were allocated to peasants for direct taxation. With peasant cultivation, reclamation and settlement spread into the previously unsettled marshes and jungles of the Sundarbans (Sarkar 2010, p. 94).

A 70-year history of land use for the three districts in which the Sundarbans are located (24 Parganas including Calcutta in West Bengal, India, and Bakarganj and Khulna in Bangladesh) shows massive transformations; between 1880 and 1950 cultivated land in these districts expanded by 45 percent (Figure A1.1 and Table A1.1). During the period, the population of the districts expanded from 5.9 million to 12.9 million. Large-scale land clearance occurred between 1940 and 1950 – cropland increased by 23 percent in this period alone – due in part to the Bengal famine in 1943 and the massive movement of refugees in both directions across the newly

<sup>4</sup>The term *zamindars* is defined as follows: “In India, a holder or occupier (*dâr*) of land (*zamîn*). The root words are Persian, and the resulting name was widely used wherever Persian influence was spread by the Mughals or other Indian Muslim dynasties. The meanings attached to it were various. In Bengal, the word denoted a hereditary tax collector who could retain 10 percent of the revenue he collected. In the late 18th century, the British government made these *zamindars* landowners, thus creating a landed aristocracy in Bengal and Bihar that lasted until Indian independence (1947).” From website of Encyclopaedia Britannica <http://www.britannica.com/EBchecked/topic/655661/zamindar>.

<sup>5</sup>*Taluqdar* is a term used for an Indian landholder in Mughal and British times, responsible for collecting taxes from a district.

**Figure A1.1:** Percentage Change in Land Use of Three Sundarbans Districts (Khulna and Bakarganj, Bangladesh; 24 Parganas, including Calcutta, India), 1880–1950



Source: Percentage changes drawn from table in Sarkar 2010, p. 96.

**Table A1.1:** Changes in Land Use of Three Sundarbans Districts (Khulna and Bakarganj, Bangladesh; 24 Parganas, including Calcutta, India) 1880–1950 (area in km<sup>2</sup>, population in '000)

Sundarbans (three districts combined)	1880	1890	1900	1910	1920	1930	1940	1950
Temporary crops	1185.1	1191.1	1248.4	1382.6	1281.9	1350.8	1387.6	1737.9
Permanent crops	89.7	93.4	99.4	102.8	107.3	123.2	114.8	105.1
<i>Net cultivated area</i>	<i>1274.8</i>	<i>1284.5</i>	<i>1347.8</i>	<i>1485.4</i>	<i>1389.2</i>	<i>1474.0</i>	<i>1502.4</i>	<i>1843.0</i>
Settled, built up, etc.	99.8	108.9	119.9	131.1	137.3	150.7	185.6	204.9
Temperate broad-leaved humid forest	20.2	19.0	16.4	14.5	15.6	15.9	14.5	13.4
Interrupted woods	99.9	94.1	86.4	70.7	65.2	64.8	60.3	67.5
Grassland and shrubland	105.5	169.2	158.6	153.9	246.1	238.2	220.5	40.7
Degraded or semidesert shrub	3.7	4.7	7.1	8.2	7.1	6.6	10.8	6.3
Unvegetated	53.4	59.1	64.8	59.9	61.5	64.6	63.3	52.9
Barren/sparsely vegetated	57.1	63.8	71.9	68.1	68.6	71.2	74.1	59.2
Marsh/herbaceous wetlands	253.2	242.5	250.7	239.2	256.4	196.4	216.0	161.9
Peat/swamp forest	6.7	6.2	5.3	4.6	4.9	4.8	4.3	3.9
Mangrove/tidal/littoral forest	1029.1	993.1	952.9	870.9	866.1	863.5	816.9	701.2
<i>Wetlands</i>	<i>1289.0</i>	<i>1241.8</i>	<i>1208.9</i>	<i>1114.7</i>	<i>1127.4</i>	<i>1064.7</i>	<i>1037.2</i>	<i>867.0</i>
Surface water	886.2	851.0	822.4	793.9	782.9	752.8	737.7	736.6
Total land area	2946.1	2981.3	3009.9	3038.4	3049.4	3079.5	3094.6	3095.7
Total area	3832.3	3832.3	3832.3	3832.3	3832.3	3832.3	3832.3	3832.3
Total population	5655.6	6175.6	6815.0	7451.6	7965.4	8922.1	11532.6	12875.5

Source: Adapted from Sarkar 2010, p. 95–96.

Note: Estimates of area are in km<sup>2</sup> and were derived from different sources and definitions over time. Estimates include districts in present-day Bangladesh and West Bengal. Population figures include Kolkata (24 Parganas district) which, for 1950, was estimated to be around 4.45 million.

created India-Pakistan border following the 1947 Partition. As Sarkar (2010, p. 97) notes:

Visible changes were seen in the landscape of the Sundarbans. After reclamation the Sundarbans now displayed a landscape of embanked paddy fields and farmsteads. The homestead clusters and their gardens of areca palm mingled with coconut and tamarind looked graceful. The most enthusiastic proponents of expansion into the Sundarbans were the district officers charged with collecting revenue from agricultural production and with peacekeeping duties.

Other factors contributing to land clearance for agricultural purposes include the desire of the state to raise revenues by taxing the rice harvest, and the siltation of fish-bearing lagoons. Rahman (2000), citing various sources, reports on the early efforts at systematic management of the Sundarbans as follows:

[The Sundarbans has the] distinction of being the first mangrove forest in the world to be brought under scientific management. The area was mapped by the Surveyor General as early as 1764 following soon after proprietary rights were obtained from the Mughal Emperor, Alamgir II, by the East India Company in 1757. Systematic management of this forest tract started in the 1860s after the establishment of a Forest Department in the Province of Bengal, in India. The first Forest Management Division to have jurisdiction over the Sundarbans was established in 1869. The Sundarbans was declared a reserved forest in 1875–76. ... The first management plan was written for the period 1893–98.

In 1947, at the time of Indian independence from Britain, Bengal was divided into two separate entities – West Bengal (a state of India) and East Pakistan. The latter was a part of Pakistan until 1971, when it seceded and became the independent country of Bangladesh (Eaton 1993). In West Bengal, the Sundarbans was part of the district of 24 Parganas, which was further divided in 1986 into North 24 Parganas and South 24 Parganas.

By the mid-20th century, human interventions to reclaim coastal lands and convert them into agricultural land were taking their toll. Large sediment loads in the river systems were now enclosed by embankments systems, effectively raising riverbeds and necessitating further human intervention. Embankment breaches became common, negatively affecting agricultural production. As the Government of West Bengal (GoWB's) District Development Report notes:

Under normal circumstance, the sediments get deposited between the inter-lacing river channels. But this condition has been largely altered by human action. To expand agriculture on this newly forming land mass, embankments have been created along the banks of the channels to prevent incursions of saline tidal water. These embankments enclose a tract to permit cultivation of rice with the help of rain water. As a result, features of the geomorphic processes have been altered. (DDP 2009, p. 11)

Access to freshwater resources remains one of the greatest challenges to agricultural production. Nonsaline aquifers can be accessed only by deep tubewells at great expense, and shallow tubewells accelerate the penetration of saline prisms into the aquifers (DDP 2009). Thus, while significant tracts of land were converted into agricultural areas, the productive capacity of this land is continuously undermined, contributing to erosion and environmental difficulties (DDP 2010a, 2010b).

While the formal rules relating to access to and use of the Sundarbans changed over time, most notably with British rule, many of the informal rules of access and use continued to be recognized. The observations below, which are based on work by Danda (2007, p. 30–36) and Mitra (2000), concern the formal and informal rules relating to access and use of the Sundarbans.

- Historically, indigenous peoples were able to access forested portions of the Sundarbans. This continued until 1878, when uncleared forest was declared as either “reserved” or “protected.” The Indian Forest Service, established in 1865, was given responsibility to facilitate appropriation of forest by the state in order to generate revenues from forest resources. Thus began the legal restriction against the use of forest resources in certain areas;
- Before the beginning of extraction of timber and nontimber forest products for commercial purposes in the first half of the 19th century, traditional rules governed the behavior of peasants entering the forests. “In the area of fisheries, traditional fishers were aware of the spawning seasons of different species of fish and catching of these types of fish during such months was prohibited. ... traditional fishers knew from childhood when the different species were not to be caught. If such fish entered the nets, the practice was to release them” (Mitra 2000, p. 4);
- For many years, *bhawalis* (woodcutters) of the Sundarbans had maintained a prescriptive right to fell forest timber without providing revenues to the government. After commercial forestry emerged in the 1830s, free access for woodcutting was limited to the subsistence needs of local peoples. After that, “the role of zamindars... with regard to controlling access by their peasants to the forest, changed from deciding the principles of determining access to the forest, to that of charging of various taxes from the resource extractors, who increasingly came from areas further off from the forest, with commercial interests” (Mitra 2000, p. 5). Access to forest products changed later, after the state created the Sundarbans Reserve Forest and established restrictions on the use of forest and, more generally, managed the common pool resource; and
- Notwithstanding an unsuccessful government effort (in 1868) to privatize the right to dole out fisheries in tidal waters to private persons, the right to fish in the watercourses of the Sundarbans has remained in the realm of a common pool, and no revenue is collected on behalf of the government from fishers.



### 1.3. The Sundarbans Today

Today, the basic governance structure of West Bengal applies in the Indian Sundarbans. That structure includes the numerous state-level departments (for example, Forestry and Tourism) as well as 19 districts (zilas). As mentioned, portions of the Sundarbans are in two of these districts, South 24 Parganas and North 24 Parganas. Each district is, in turn, divided into several subdivisions, which are further divided into development blocks. For example, North 24 Parganas has five subdivisions and 24 development blocks (Danda 2007, p. 36). A total of 19 blocks are considered today to be in the Sundarbans.

Agriculture, fisheries, forestry, and tourism constitute the region's main economic activities, with agriculture and aquaculture standing out as significant drivers of the economy. Under current conditions, these activities have a modest effect on poverty reduction; profit made from selling crops, fish, or other goods is limited because of the isolation of the Sundarbans from markets (Danda 2007). Indeed, many local residents are unemployed or underemployed. A 2003 study indicated that “the current production system [in the Indian Sundarbans] could reach or exceed its employment and subsistence support carrying capacity” in the near future, “leading to significant out-migration or a move from income poverty to more broadly based consumption poverty” (ADB 2003).

Cyclonic storms in the Sundarbans often devastate communities along the coastline and other low-lying areas. Available climate change models suggest that the intensity of these events will increase over the coming decades. Rising sea levels associated with changes in climate and ongoing hydrologic processes threaten the local population's livelihoods and the existence of the Sundarbans in its current form. Currently, the Sundarbans' main line of defense against cyclones and flooding consists of embankments built during the 1800s with mud and basic technologies. Breaches in the embankments have been common for generations but the magnitude and occurrence of breaches have increased, and serious questions have been raised about their efficacy.<sup>6</sup>

The diversity of the flora and fauna of the Sundarbans has been well documented, and threats to biodiversity are of key concern. Such threats include changes in land use, water management, and resource extraction practices, which have led to the disappearance

of many species and have threatened extinction for others (Ghosh and Danda 2001).<sup>7</sup>

In order to address the interlinked issues of poverty reduction, biodiversity conservation, and resilience to natural disasters in the Sundarbans, the World Bank initiated a Non-Lending Technical Assistance (NLTA) to GoWB to better understand the key issues and priority actions of the Sundarbans. Under this NLTA, 21 studies were conducted, one of which was a comprehensive household survey of the 19 Sundarbans blocks to address the significant data gaps that exist and to raise the levels of knowledge and understanding of the household profiles, livelihoods, and poverty estimates of the Sundarbans districts.

The main findings of the household survey show the population in the Sundarbans districts to be extremely poor and highly vulnerable to natural disasters and climate variability. Agriculture is insufficient to sustain households in the Sundarbans, and many respondents indicated some reliance on alternative livelihood options, including forest dependence and migration. Educational attainment is quite low and access to health services less than satisfactory. The following section outlines the methodology used and details some of the main findings of the household survey.

#### 1.3.1 Demographic Profile of the Sundarbans Blocks

According to the household survey of the Sundarbans districts of North 24 Parganas and South 24 Parganas conducted in 2011, the population of the Sundarbans districts is currently 4.4 million.<sup>8</sup> This represents a doubling of the population since 1971, when the population was just over 2 million (Planning Commission 1981), and the addition of around a quarter of a million people over the last decade, when the population of the Sundarbans districts was estimated to be 3.76 million in 2001.<sup>9</sup> The decennial growth rates registered during 1971-81, 1981-91 and 1991-2001 were 21.47 percent, 29.55 percent and 17.4 percent, respectively. These rates are comparable with the statewide decadal growth rate in West Bengal of 14 percent, and an India-wide decadal growth of 17.64 percent (Government of India 2011). In the 2011 Census, North 24 Parganas was listed as the second most populous district, after Thane (Maharashtra), with around 10 million inhabitants (Table A1.2).

<sup>6</sup><http://www.sadepartmentwb.org/Livelihood.htm>

<sup>7</sup>Note that the following mangrove species in the Indian Sundarbans “require immediate conservation measures”: *Aegiceras corniculatum*, *Heritiera fomes*, *Kandelia candel*, *Nypa fruticans*, *Rhizophora* spp., *Sonneratia acida*, *S. apetala*, and *S. caseolaris*.

<sup>8</sup>Based on the results of a representative household survey of the Sundarbans districts North 24 Parganas and South 24 Parganas, commissioned under the World Bank's NLTA to GoWB, titled “Building Resilience for Sustainable Development of the Sundarbans through Estuary Management, Poverty Reduction, and Biodiversity Conservation: A Non-Lending Technical Assistance.”

<sup>9</sup>Based on subdistrict data from the website of the Department of Sundarban Affairs <http://www.sadepartmentwb.org/Population.htm>.

**Figure A1.2:** Sundarbans Districts and Blocks, West Bengal, India (2011)



Source: World Bank cartography department, 2011.

**Table A1.2:** Comparative Population Figures for India, West Bengal, North 24 Parganas, South 24 Parganas, and the Sundarbans Blocks

Country/State/District	Population (millions)	Population Rural (percent)	Population Urban (percent)	Decadal Growth Rate 2001–11 (percent)
India	1,210.0	86.84	31.16	17.74
West Bengal	91.3	68.10	31.90	13.93
North 24 Parganas	10.1	42.21	57.79	12.86
South 24 Parganas	8.2	74.39	25.61	18.05
Sundarbans blocks	4.4	100.00	0.0	17.00

Source: Census of India 2011, Provisional Population Totals, India & West Bengal (Government of India 2011); 2011 household survey of 19 Sundarbans blocks.

In 2011, there were approximately 895,352 households, with an average household size of 4.47, down from an average household size of 6.9 people in 2001 (ADB 2003). However, population density remains high, with an estimated 2,462 persons per km<sup>2</sup> in North 24 Parganas and around 998 persons per km<sup>2</sup> in South 24 Parganas. This compares with a population density of 1,029 per km<sup>2</sup> in West Bengal, and 318 in India as a whole.

Most of the population (76 percent) in the Sundarbans blocks is Hindu, followed by around 24 percent Muslims. This represents a higher-than-average Muslim population; the national average is around 13 percent (Government of India 2011). Households in the Sundarbans are characterized by high poverty and social marginalization, and high levels of vulnerability to natural disasters. Over half the population of the two districts lives below the poverty line,<sup>10</sup> with 10 percent being classified as extremely poor.<sup>11</sup> The 2011 household survey found that most live in poor housing conditions: the population is primarily rural, living in *katcha* (thatched) (67.8 percent) houses of one room (72 percent) with mud floors (86 percent). Over 60 percent of the population in the Sundarbans districts belongs to historically marginalized populations, with 56 percent belonging to SCs, 6 percent belonging to STs, and 34 percent belonging to the General Caste category. The SC population in these districts is significantly higher than the national average of around 14 percent, and the ST population is only slightly lower than the national average of 8 percent.

### 1.3.2 Vulnerability to Natural Disasters

The Sundarbans districts are characterized by high exposure and vulnerability to natural disasters, particularly cyclones and storms off the Bay of Bengal. The household survey found that nearly two-thirds of the Sundarbans residents live in areas that are either prone, or highly prone, to floods or cyclones (Table A1.3), and 87 percent reported being affected by an adverse weather event in the last year. Climate change predictions show that the frequency and intensity of natural disasters are expected to increase over the coming decades, and greater numbers of cyclones and other extreme weather events are expected to make landfall along the coastal areas of the Sundarbans.

Cyclone Aila, which made landfall in 2009, affected two-thirds (67 percent) of households in the Sundarbans districts. As a result of Cyclone Aila, many households saw their dwellings fully or partially destroyed (69 percent), and almost all (94 percent) saw some damage from the storms. Around a quarter of households lost livestock, and more than half of all households had to evacuate (55 percent). Of these households, around 43 percent were displaced for three months or more.

The household survey of the Sundarbans blocks found that very few households were informed of the cyclone; almost 97 percent had no prior warning of the storm and were caught off guard when the cyclone made landfall (Table A1.4). Evidence from Bangladesh has shown the number of fatalities and impacts of the storms to drop dramatically with early warning systems and cyclone shelters that allow households to move to a safe shelter with livestock and family members, thereby greatly reducing the negative impacts of extreme weather events. In the households of the Sundarbans blocks, only around 3.5 percent of households were informed about Cyclone Aila.

In addition to being caught off guard by extreme weather events, households often face adverse conditions during recovery. The

**Table A1.4: Source of Getting Information about the Adverse Event (Cyclone Aila)**

Source of Information	% of Households
From television	0.3
From radio	1.8
Through mobile phone	0.0
From newspaper	0.1
Informed by the local government (Gram Panchayat)	0.7
From neighbors	0.6
Did not receive any prior information	96.5
Total	100.0

Source: Household survey, 2011.

**Table A1.3: Proneness of Gram Sansads in the Sundarbans Districts to Floods and Cyclones**

Proneness to Flood/Cyclone	Proportion of Gram Sansads (%)		
	North 24 Parganas	South 24 Parganas	Total
Not at all or seldom prone to flood/cyclone	36.77	41.89	40.30
Prone to flood/cyclone	46.64	31.38	36.13
Highly prone to flood/cyclone	16.59	26.73	23.57
Total	100.00	100.00	100.00

Source: Household survey, 2011.

<sup>10</sup>As measured by the number of households having a BPL card.

<sup>11</sup>As measured by the number of households having an Antyodaya card.

household survey of the Sundarbans blocks found that, in the three months after an extreme event, households faced price increases for essential food, goods, and services. In addition, the value of livestock and other assets also dropped during this time, undermining food and livelihood security. As Table A1.5 shows, prices of essential foods and services, such as rice, dal, or doctor's fees, would typically rise by between 25 and 40 percent, while the value of livestock would drop by comparable amounts.

Many residents continue to feel the impacts of Cyclone Aila today. Given the extreme poverty, meager assets, and limited livelihood opportunities, the threat of growing natural disasters and climate variability poses challenges for the populations of the Sundarbans. High-velocity winds caused saline water to overtop embankments and flood agricultural holdings, and around 4 percent of the population has not cultivated paddy in the last two years because of salinity issues. For those who were able to either pump or wash the saline water off the fields, there has been a significant fall in production over the last five years, estimated at around a 36 percent in production of paddy, and 42 percent in vegetable production. In addition, many residents of the Sundarbans districts saw their livestock fall ill or washed away because of the cyclone; around 80 percent of households surveyed said that the number of livestock owned had reduced due to floods (40 percent), disease (30 percent), or shortage of fodder (15 percent) in the previous year. Most households surveyed (82 percent) indicated that they were not at all or barely prepared to deal with another adverse weather event.

In the event of a natural disaster, such as Aila, Sundarbans residents have few options for recovery. Residents indicated that there was little government presence or few community initiatives to help rebuild in the aftermath of a disaster. Only 6 percent of households surveyed in the Sundarbans blocks said that they had fully recovered from the economic consequences of Cyclone Aila.

However, the household survey found that most residents were also not prepared to move; the majority of respondents (78 percent) had not considered migrating out as a strategy to tackle a future disaster. A majority (63 percent) was also not willing to consider reducing their reliance on agriculture. Aversion to out-migration is significantly higher among Muslims than Hindus. The higher the level of education or household amenities, the greater is their stated unwillingness to move out in the case of a disaster. People are also not willing to use saline-resistant seed for paddy or undertake rainwater harvesting as a preparatory step to meet disaster. It is quite possible that many of them may not have adequate knowledge about the utility of these strategies.

In general, people have used their savings or borrowed money either from friends or moneylenders as a coping strategy to deal with disasters (55 percent). A sizeable proportion of the respondents did nothing specific to deal with the situation. A significantly higher proportion of Muslims than Hindus indicated that they had not taken any specific action. As can be expected, a significantly higher proportion of respondents belonging to poorer groups<sup>12</sup> resorted to borrowing than the middle class group. The majority of the respondents from the latter group either used their own savings (37 percent) or did not take any specific action (50 percent).

About half of respondents in the disaster-prone areas (48 percent) reported that they had not made any changes in their usual practices to adapt to the emerging situation. Among those that said they had, changes regarding agriculture-related practices dominated. There were noticeable religious differentials in the changes implemented – Hindus were more likely to amend their agricultural practices and to send household members to other places for employment.

**Table A1.5: Prices of Items before and within Three Months of a Flood**

	Average Price before Adverse Weather Event (Rupees)	Average Price in First Three Months after Adverse Weather Event (Rupees)	Percentage Change
Rice, 1 kg	15.33	18.84	22.9
Dal, 1kg	47.84	60.41	26.3
Interest charged by the moneylender	57.30	70.80	23.6
Doctor's fees	58.17	72.67	24.9
Medicines	62.82	86.63	37.9
Day wages for unskilled labor	81.63	100.41	23.0
Goats (sale price)	953.83	533.29	-44.1
Cows (sale price)	2,793.19	1,665.14	-40.4

Source: Household survey, 2011.

<sup>12</sup>As represented by households with relatively low asset levels.



### 1.3.3 Livelihoods

The main livelihood activity in the Sundarbans is agriculture, with fishing, forestry, and tourism also offering sources of income. The predominance of agriculture is derived from periods of reclamation in the latter part of the 19th and early part of the 20th century, when exploitation of forest resources and taxation of agricultural produce drove many of the Sundarbans blocks to be settled. However, the ageing embankment system contributes to the vulnerability of its residents, exacerbates erosion and deltaic shifts, and provides inadequate security for agricultural production. Additional income from fishing and shrimp production is growing, although lack of regulation in the industry has increased erosion downstream in the coastal areas (World Bank 2011a). Forest dependence also plays a role in local livelihood strategies, although the exact number of residents who enter the forest to collect honey, crabs, or other forest produce is typically underestimated, given restrictions by the Forest Department.<sup>13</sup>

According to the household survey, even though nearly the entire population of the Indian Sundarbans depends on agriculture, the great majority of farms are classified as “small” and “marginal,” with typical landholdings of less than 1 hectare (ha) per family. The household survey of the Sundarbans blocks found that, for more than half of all households who own their own land (55.5 percent), the holding size was between 0.01 and 0.20 ha. This is significantly smaller than the average landholding size of 1.16 ha<sup>14</sup> in India. Only 16.3 percent of households surveyed used agricultural lands for multicrop farming. Although rice is the principal agricultural output, other crops are also grown, including fruits, vegetables, sesame, cotton, pulses, and betel leaf. The primary constraint to agricultural production cited was lack of irrigation. This is because reclaimed intertidal lands are only suited to single crops of paddy; in these areas, winter irrigation is not possible because of the effects of salinity from the tidal waters.<sup>15</sup> Around 17 percent of households indicated that they faced problems of saline intrusion affecting their crop production every year (Table A1.6 and Box A1.1). Households also reported relying mostly on rainfall as a water source (42 percent), with only 6 percent reporting access to a well or pond, and 3 percent reporting access to boreholes. This makes growing in multiple seasons extremely difficult, and households cited the lack of freshwater resources as a severe constraint to improving agricultural productivity.

The seasonality of agriculture is also reflects in the seasonality of income that it provides for households in the Sundarbans. While 99 percent of households cited they had at least one member of the household engaged in agriculture, the household survey of the Sundarbans blocks found that residents relied on multiple supplementary livelihood strategies for survival. For example, the

**Table A1.6: Percentage of Households Suffering from Saline Water in Fields**

Occurrence of Problem	Percentage
Every year during monsoon	16.9
Only when there is flooding	17.7
Only when embankments breach	39.8

Source: Household survey, 2011.

#### Box A1.1: Livelihoods in the Sundarbans

“The common livelihood activity of the people in the village is agriculture but, after Cyclone Aila, due to waterlogging of their fields with saline water, they have been unable to undertake any agricultural activity for the last two years. Besides agriculture, other livelihood activities of the villagers are fishing and collection of honey. People from outside also come to the village for this purpose.”

(Participant in a focus group discussion, Hemnagar, Hingalgaon)

primary agricultural season for paddy occurs from mid-May to mid-September, and 100 percent of households in the Sundarbans blocks indicated that, during this season, agriculture was their primary source of income. However, during mid-January to mid-May, nearly a quarter of respondents indicated that they relied on public assistance programs.

Residents in the Sundarbans rely on multiple livelihood strategies to survive. As a secondary livelihood strategy, households cited relying either on public assistance programs, most notably the 100 days’ work program under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) (11 percent), or on agricultural labor (7.2 percent). A higher proportion of Hindus (25.7 percent) than Muslims (21.6 percent) received assistance from MGNREGA. Around 45 percent of households in the Sundarbans districts own livestock, which supplements livelihoods through consumption or sale of milk, eggs, or other produce. Very few households admitted to accessing the forest for resources to supplement their livelihoods, although of the households who admitted to accessing forest resources, 43 percent indicated that the reason was a lack of land to cultivate, and 30 percent said they needed to supplement their income with additional earnings.

However, these figures also mask a strong seasonality of income sources. As Table A1.7 shows, during the primary agricultural season, most residents of the Sundarbans districts rely on agriculture and

<sup>13</sup>For example, the household survey conducted in 2011 found that 99.1 percent of households claimed not to enter the forest for incomes or livelihood. This figure is almost certainly an overstatement.

<sup>14</sup>India Agricultural Census 2010–11.

<sup>15</sup>Website of Mangroves of India, <http://www.niobioinformatics.org/mangroves/MANGCD/biog2.htm>.

agricultural activities for survival. However, in the nonagricultural seasons, most residents rely on other sources of income from trading or on public programs, most notably MGNREGA (which allows beneficiaries up to 100 days of paid public works jobs), other nonagriculture-based labor, or livestock produce.

Access to credit exists primarily through moneylenders and through an informal network, and the household survey found that around 35 percent of households had some debt. However, unlike many other parts of India, respondents indicated that the most important source of loans was relatives or friends (around 50 percent), rather than moneylenders (only around 19 percent). The primary reason for borrowing money was to streamline consumption (28 percent), followed by improving or building dwellings (24 percent), and for ceremonies (13 percent). A further income source came from remittances sent by migrants from the household. Around 20 percent of households had someone who had migrated since 2005. However, around 80 percent of households in the Sundarbans districts reported receiving no remittances from migrants.

### 1.3.4 Human Development

The Sundarbans districts are characterized by poor infrastructure services and relative isolation; due to the riverine nature of the Sundarbans and proximity to the Reserve Forest, many essential public services are limited or difficult to access. For drinking water, public tubewells are the main source for households (88 percent). Around a quarter of the households surveyed indicated that they did not have a toilet. With respect to energy, only a quarter of the households surveyed had access to electricity, with the majority relying on kerosene as the main source of lighting (68 percent). Households relied most on firewood and chips for cooking fuel (43 percent), and spend, on average, around 40 minutes collecting firewood every day. There was a strong gender dimension to this as well, with the burden of collecting firewood falling primarily on the women of the house (71 percent indicated that the

household head's spouse was primarily responsible, followed by unmarried children).

West Bengal is considered to be one of the most literate states but, in the Sundarbans, slightly fewer than three-quarters (72.2 percent) of the school age population (aged 5–22) attended school in the 2010-11 school year. As education levels progress, there are problems of retention: while almost one-third of household members had attained the highest education level of primary, only 16.3 percent of household members had attended education levels of secondary and above. With respect to health, while less than half of households reported members suffering from disabilities or chronic illnesses, the major source of medical treatment among Sundarbans residents was given as private doctor (35.3 percent), followed by quacks (15.4 percent) and tertiary government hospital (12.7 percent). These findings were confirmed by studies conducted under the NLTA on health and education, which found that access to basic services remained a challenge for many of the Sundarbans blocks (World Bank 2011b).

### 1.3.5 Spatial Transformation of the Sundarbans

Growing risks to the populations of the Sundarbans districts will increasingly undermine efforts at poverty reduction and human development over the next several generations. Increasing intensity and frequency of cyclones and storms in the region will threaten livelihoods, and the riverine terrain will continue to make access to basic health and education services a challenge. Today's population in the Sundarbans reflects this, with high poverty, low levels of human capital, and growing risks from weather shocks, embankment breaches, and other environmental factors.

Risks and opportunities in the Sundarbans can be addressed through a spatial transformation of the region that will serve to build the health and skills of the inhabitants and enhance their mobility, thus linking them with growing opportunities in less risky environments. This is expected to be the least disruptive way to promote socioeconomic development and poverty reduction efforts over the short, medium, and long terms.

**Table A1.7: Major Sources of Income for Households in Different Seasons**

Season	Major Sources of Income	Percentage of Income in Season
Mid-May to mid-September (Jaistha to Bhadra)	Agricultural labor in the village	37.1
	Growing rice	34.9
	Daily nonagricultural labor in nearby village	31.3
Mid-September to mid-January (Aswin to Pous)	Daily nonagricultural labor in nearby village	38.5
	Self-employed income from trading	22.7
	Selling milk and eggs	22.2
Mid-January to mid-May (Magh to Baisakh)	Daily nonagricultural labor in nearby village	40.4
	MGNREGA	25.1
	Daily nonagricultural labor in the village	23.5

*Source:* Household survey, 2011.

*Note:* Percentages add up to more than 100 because of multiple answers.

Without efforts to improve the health, education, and skills of the local population, residents of the Sundarbans will continue to face limited opportunities outside the high-risk areas. And when subsistence in the Sundarbans is no longer a viable option, poverty and limited opportunities will drive out residents. The household survey of the Sundarbans blocks found that current population movements are driven in part by limited work opportunities in the Sundarbans, and in part by growing opportunities outside the Sundarbans. Of the households surveyed with at least one member who had migrated out, 46 percent said that lack of employment opportunities in the place of origin was the primary reason for migration, and 47 percent cited better employment opportunities elsewhere as the primary reason. There are several different types of migration patterns in the Sundarbans (Box A1.2).

#### Box A1.2: Migration Patterns in the Sundarbans

“There are three kinds of migrants from this village. Some people go on a long-term basis, between one and two years. Such people go to places like Mumbai, Chennai, Surat, Andaman, and Bengaluru. Both males and females go in search of any available work. There is another kind of migrant, who migrates to other districts in the state during the seasons of paddy sowing and harvesting, potato harvesting, jute harvesting, etc. They go in a group of five or six persons and return home in groups. The third kind of migrants is those who go to Kolkata and its neighboring areas, where they stay for two or three months. Male migrants work in masonry, house painting, road construction and repair, etc. The female migrants work as maids and in some cottage industries.”

(Participant in a focus group discussion, Kumirmari Gram Panchayat (GP), Gosaba block)

The household survey conducted in 2011 found that, among households that had at least one household member who had migrated, most moved to urban areas (77.8 percent), and the majority worked as unskilled laborers (62.5 percent). Half of migrants left with the help of family and friends to secure a job elsewhere (50 percent). For those who left, support of the household was extremely important, with a large majority (80 percent) sending remittances, mostly of INR 2,000 or above per month (Box A1.3).

#### Box A1.3: Financial Dimensions of Migration

“Those who are migrating out are financially better off than others. They are sending their children to good schools so that they can get better schooling.”

(Participant in a focus group discussion, Kumirmari GP, Gosaba block)

However, while there was a dominant perception that households with at least one migrant were better off than others, the household survey of the Sundarbans blocks found that households with migrant members continued to be in the minority. As Table A1.8 shows, around three-quarters (71.6 percent) of households surveyed did not have a household member who had migrated, and for these households, almost all (98.8 percent) indicated that they did not want to move out.

**Table A1.8: Migration of Household Members (Percentage)**

Type of Migration	Hindu	Muslim	Total
Did not migrate	71.4	72.3	71.6
Migrated within Sundarbans	4.0	6.7	4.7
Migrated outside (not Kolkata)	8.0	5.0	7.3
Migrated to Kolkata	16.5	16.0	16.4
Total	100.0	100.0	100.0

Source: Household survey, 2011.

The primary set of “migrants” captured in the survey was daughters who married and moved out of their household (76.9 percent). Most of these young women moved to another location in the Sundarbans (67.1 percent), although around one-fifth (18 percent) stayed in the same village but moved to a different house. Most women left the household before the age of 20, with around three-quarters (75 percent) listed as being between the ages of 10 and 19 when they left the household. The primary reason cited for women to leave was marriage, although the qualitative data picked up some evidence of trafficking of women. Focus group discussions that were conducted in the Sundarbans districts also indicated some reservations about migration of young women because of perceptions of the risks involved, such as trafficking. These discussions also revealed a large variation by village as to whether women migrated for work or for marriage, with some villages citing figures as high as 20 percent of women migrating outside the state for work.<sup>16</sup>

For those households that indicated, in the survey, that they would like to move, most said that they would like to go to Kolkata and environs. The major impediments identified to moving out were age (too old or too young – 16.2 percent), or to keep land in the family (13.7 percent). One interesting finding from the survey was that many households expressed willingness to send their children outside the Sundarbans for educational opportunities (86 percent) or to pursue training programs in Kolkata or other parts of West Bengal (78 percent) (Table A1.9). This lends support to a longer-term strategy to provide alternative livelihood opportunities outside the Sundarbans. Qualitative evidence from focus group discussions held with survey respondents also indicated that education was a priority, especially for many women in the Sundarbans who saw education as a key to improved livelihood opportunities for their children.<sup>17</sup>

<sup>16</sup>Focus group discussion in Pakhiralay, conducted as a part of the 2011 household survey.

<sup>17</sup>Focus group discussion in Hingalganj, conducted as a part of the 2011 household survey.

**Table A1.9: Willingness to Send Children Away for Education**

Whether household is willing to send its children to Kolkata or other parts of West Bengal	% of Households
Yes, for all children	84.5
Yes, but only for male children	9.7
Yes, but only for female children	0.1
No	5.8
Total	100.0

Source: Household survey, 2011.

One additional factor potentially contributing to the relatively low levels of population movement away from such a high-risk area is the institutional and social assistance that many of the households receive, some of which is tied to residence in the rural areas. The 2011 household survey found that, in the last 12 months, more than 40 percent of households had received assistance from government programs (Table A1.10).

**Table A1.10: Frequency of Receiving Government Assistance through Established Schemes**

Program	Percentage of Households Receiving Assistance
Kerosene through ration card	37.96
Ration through Above the Poverty Line (APL) card	22.08
Midday meal for children studying up to class 8	19.40
Ration through BPL card	16.60
MGNREGA (100 days' work program)	12.60
Ration through Antyodaya Anna Yojana	3.92
Old-age pension	3.20
Janani Suraksha Yojana (prenatal & postnatal healthcare)	2.88
Indira Awaas Yojana (housing funds)	1.72
Swarna Jayanti Gramin Swarojgar Yojana (rural employment)	0.96
Widow's pension	0.04
Pradhan Mantri Rojgar Yojana (self-employment loan)	0.28
National family benefit scheme	0.12
Annapurna Yojana (food rations)	0.12
Public provident fund for landless workers	0.12

Source: Household survey, 2011.

Note: Because of multiple answers, percentages add up to more than 100.

Overall, present population movements reflect the limited human capital that households in the Sundarbans blocks have available to them; low levels of health, skills, and education mean that pursuing opportunities is difficult. Most households continue to barely subsist on declining agricultural yields and face growing risks

from natural disasters, floods, and erosion. However, for those that do manage to find opportunities for employment outside the Sundarbans, there is widespread perception that they are better off, despite working predominantly in unskilled labor.

## 1.4. Conclusion

Despite rapid economic growth in India, the Sundarbans blocks of North and South 24 Parganas remain some of the poorest and most isolated areas of the country. Residents face difficulties subsisting on agriculture, and poor access to services means that human development levels are low. This places residents in conditions of poverty that are difficult to escape. Growing risks over the next several decades do not bode well for residents of the Sundarbans; present-day weather shocks already severely undermine the well-being of households, and future climate change predictions show these patterns to be increasing in frequency and intensity. The future development of the Sundarbans blocks will necessitate a new strategy that approaches this area from a spatial development perspective to capitalize on the unique biodiversity and heritage of the Sundarbans for improved conservation and socioeconomic development.

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# Annex 2.

## Methodology for the Study<sup>1</sup>



### Abstract

Studies conducted as a part of this NLTA used a variety of methodologies to compile information on different sectors that were then synthesized into an overarching spatial strategy for building the resilience of the socioeconomic and biophysical systems of the Indian Sundarbans. Each study drew on primary and secondary information to investigate the state of the sector in the Sundarbans blocks, and how this compared to other blocks and districts in West Bengal and India. The objective of the various analyses was to address significant data gaps to assist formulation of a strategy to address socioeconomic development and biodiversity conservation goals in a shifting climate in the Sundarbans blocks. This annex outlines the methodologies used in the various studies.

### 2.1. Introduction

The Sundarbans is considered to be one of the least developed regions in West Bengal, with over 4.4 million people living in an extremely fragile eco-environment. The Government of India (GoI) and GoWB requested World Bank support to design a

comprehensive program that responded to the development challenges of the Sundarbans area of West Bengal. As part of the NLTA, a series of studies was commissioned on different sectors in the Sundarbans to enable GoWB to develop a strategic action plan that addresses three main objectives: (a) protection of life, property, and assets; (b) income growth and poverty reduction; and (c) biodiversity conservation. The studies provided analyses across disciplines, including climatology, geomorphology, economics, education, health, social anthropology, demography, ecology, tourism, water and sanitation, energy, agriculture, forestry, fisheries, and management (Table A2.1). Original modeling and surveys of several thousand households informed the data gathering and modeling underlying these analyses. In addition, interactive workshops and consultations were held with government representatives, researchers, nongovernmental organizations (NGOs), and other stakeholders to scope out the analytical work and discuss the preliminary findings. The information was later integrated into a comprehensive strategy that aims to provide the best available near-term protection and longer-term opportunities to vulnerable populations while also maintaining the integrity of the ecosystem. This annex summarizes the various methodologies used under this NLTA.

**Table A2.1: Background Papers Completed under the NLTA**

No.	Sectoral Study	Objectives
<b>I</b>	<b>Vulnerability reduction</b>	
i.	Strategic approaches to vulnerability	Geomorphological modeling of river and sea embankments of the Sundarbans with reference to climate change and sea level rise
ii.	Economic analysis of embankments	(a) Benefit–cost analysis of alternative embankment interventions; and (b) development of a typology of islands that permits priority setting and assessment of relative vulnerability levels

<sup>1</sup>This Annex was prepared by Ernesto Sánchez-Triana and Anna O'Donnell based on the various background reports and analyses.



**Table A2.1 (continued): Background Papers Completed under the NLTA**

No.	Sectoral Study	Objectives
<b>II</b>	<b>Poverty reduction</b>	
	<i>Socioeconomic and human development</i>	
i.	Demographics, livelihoods, and migration	Analysis of the linkages between population growth, employment, and migration
ii.	Infrastructure	Analysis of programs and interventions to improve access to energy transportation, and water supply and sanitation.
iii.	Gender study	Development of a comprehensive profile of women regarding employment, human development outcomes, migration, widowhood, and trafficking of women, and recommendations on how to address women's concerns
iv.	Health services	Analysis of programs and interventions to improve access to and quality of health services and recommendations on cost-effective interventions to improve health conditions
v.	Education and training	Analysis of programs and interventions to improve access to and quality of educational services and make recommendations for the sector
vi.	Environmental health in the Sundarbans	(a) Estimation of the health effects and their costs in the Sundarbans from inadequate water supply, sanitation, and hygiene, and household air pollution caused by the use of wood and other biomass fuels for cooking; and (b) evaluation of the costs and benefits of selected interventions to improve environmental health
	<i>Livelihoods</i>	
i.	Agriculture	Assessment of the productivity of the agriculture sector and potential impacts of agroclimatic developments and hazards on agriculture practices and livelihoods, and recommendations for improving sector services and outcomes
ii.	Livelihoods and forestry	Assessment of the current situation of the forestry sector in the Sundarbans and the benefits and costs associated with alternatives that could be pursued to manage the forests in a way that balances conservation and socioeconomic development objectives
iii.	Fisheries and aquaculture	Examination of the contribution and role of fisheries and aquaculture in human and economic development and poverty reduction in the Indian Sundarbans
iv.	Ecotourism action plan	Assessment of the potential of tourism and ecotourism in India's Sundarbans National Park
<b>III</b>	<b>Biodiversity conservation</b>	
i.	Assessment of current status of biodiversity in the Sundarbans	Development of a report on the status of biodiversity in the Sundarbans
ii.	Biodiversity conservation management of the Sundarbans	Development of a management plan for biodiversity conservation based on stakeholder forums
iii.	Benefit–cost analysis of development and conservation alternatives in the Sundarbans of India.	(a) Analysis of the ecological situation in the Sundarbans, including ranking of major risks and potential natural resource damages; (b) economic analyses of alternative investments in area protection, conservation, and development; and (c) guidance on mainstreaming responses to climate change and conventional environmental degradation within economic development planning and policies in the Sundarbans, including estimation of benefits and cost of conservation and development projects in the Sundarbans
<b>IV</b>	<b>Institutional change</b>	
i.	Institutional analysis	Cross-cutting analysis of existing institutions and recommendations to reform the institutional structure for improved delivery of public services



**Table A2.1 (continued): Background Papers Completed under the NLTA**

No. Sectoral Study	Objectives
<b>V General</b>	
i. Household survey work	Generation of a database on key themes, including socioeconomic activities, adaptation and coping activities in relation to changing natural resources and biodiversity, livelihoods activities, migration, and other related issues
ii. Knowledge and information systems	(a) Development and implementation of a system that integrates relevant sources of data and information, which will guide the future development of a cost-effective application supporting decision making and predictive modeling, ensuring up-to-date quality data and mechanisms to increase coordination among stakeholders, including the adoption of international standards for information interchange; and (b) development of training strategies to encourage involvement of relevant stakeholders in this NLTA, using the knowledge and information system for the Sundarbans
iii. Public awareness and consultation	(a) Identification of key stakeholders; (b) carrying out a stakeholder analysis that will inform the various studies on characteristics of key stakeholders and identify their key concerns, issues, expectations, priorities, and potential options; (c) preparation of simple and easy-to-understand summary documents of key studies in Bengali for dissemination; and (d) thematic consultations on viability and feasibility of broad options that emerge from study findings

## 2.2. Methodology

The objective of the NLTA was to address the issues associated with biodiversity conservation and socioeconomic development in a changing climate. The overall methodology for this study drew on sector-specific findings to elaborate on a spatial planning approach for the Sundarbans that would better account for the unique geographic realities of the Sundarbans area, while recognizing interlinkages among sectors in the area. To develop an area-based plan, each sector-specific study: (a) examined the state of the particular sector; and (b) identified a preliminary set of recommendations for the Sundarbans. The findings and recommendations of each of the studies were then compared and synthesized in a workshop that brought together all of the consultants in January 2011. The outcome of this workshop was the development of a preliminary strategy that identified three areas in the Sundarbans – the core zone, the transition zone, and the stable zone – and proposed strategies to address the issues identified in each of the sectors in the short, medium, and long terms. The proposed strategy was tested in a representative household survey of the Sundarbans blocks (2,188 households) that further substantiated the findings of the sector reports, and provided insights into the interlinkages among sectors. Based on all of the studies completed under the task, the strategy for the Sundarbans was finalized.

The following sections outline the different methodologies used for the various studies completed.

### 2.3. Pillar 1: Vulnerability Reduction

To understand the challenge of reducing vulnerability and building

resilience as components of disaster management, a series of studies was conducted, including one on management of embankments and estuaries, and economic analyses were undertaken. Necessary data were collected during the course of the NLTA, and were augmented by an extensive series of field observations, both before and after Cyclone Aila (2009) affected the area. The methods used to arrive at the results for each of these are outlined below.

#### 2.3.1 Management of Embankments and Estuaries

This study was primarily informed by a regime model developed specifically for use in estuaries and described in full in Wallingford et al. 2007.

The regime model consists of four main components:

- Theoretical tidal prism distribution along the estuary channel, using an entropy (least work) approach (for example, Leopold et al. 1964);
- Prediction of cross-sectional areas along the estuary channel using the O'Brien (1976) regime equation, as quantified by Gao and Collins (1994);
- Prediction of equilibrium scour depth for a tidal depositional channel using the classic equations developed by Lacey (1930). Inputs into this component include observed sediment grain size distributions throughout the estuary; and
- Prediction of channel width along the estuary using cross-section and depth data.

The model was used to assess five scenarios: (a) existing conditions as a control benchmark that were also used to test and confirm the model's predictive ability; (b) existing aquaculture water management; and (c) 1-meter (m) sea level rise; (d) 2-m sea level rise; and (e) 3-m sea level rise. For each of these scenarios, the equilibrium (or regime) morphology was calculated and the channel width reported.

The data available for use in the study consisted of: (a) digital map data derived from satellite imagery showing high water and low water for the entire Sundarbans area; (b) bathymetric data from the Kalchara River derived from a primary field survey; (c) tidal range data from two stations on the Kalchara estuary; and (d) sediment grain size data derived from field samples. These data were produced by the Institute of Environmental Studies and Wetland Management of Kolkata, in its role as data coordinator to the project.

### 2.3.2 Economic Analysis

The economic analyses undertaken in this work were conducted through three stages. The first stage consisted of a number of stand-alone parts that formed the building blocks of the overall analysis. Simply stated, these included: (a) an assessment of current and future livelihood opportunities, showing typical development values on a per ha or per capita basis; (b) costs of physical options relating to embankment improvement (this summarized basic engineering costs for embankment rehabilitation); and (c) valuation of the coastal protection function of bioshields (mangroves).<sup>2</sup> The livelihoods information was informed by statistical collections maintained by the Department of Sundarban Affairs (DSA), complemented by the specific livelihoods studies undertaken for this NLTA. Engineering costs were originally based on costs provided by the GoWB Irrigation Department, which were subsequently updated and reconfirmed after Cyclone Aila (2009) created the need to commence an embankment reconstruction and repair program. These building blocks provide a basis for determining the conditions in which it would be economic to protect a given area under various sea level rise considerations.

The second stage incorporated linkages or feedback effects within the system arising primarily from biophysical considerations reflected in the geomorphological study. The analysis was operationalized through defining approximately 70 "clusters" which are currently protected by circle embankments. The islands vulnerability study considered the erosion conditions and local biophysical characteristics to determine a minimum threshold size for protecting any given cluster. This threshold size was then used as a basis for prioritizing whether the protection of an area was justified on a stand-alone basis, or whether it should be further amalgamated with other areas or otherwise adjusted through, for example, closure of tidal creeks.

## 2.4 Pillar 2: Poverty Reduction

### 2.4.1 Socioeconomic and Human Development

Several studies were conducted under the heading of sustainable socioeconomic development, including under the subheadings of infrastructure (water supply and sanitation, transport, energy), livelihoods (agriculture, fisheries, forestry, and demographics and migration), human development (health and education), and gender. The methods used for these studies are summarized below.

#### 2.4.2 Infrastructure

##### Water Supply and Sanitation

The methodology used for this study drew on secondary data collection complemented by field visits and interviews with officials, NGOs, and users. Specifically, information on the status of water supply and sanitation available from the official websites was obtained and discussed with engineers from the Public Health Engineering Department (PHED) and Total Sanitation Campaign (now called Nirmal Bharat Abhiyan) coordinators. These discussions were complemented by interviews with NGOs involved in the sector. Field visits were conducted to inspect habitations, schemes, and facilities, and to meet with field-level staff and users.

##### Transportation

The methodology used for this study was a mix of primary and secondary data collection, including surveys and stakeholder consultations, key informant interviews, and use of secondary data sources. The survey activities and data collection were conducted during the period January to March 2011. The data collection commenced with a World Bank mission in Kolkata. The mission met with key stakeholders, including senior officials of the Sundarban Development Board (SDB). In addition, field visits were conducted in the Sundarbans and stakeholders were consulted. Following the mission, an individual consultant was engaged to collect detailed data from various sources.

As part of the study, a series of stakeholder surveys was carried out during the months of February and March 2011. The survey stations were chosen based on their strategic locations and importance. The locations included Canning; Lot8, Kakdwip; and Murarisaha, Chowmatha. The survey included consultations with private tour operators. Informal discussions with the general public (people living in the study area) were also carried out. Various government agency officials were consulted, including those from the SDB, Ministry of Surface Transport in Kolkata, Ministry of Shipping, Inland Waterways Authority of India, National Highway Authority of India, Kolkata office, and Public Works Department.

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<sup>2</sup>The valuation work was also informed by a stand-alone study for this NLTA relating to the cost of environmental degradation, and by mangrove survey valuation work on Sagar Island conducted under the West Bengal component of the Integrated Coastal Zone Management Project.

**Table A2.2: Sources of Information**

Source	Information Collected
West Bengal State Electricity Development Corporation Ltd.	Data on electricity supply and existing electricity infrastructure Planned work for extending electricity network and intensification of household electrification under Rajiv Gandhi Grameen Vidyutikaran Yojana
West Bengal Green Energy Development Corporation Ltd.	Detailed project reports submitted to the Rural Electrification Corporation Ltd. for the electrification of 39 villages under the decentralized distributed generation program
Rural Electrification Corporation Ltd., Eastern Regional Office, Kolkata	Data on village electrification projects
SDB	List of villages for which the funds for electrification would be given by the board
West Bengal Renewable Energy Development Agency	List of existing renewable energy power plants and details of solar home system program
Census 2001	Population figures
National sample survey (energy sources of Indian households for cooking and lighting 2004–05)	Use of kerosene for lighting
GoWB	District statistics on population and electricity use

## Energy

The methodology for the energy sector report drew on secondary and primary sources (Table A2.2) to prepare energy maps and to develop estimates of the supply- and demand-side scenarios.

In addition, a sample survey of 88 villages in the Sundarbans was carried out. The sample selected for the survey covered households, commercial establishments, industries, and so on. The main purpose of the survey was to collect data on: (a) electrification status; (b) electricity demand; (c) willingness to pay for electricity; and (d) level of satisfaction with the supply of electricity. The data on commercial and other loads were also analyzed to calculate average electricity demand for all nonhousehold loads. The present electricity demand was calculated using the average connected load for household and nonhousehold loads.

**Preparation of maps.** Based on the information collected from the primary survey and secondary sources, the following maps were prepared: (a) present electrification status (by marking electrification status of the village based on household electrification data collected through the primary survey and using the latest definition of electrified village); (b) renewable energy status (by marking all existing renewable energy power plants and villages covered under the solar home system program); (c) proposed electrification map (marking the villages that are planned to be electrified through grid extension and the decentralized distributed generation scheme); and (d) block maps showing electrification status of the villages.

To estimate the supply-side scenario, data on existing electricity infrastructure – substations, distribution lines, renewable energy power plants, and electricity supply – were collected from the West Bengal State Electricity Development Corporation and the West Bengal Renewable Energy Development Agency.

## 2.4.3 Livelihoods

### Agriculture

To assess the agriculture sector in the Sundarbans, a detailed desk review and collection of secondary data were undertaken to examine information such as area under cropping, cropping pattern, cropping intensity, and productivity. A list of government officials, agricultural scientists, and NGOs working in the Sundarbans was prepared. This was followed by a visit to Kolkata and the Sundarbans, May 9–14, 2010. During this visit, meetings and discussions were held with government officials, DSA, and several NGOs and scientists working in the area of agriculture in the Sundarbans. The visit also included field visits to Nimpith, Canning, and Rangabelia, where focus group discussions with farmers were held, and visits were made to farmers' fields and agricultural markets to better understand the issues, constraints, and opportunities in the sector.

### Fisheries

The fisheries sector was analyzed by first conducting a desk study analysis of the relevant primary and secondary literature and statistics, including addressing the systemic complexities that frame the local conditions of aquaculture, fisheries, poverty, and vulnerability. This was complemented by interviews and discussions with a limited number of local scientists and officials.

### Forestry

An assessment was undertaken of the magnitude of forest resource exploitation, locational patterns of forest dependents, and current investments for livelihood and social benefits. The working plans of the territorial division (South 24 Parganas) and the management

plans of the Sundarbans Tiger Reserve were the main sources for ascertaining the permissible limits of culling and extraction of wood and nonwood products from government forests. The actual extent of such regulated removal was gathered from annual reports of West Bengal Forest Department units.

Local units of the Forest Department maintain a register of authorized woodcutters, honey gatherers, and fishers holding boat license certificates, which are renewed on an annual basis. These records were consulted and, in addition, knowledgeable foresters and villagers were approached to collect information on the number, social identity, and spatial spread of the forest-dependent populace.

Schematic actual expenditure reports of district forest officers and the field director of the Sundarbans Tiger Reserve facilitated assessment of the annual scale of investments for livelihood support from the Forest Department and central assistance. Some NGOs actively provide livelihood support and social services in the Sundarbans with the help of government and international donor funding.

Livelihood opportunity enhancement options through forestry and related activities were identified and analyzed. Various silvicultural and wildlife management practices open up livelihood opportunities for poverty alleviation among the marginalized segments, including village women. Some of these are being implemented in the Sundarbans by government agencies and NGOs. The more successful models were identified in order to shortlist cost-effective, locally appropriate, sustainable models for replication.

Suggestions were made regarding incentives and opportunities for conservation practices to contribute to the economic sustenance of the poor. Existing participatory models of conservation exist under various joint forest management, community forest management, eco-development, and integrated conservation development programs in India and elsewhere to strengthen linkages between conservation and livelihoods of local communities that live adjacent to protection and production landscapes. Lessons from those models were discussed during experience-sharing sessions involving the local people, aimed at aiding replication of best practices in this area. Field trials would, however, be subject to assessment of environmental and social impacts, particularly on the marginalized, for example, women.

An assessment of current levels of capacity and skills among community members, staff of the Forest Department and other departments, and NGOs was conducted to help identify possible techniques for skills improvement. Stakeholder consultations were undertaken to identify feasible and cost-effective methods for sharing available information, interpreting the information being disseminated, and facilitating the informed persons to benefit from the knowledge. Based on local needs, capacity enhancement through structured learning and nonformal education through experience sharing and cross visits were suggested. Reducing Emissions from Deforestation and forest Degradation (REDD)-plus was viewed as a positive program providing multiple benefits for livelihoods and ecosystems.

### Demographics and Migration

The study builds on already available information and seeks to synthesize existing data and address relevant gaps. It draws upon available studies, government documents, and documentary research. This includes information from the Census of India in 2011 and 2001 (GoI 2001) and other data sources, such as the detailed Rural Household Survey (RHS) data made available for this work by the Department of Panchayat and Rural Development of GoWB. In addition, a baseline household-level survey of 2,188 households covering all 19 blocks of the Sundarbans was conducted.<sup>3</sup> The household survey was drawn from 38 randomly selected GPs. For every GP, 15 households each from four booths<sup>4</sup> (approximately equivalent to a village) were selected after randomly drawing from a weighted pool including both APL and BPL households. Thus, a total of 2,280 (38 x 15 x 4) households were selected in the 38 GPs. After discarding improperly administered questionnaires, data were compiled and analyzed for 2,188 households (net).<sup>5</sup> The survey revealed important characteristics of the population and its growth, socioeconomic groupings, livelihood preferences, and migration patterns, which were not otherwise available. Although the region and population of the Sundarbans is largely rural, some pockets of population concentration also exist and were given close attention in the study. These have a semi-urban character and are centers for trade and commerce, and also have such facilities as government establishments, hospitals, and colleges. Results from the field survey were also supplemented by open-ended focus group discussions on livelihood patterns and histories. An analysis of the dynamics of migration was also based on existing literature, survey data, and

<sup>3</sup>The Indian Sundarbans is spread over two districts of southern West Bengal, North 24 Parganas and South 24 Parganas, adjoining the neighboring country of Bangladesh. There are 19 administrative blocks in these two districts, of which six are in North 24 Parganas and 13 in South 24 Parganas. The blocks in South 24 Parganas are Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Canning I & II, Basanti, Gosaba, Mathurapur I & II, and Jaynagar I & II. The blocks in North 24 Parganas are Haroa, Sandeshkhali I & II, Hingalganj, Hasnabad, and Minakhan.

<sup>4</sup>The 19 blocks spread over two districts were divided into four regions for the purposes of this study, primarily in terms of access to the main urban centers, which act as magnets for the entire region.

<sup>5</sup>Sixty-eight survey personnel were selected locally through personal interviews. They were mostly undergraduate students pursuing or having recently completed their studies. The selected individuals were trained in administering the survey questionnaire in day-long workshops conducted in each of four locations. The survey was monitored in the field by supervisors in each location. Data gathered from the survey were further analyzed and refined, and given a human dimension by using trigger question-based focus group meetings and collecting life histories of selected individuals to trace migration and livelihood histories. This was supplemented by interviews with key informants and experts, including civil society and government representatives, scientists, officials of Project Tiger, and members of NGOs (who have been active in some parts of the study area for decades).



interviews with experts and key informants. Real-life experiences of migrants, both in the Sundarbans and Kolkata, were used to document how migrants moved from the hinterland and to shed light on the underlying push and pull factors that affect migration.

## Tourism

The consulting team made two separate visits to the Sundarbans, the first in October 2009 and the second in December 2009. Based on the *Destination Review*, and on field observations and meetings with GoWB officials, local tourism businesses, tour operators, academic researchers, and NGOs, the consulting team developed a report that drew on global best practices deemed feasible in the Sundarbans context.

## 2.4.4 Human Development

### Health

The data collection methodology employed for this study included: (a) a review of existing literature; (b) analysis of different health sector reforms and interventions for the Sundarbans; (c) studies commissioned by the government and independent research, as well as a compilation and analysis of information obtained from official records and reports from government and official information systems for each health center in terms of human resources and performance in preventive, curative, and outreach services; (d) patient satisfaction surveys; (e) reporting formats (primarily National Rural Health Mission data) compiled at block and district levels for two consecutive years (2008 and 2009) and from some primary health centers; and (f) reports and data collected from NGOs. Data were complemented through interviews with key stakeholders, including health administrators, medical officers, healthcare workers at different levels, NGOs, and Panchayat representatives at the GP level. Based on this information, service delivery maps were developed showing health facilities, catchment areas, coverage and gaps, and vulnerability indices for service availability and accessibility, and disease profiling and categorization. This information was augmented by secondary data collection and through field observations collected during April and May 2009 from all 19 blocks of the Sundarbans, and by in-depth interviews and discussions with beneficiaries.

### Education

Data from both primary and secondary sources were collected and analyzed. The primary sources were the District Information System for Education (for elementary and secondary education), the Education Management Information System (for secondary education), and state educational statistics. The secondary sources included relevant studies, available relevant reports, and analysis from both government and nongovernment sources. Primary data were also collected from a sample of schools and other educational institutions, households, education administrators, school heads

and teachers, parents, Panchayat members, and some villagers through interviews and focus group discussions. Stratified random sampling was used to select schools and villages for primary data collection. Semi-structured interview schedules and guides were administered to solicit information from schools, teachers, parents, Panchayat members, education administrators, and other relevant stakeholders.

## 2.4.5 Gender

Analysis of gender issues in the Sundarbans was based on an extensive review and analysis of existing literature (including decadal census reports),<sup>6</sup> data from human development reports for North and South 24 Parganas (which provided information for each block or subdistrict administrative unit in each district), and other publications such as the annual administrative reports published by the Directorate of Health Services and the *Economic Review* (an annual publication that is part of the budgetary papers of the state government).

Furthermore, a household survey on women's health issues was also conducted in one selected village in each of the eight blocks. As the major part of the Sundarbans falls within South 24 Parganas, seven of the sampled blocks were from that district while one was from North 24 Parganas. Fieldwork was done in collaboration with the Sundarbans Rural Development and Training Institute. The survey included 5 percent of households from each selected village. The sample was drawn randomly from the listing of all village households prepared by the local Panchayat. From each randomly selected household, one woman was selected for detailed inquiries about her health and work experience. In all, 313 households and women from those households were interviewed through structured questionnaires. Finally, interviews were also carried out with selected women to better understand the dynamics of women and migration, particularly relating to domestic employment and sex work. As there are few official records related to these categories, locating those women and their families was difficult. In all, 28 families were interviewed from where women had either migrated for work, or had been abducted. In Kolkata, while it was relatively easy to locate migrant women from the Sundarbans who were working as domestic help, it was very difficult to interview commercial sex workers; efforts were made through NGOs, which worked particularly well in the case of young girls forced into sex work but since rescued. It was possible to build case histories of eight sex workers and 12 domestic workers. In addition, interviews were held with three women, two of whom had been able to run away from their abductors, while the other had been married off hurriedly but had come back to the village.

## 2.5. Pillar 3: Biodiversity Conservation

To analyze the issue of biodiversity conservation, several studies were conducted, including a study on environmental management

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<sup>6</sup>The latest available census reports are for the year 2001. Therefore, census data for 1991 were also tabulated and a comparison was made between the two to highlight the emerging trends.

and biodiversity conservation in the Sundarbans and a study on environmental health. The methods used in each of these studies are summarized below.

### 2.5.1 Environmental Management and Biodiversity Conservation in the Sundarbans

A report on the status of biodiversity in the Indian Sundarbans was developed to provide a critical evaluation of the current state of biodiversity in the area. To achieve this objective, a group of experts was selected to provide stand-alone reports covering numerous topics ranging from microbes to flowering plants and from unicellular organisms to mammals.

In addition, a Biodiversity Conservation and Management Plan for the Sundarbans was prepared, taking into account the region's development challenges which had a bearing on biodiversity conservation. Based on the status report on biodiversity, summary recommendations of other consultancy outputs, the tiger conservation plan of the Sundarbans Tiger Reserve, and the working plan of South 24 Parganas Forest Division, the Biodiversity Conservation and Management Plan identified conservation targets, prioritized conservation actions, and articulated the necessary investments needed to pursue conservation actions.

### 2.5.2 Environmental Health

Environmental health comprises a broad range of impacts relating to water supply, sanitation, hygiene practices, and indoor air pollution associated with fuel choice, and manner and place in which food is prepared. Impacts include malnutrition, acute respiratory infections, and cardiovascular illness and mortality. Distributional effects are by no means uniform, with women and children often suffering disproportionately from some environmental health risks. The report used standard methods across all standard environmental diseases and risks, and also addressed pneumonia. Data were based on the National Family Health Survey (NFHS) 2005–06 (IIPS/Macro 2008) and on a wide variety of other information sources, including the district fact sheets of the District Level Household and Facility Survey (DLHS-3) 2007–08 (IIPS 2009), and a dedicated survey of 340 households administered as part of this NLTA in seven blocks in South 24 Parganas and one block in North 24 Parganas. To determine incremental impacts of environmental health, baseline estimates were also informed by current Global Burden of Disease data from the World Health Organization (WHO).

An economic valuation of the health impacts of environmental illnesses was also undertaken using a variety of methods with best available data. The valuations potentially reflect economic measures of morbidity, premature death, and defensive expenditures to prevent disease. Two distinct methods of valuation of mortality are commonly used by economists to estimate the social cost of premature death: the human capital approach (HCA) and the value of a statistical life (VSL). In the environmental health valuations for the NLTA, the HCA was applied as a lower bound and VSL as a

higher bound in estimating the cost of adult mortality. For child mortality, the HCA was applied.

The estimated VSL for the Sundarbans is INR 1.9 million, or US\$48,000. The approach acknowledges that there are few studies of VSL conducted in India, and that values have to be transferred from studies in other countries. It should be noted that the overwhelming majority of VSL studies has been conducted in countries with substantially higher income levels than in India. VSL estimates from these countries must, therefore, be adjusted to India using income elasticity estimates, which may be problematic because India falls out of the income band of these other countries. The general range of estimates provided by this methodology should, thus, in turn, be regarded as a conservative lower bound with some uncertainty because of the data on which it relied: the VSL valuation was informed by a relatively small set of surveys undertaken in India, to which an additional judgmental estimate was applied that would have the effect of increasing the VSL for the Sundarbans but might still underestimate it compared, for example, to the VSL in developed countries.

The estimated health effects and associated costs do not include undetermined impacts from arsenic contamination in groundwater; parasite infestations, typhoid, and other diseases related to water, sanitation, and hygiene; and cardiovascular and tuberculosis morbidity and other health effects from household air pollution. In this respect, the estimates of health effects and their social cost should also be considered conservative.

## 2.6. Pillar 4: Institutional Change

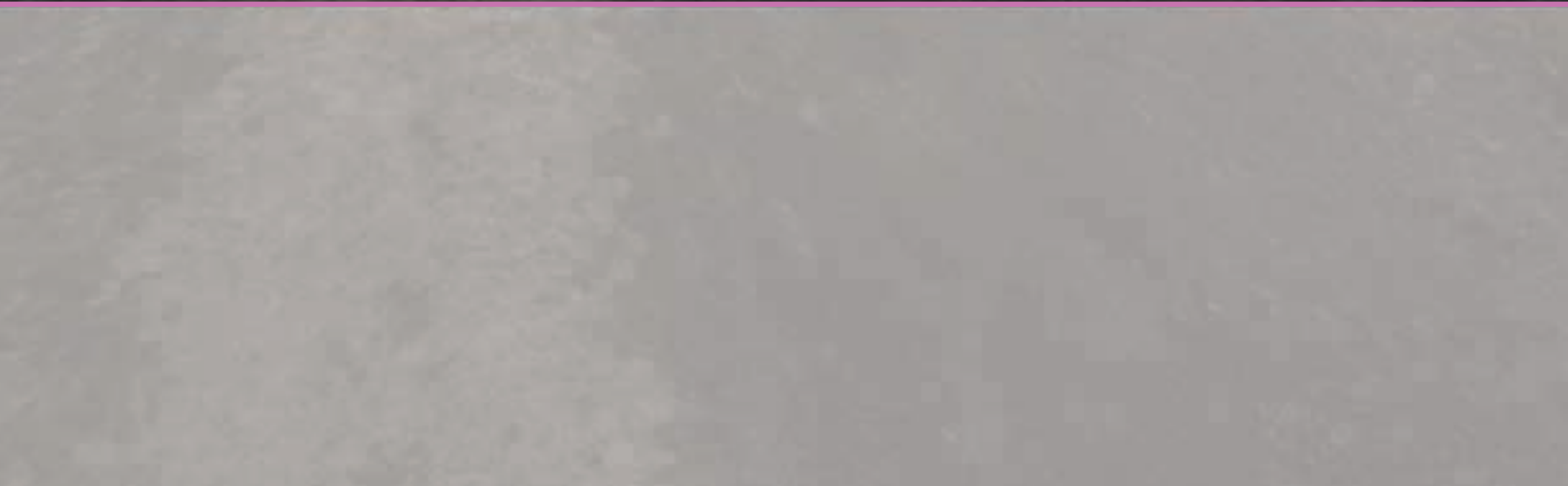
To analyze the institutional constraints and opportunities in the Sundarbans, a stakeholder analysis was completed. This drew on the following data sources and methods:

- A review was undertaken of existing literature on the Sundarbans, national and state laws and rules applicable in this area, and priorities of organizations working in the Sundarbans;
- Secondary data were collected from government departments, libraries, academicians, and the Internet;
- Meetings and interviews were conducted with retired and current officials of key departments (Sundarban Affairs, Forests, Irrigation and Waterways, and so on), representatives of NGOs, and experts recognized for their academic work on the Sundarbans. The meetings were held both during World Bank missions and separately;
- Interviews were conducted both for data collection and to gain insight into the motives and actions of the functionaries, and informal rules that guide decision-making and implementation;
- Discussions were held with the local people of the Sundarbans during visits, providing valuable insight into the sociopolitical environment of the Sundarbans; and

- Studies were undertaken of institutional models in the state and country to help determine appropriate institutional and organizational solutions for the Sundarbans.

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# Annex 3.

## Effective Forecasting Systems for Reducing the Impacts of Cyclones and Extreme Weather Events<sup>1</sup>



### Abstract

A description of tropical cyclones and severe local convective storms (mesoscale convective clusters) in the Bay of Bengal region of the North Indian Ocean is presented. Although 5 – 6 percent of the total number of tropical cyclones worldwide occur in the Bay of Bengal, these account for over 90 percent of global damage and death due to tropical cyclones. The impacts of these tropical cyclones on Bangladesh, India (including the Sundarbans), Myanmar, and Sri Lanka are described in detail in this annex. Also, the disaster risk reduction and risk communication systems of each country, which vary in sophistication and effectiveness, are discussed. It is noted that the limiting factor of any disaster preparedness system lies in the quality and leadtime of tropical cyclone forecasts. The current forecasts are very limited, extending only three days into the future. Examples of externally produced probabilistic forecasts with lead times of 15 days, using a tropical cyclone prediction system driven by forecasts from the European Centre for Medium-Range Weather Forecasts, are presented for the severe tropical cyclones such as Nargis and Sidr, and illustrate the very high degree of predictability attainable by modern extended prediction techniques. Major recommendations are made that call for the use of modern predictive techniques in the region for both tropical cyclones and severe convective events. In addition, it is recommended that national disaster reduction plans be modified to take into account the extended prediction horizon of tropical cyclones. Finally, noting the vulnerability of the large Bay of Bengal delta regions to sea level rise and increasing intensity of tropical cyclones, it is recommended that a study be commissioned to determine the level of risk in a changing climate and suggest ways of mitigating future impacts.

### 3.1. Tropical Cyclones and Severe Local Convective Storms

#### 3.1.1 Definitions

This section explores historical records of cyclone landfalls in the Bay of Bengal as identified by the Joint Typhoon Warning Center (JTWC).<sup>2</sup> It also discusses the impacts of severe convective storms that are not tropical cyclonic storms but cause significant crop damage, and loss of life and infrastructure (Figure A3.1). Cyclone and storm frequency and impacts across the Bay of Bengal and littoral countries are discussed generally, but with a focus on Bangladesh, India, Myanmar, and Sri Lanka. The data used in this analysis are a combination of material from the JTWC and the Centre for Research on the Epidemiology of Disasters.<sup>3</sup>

A **tropical cyclone** is a storm system characterized by a large low-pressure center and walls of deep thunder storms that produce extremely strong converging cyclonic winds and heavy rain. Most damage and loss of life occur through seawater inundation of low-lying coastal regions, due to storm surges driven by strong onshore surface winds in the right-forward quadrant of the storm. A tropical cyclone can be 1,000 km in diameter, with destructive winds having speeds as high as 250 km per hour. A tropical cyclone typical of the Bay of Bengal may have a lifetime of two to five days (genesis to landfall). Formation occurs over the ocean, with dissipation occurring over land following landfall.

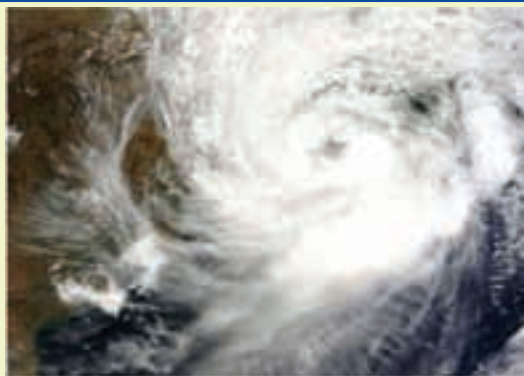
A **severe local convective storm** (or **mesoscale convective cluster**) is a more localized event that brings strong winds and intense sudden rainfall, often producing destructive flash flooding and wind damage. Its lifetime is restricted to hours, with formation often occurring over elevated terrain, as in northeast

<sup>1</sup>This Annex was prepared by Peter J. Webster based on the various background reports and analyses.

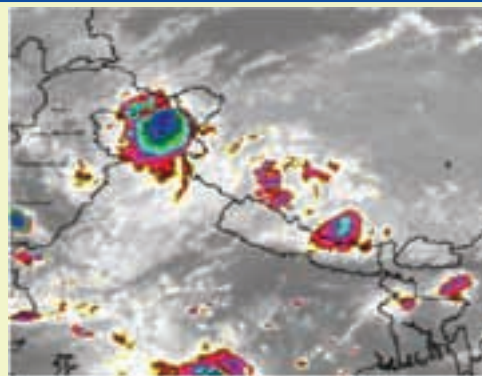
<sup>2</sup>The JTWC is a joint United States Navy–United States Air Force task force located at the Naval Maritime Forecast Center in Pearl Harbor, Hawaii. See <http://www.usno.navy.mil/JTWC/>.

<sup>3</sup>See <http://www.cred.be/>.

**Figure A3.1: Tropical Weather Events Considered in the Report: Cyclone and Severe Convective System**



Severe tropical Cyclone Aila (May 25, 2009) making landfall in Bangladesh at the top of the Bay of Bengal.



Severe convective system (often called a mesoscale convective cluster) in northern Pakistan responsible for flash floods, mudslides, loss of life, and destruction (August 12, 2009).

Bangladesh, Nepal, Bhutan, and the sub-Himalayan regions of India. Mesoscale convective clusters have a distinct diurnal cycle, occurring during the late evening and early morning. Their location over terrain often funnels intense rain to produce flash floods that spread out into the valleys and plains, destroying agriculture. The loss of life is substantial, though villages are most often built in locations above the level subject to valley flooding.

### 3.1.2 Climatology of Bay of Bengal Cyclones and Severe Mesoscale Convective Clusters

Some of the most devastating tropical cyclones in the world have occurred in the Bay of Bengal. Table A3.1 shows that nine of

the 14 global tropical cyclones associated with the highest fatalities have occurred in the Bay of Bengal. Although the Bay of Bengal accounts for less than 6 percent of the total number of tropical cyclones occurring globally, it accounts for 18 of the top 25 most fatal tropical cyclones. The triangular geography of the bay ensures that almost all tropical cyclones recurving northward from the lower latitude development region encounter a highly populated coast.

### 3.1.3 Impacts

Table A3.2 provides information on cyclones and severe convective storms across the Bay of Bengal over the last 40 years that caused damage of some type.

**Table A3.1: Tropical Cyclones Ranked by Number of Fatalities**

Rank	Name/Areas of Largest Loss	Year	Ocean Area	Deaths
1.	Great Bhola Cyclone, Bangladesh	1970	Bay of Bengal	300,000 - 500,000
2.	Hooghly River Cyclone, India and Bangladesh	1737	Bay of Bengal	300,000
3.	Haiphong Typhoon, Vietnam	1881	West Pacific	300,000
4.	Coringa, India	1839	Bay of Bengal	300,000
5.	Backerganj Cyclone, Bangladesh	1584	Bay of Bengal	200,000
6.	Great Backerganj Cyclone, Bangladesh	1876	Bay of Bengal	200,000
7.	Chittagong, Bangladesh	1897	Bay of Bengal	175,000
8.	Super Typhoon Nina, China	1975	West Pacific	171,000
9.	Cyclone 02B, Bangladesh	1991	Bay of Bengal	138,866
10.	Cyclone Nargis, Myanmar	2008	Bay of Bengal	138,366
11.	Swatlow, China	1922	West Pacific	100,000
12.	Great Bombay Cyclone, India	1882	Arabian Sea	100,000
13.	Hakata Bay Typhoon, Japan	1281	West Pacific	65,000
14.	Bangladesh	1942	Bay of Bengal	61,000

Source: Weather Underground <http://www.wunderground.com/hurricane/deadlyworld.asp>.

**Table A3.2: Impacts of Storms and Cyclones in Bay of Bengal 1971–2009**

	<b>Cyclones (1971–2009)</b>	<b>Storms (1971–2010)</b>
Events across the Bay of Bengal	141	140
Average events/year	3.6	3.5
Average deaths/year	8,793	368
Average deaths per event/year	1,955	119
Average affected/year	3,085,916	345,376
Number affected per event/year	834,545	75,105

Three sets of findings from Table A3.2 are of immediate interest:

- There is parity between the number of cyclones and of mesoscale convective clusters (localized severe convective storms). From 1971 to 2009, the JTWC tracked 141 cyclone events across the Bay of Bengal. From 1971 to 2010, 140 mesoscale convective clusters impacted Bangladesh, India, Myanmar, and Sri Lanka;
- The mortality from cyclones is far greater than from mesoscale convective clusters. On average, the annual death toll from cyclones was over 8,700, while from severe local storms it was 368. Per event, the average death toll from cyclones was 1,955, while each local convective storm, on average, resulted in 119 deaths. In terms of people negatively affected (injuries, property damage, and destruction, and so on), the pattern is similar. Over 3 million individuals were affected, on average, by cyclones each year, giving an average of 834,545 people affected per cyclonic event. Storms, by comparison, affected an average of 345,376 people per year, or 75,105 per event. The main reason for the difference in mortality is that a tropical cyclone affects a broad coastal region, often in a delta area

that is densely populated and highly fertile, with limited shelter from tropical cyclone-driven surges; and

- While less damaging, mesoscale convective clusters still have sizable impacts. While these storms certainly affect fewer people than cyclones, an average of over 75,000 people affected per event – and the resulting impacts on regional economies – is nevertheless considerable. Similarly, while deaths due to mesoscale convective clusters are less than 10 percent of those from tropical cyclones, over 100 individuals dying as a result of each major severe local storm is significant. One reason for the lower mortality per event is the traditional location of villages in hill country on higher ground to avoid the impacts of flash floods.

### 3.1.4 Location and Seasonal Cycle of Tropical Cyclones and Mesoscale Convective Clusters

Table A3.3 shows the frequency of cyclones and major severe local convective storms that occur in the littoral countries of the Bay of Bengal. Between 1971 and 2010 most storms and cyclones occurred in the Bay of Bengal during April–May and October–November. April was the most dangerous month, with 54 storms and cyclones occurring – 19 percent of all events.

A breakdown of monthly frequencies between storms and cyclones shows that the periods during which most storms and cyclones take place are quite different. Cyclones tend to occur most frequently during October and November, with 21 percent and 29 percent of the total number, respectively. Destructive mesoscale convective clusters, on the other hand, take place earlier in the year, primarily during April and May. Nearly half – 46 percent – of major convective storms that cause damage and death occur in the Bay of Bengal region during April, while May is the month with the next highest frequency of damage-causing local storms.

**Table A3.3: Occurrence of Tropical Cyclones and Mesoscale Convective Clusters in Bay of Bengal Region by Month, 1971–2010**

Month	Total TCs & MCCs	% TCs & MCCs per Year	TCs per Month	% TCs per Year	MCCs per Month	% MCCs per Year
January	7	3	4	3	3	2
February	2	1	1	1	1	1
March	21	8	1	1	20	14
April	54	19	8	6	46	33
May	47	17	20	14	27	19
June	11	4	7	5	4	3
July	7	3	2	1	5	4
August	8	3	0	0	8	6
September	16	6	11	8	5	4
October	41	15	30	21	11	8
November	47	17	41	29	6	4
December	20	7	16	11	4	3

Key: TC = tropical cyclone; MCC = mesoscale convective cluster.

Figure A3.2 shows the annual distribution of tropical cyclones and mesoscale convective clusters. The curve showing “total cyclones and convective storms” smoothens out the frequency throughout the year – it masks the two time periods during which the two different event types take place. That is, while the Bay of Bengal is subject to both types of storms during both spring and fall (autumn), cyclones occur more frequently in the fall, while most major storms occur in the spring.

Figure A3.2 shows the differing impacts of tropical cyclones and local convective storms:

- Most tropical cyclones occur in the fall, and have the potential to cause great harm through inundation from storm surges and subsequent rains causing widespread flooding. Many tropical cyclones occur as the summer rice crop is maturing. The national cost of tropical cyclones is huge. For example, the cost to Myanmar from Cyclone Nargis (April–May 2008) was estimated at US\$10 billion, with almost 140,000 lives lost (Webster 2008; Fritz et al. 2009). Cyclone Sidr (November 2007) cost Bangladesh an estimated US\$1.7 billion and about 10,000 lives.<sup>4</sup> The costs associated with the more recent Cyclone Aila (May 2009) was about US\$500 million with a loss of more than 300 lives;<sup>5</sup>
- Most severe mesoscale convective clusters occur in the spring, often at the harvest time of winter rice. The resulting flash floods are events of short duration arising from severe convection events occurring in locations where the torrential rain may be funneled orographically, and are not to be confused with slow-rise monsoonal floods that occur during the monsoon season. This convective event caused major flooding in the city of Leh in north India, resulting in extensive damage and loss of life; and
- The third form of flood hazard, not reported on here, occurs in the summer in the form of slow-rise floods. The accumulation through the river systems of monsoonal rainfall causes extensive damage that persists often for weeks, destroying both crops and infrastructure (Webster et al. 2010).

### 3.1.5 Tropical Cyclones and Severe Convective Events by Country

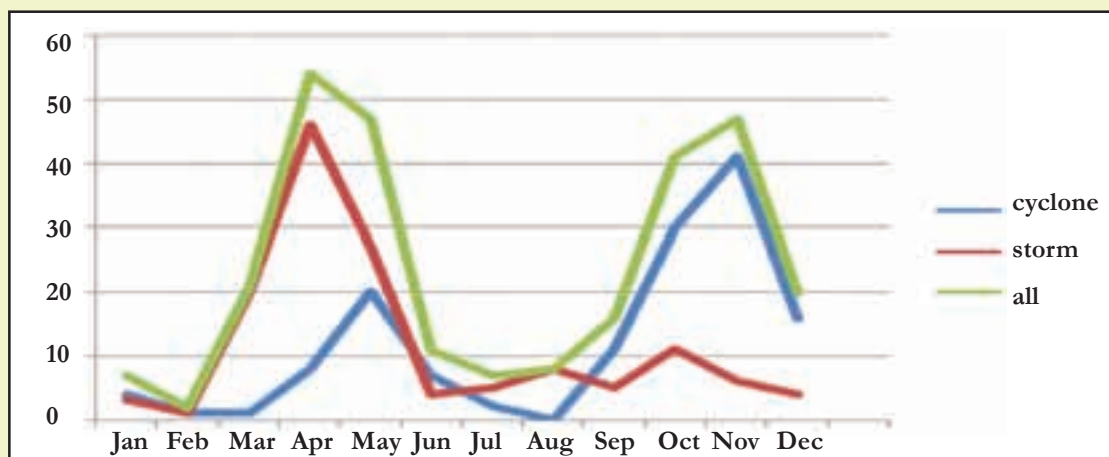
In terms of total numbers, Bangladesh and Myanmar have been most impacted by landfalling cyclones and major storms, suffering 174,031 and 139,145 deaths, respectively. India has sustained 44,695 deaths from events that originate in the Bay of Bengal, and Sri Lanka has had 754 recorded deaths from cyclones and storms (Table A3.4).

Overall, India has a higher average frequency of cyclones that have made or threatened to make landfall. From 1971 to 2009, an annual average of 2.5 tropical cyclone events originated in the Bay of Bengal. Bangladesh, Myanmar, and Sri Lanka had significantly fewer events – on average, 0.9, 0.7, and 0.5 per year, respectively.

The differential impacts, by country, may be a function of whether cyclones made landfall, where they made landfall (populated or unpopulated areas), area of low-elevation delta, and levels of disaster management preparation at the time of landfall. Also, the paths of tropical cyclones tend to recurve in a clockwise manner so that much of India, being on the west side of the Bay of Bengal, does not encounter the devastating right-forward quadrant winds that cause storm surge. The Ganga-Brahmaputra delta of Bangladesh and northeast India and the Ayeyarwady (Irrawaddy) delta of Myanmar more often encounter the right-forward quadrant of the cyclone.

As shown in Table A3.4, the number of severe convective events is greatest in the more northern Bay of Bengal countries: India and Bangladesh. Similar convective events occur in Nepal and Bhutan in the pre-monsoon period. Severe convective events are thought to arise from thermodynamic instabilities due to intense surface heating of the atmosphere. In moister locations (Myanmar and Sri Lanka) and after the monsoonal rains commence over Bangladesh, India, and Nepal, the conditions are not conducive to intense rain events but rather to prolonged, less intense precipitation.

**Figure A3.2.** Frequency of Bay of Bengal Region Cyclones and Severe Convective Storms by Month, 1971–2010



<sup>4</sup>See [http://en.wikipedia.org/wiki/Cyclone\\_Sidr](http://en.wikipedia.org/wiki/Cyclone_Sidr).

<sup>5</sup>See [http://en.wikipedia.org/wiki/Cyclone\\_Aila](http://en.wikipedia.org/wiki/Cyclone_Aila).



**Table A3.4. Impact by Country of Tropical Cyclones and Mesoscale Convective Clusters, 1971–2009**

	TCs	MCCs	TCs	MCCs
	India		Bangladesh	
Number of events	97	37	34	100
Number of deaths	41,406	3,289	162,879	11,152
Events/year	2.5	0.9	0.9	2.5
Deaths/year	1,062	82	4,176	279
Deaths/event/year	427	89	4,790	112
Affected/year	1,759,367	163,124	1,219,676	174,926
Affected/year/event	707,374	176,350	1,399,040	69,970
	Myanmar		Sri Lanka	
Number of events	26	2	21	1
Number of deaths	138,864	281	754	0
Events/year	0.7	0.1	0.5	0.03
Deaths/year	3,561	7	19.3	0
Deaths/event/year	5,341	141	36	0
Affected/year	91	7,126	36,667	200
Affected/year/event	137	142,525	68,095	8,000

Key: TC = tropical cyclone; MCC = mesoscale convective cluster.

## 3.2. Cyclone Case Studies

This section provides case studies of major cyclonic events that have had an impact on each of the four countries located on the Bay of Bengal that are considered in this report: Bangladesh, India, Myanmar, and Sri Lanka. The case studies focus on Cyclone Bhola (Bangladesh, 1970), Cyclone Aila (India, 2009), Cyclone Nargis (Myanmar, 2008), Cyclone Sidr (Bangladesh, 2007), and Cyclone 04B (Sri Lanka, 2000). While each of these cyclonic events impacted more than one country, this section focuses on the impacts of each on a particular country.

Three elements stand out from the case studies. First, the ability to provide extended forecasts of the cyclone's path, intensity, and landfall shows that extended prediction is critical. This is apparent in the comparison between two very similar tropical cyclones: Bhola and Sidr. Second, even with excellent forecasts (for example, for Sidr, 2007, and Nargis, 2008), the translation to mitigation requires a thoughtful disaster management system. Third, the impacts from Cyclone Aila indicate that a robust forecasting capability must be considered an integral part of an effective disaster management program. In the absence of effective – and well publicized – forecasts, even a relatively sophisticated disaster management program, such as that used by India, will be less than fully effective.

**Forecast context.** Currently, the official forecast for the North Indian Ocean is made by the Indian Meteorological Department

(IMD). The JTWC forecast is also available. Before 2010, the forecasts had a three-day lead time following identification of a vortex. The JTWC now extends the forecasts to four days. Both of these forecasts are deterministic rather than probabilistic. However, ensemble-based probabilistic forecasts are also available for up to 15 days, and these will be compared with the IMD and JTWC forecasts later.

**Case studies.** A sample of the major tropical cyclones in the Bay of Bengal has been chosen for consideration. Each case study first describes the meteorological underpinnings of the storm, and then describes the impacts relative to the forecasts of the cyclones.

### 3.2.1 Cyclone Bhola: November 1970, Bangladesh

**Meteorological history.** Cyclone Bhola was a severe tropical cyclone (category 3 on the Saffir-Simpson scale) that occurred in the northern Bay of Bengal and made landfall in Bangladesh (then East Pakistan) on November 12, 1970, with devastating impacts. It is thought that Cyclone Bhola was the sixth tropical cyclone of that year, but it is difficult to determine whether or not monsoon depressions were counted as tropical cyclones.<sup>6</sup>

**Impacts of Cyclone Bhola.** The landfall point was the Ganga-Brahmaputra delta island of Bhola and surrounding low-level islands (giving the cyclone its name). The storm surge claimed between 300,000 to 500,000 lives, making it the deadliest tropical cyclone ever recorded, and also one of the deadliest natural

<sup>6</sup>See [http://en.wikipedia.org/wiki/1970\\_Bhola\\_cyclone](http://en.wikipedia.org/wiki/1970_Bhola_cyclone).

calamities. The cyclone formed over the central Bay of Bengal on November 8 and travelled north. It reached peak wind speeds of 185 km per hour on the night of November 12. Whereas there had been ship reports of a cyclone moving up the Bay of Bengal, this scant information was not communicated. Cyclone Bhola arrived unannounced, creating devastation and, eventually, political instability.

An almost equally damaging tropical cyclone with a similar track and intensity to Bhola (designated Cyclone 02B by the JTWC) made landfall in late April 1991, leaving 138,866 dead and damage in excess of US\$1.7 billion. Cyclones Bhola and 02B led to the building of tropical cyclone shelters in coastal Bangladesh. Before Cyclone Sidr in 2007, discussed below, there were 1,500 shelters (pillared cement constructions that serve dually as community centers) in low-lying coastal Bangladesh, each capable of providing safe refuge to 500–1,500 people.<sup>7</sup> Following Cyclone Sidr, there were plans to double the number of shelters.

### 3.2.2 Cyclone Aila: May 2009, India

**Meteorological history.** Cyclone Aila made landfall in India on May 25, 2009. The JTWC first identified the event as a tropical disturbance on May 21. At that point, it was 950 km south of Kolkata, India. The following day, as the storm moved north, the IMD classified it as a disturbance. On May 23, following satellite confirmation that the event had become more organized, the JTWC classified it as a tropical cyclone. The IMD classified it as a cyclone on the same day, when it was 350 km to the southeast of India's Sagar Island. Aila was determined to be a severe cyclonic storm on May 25 and made landfall between 8.00 and 9.00 a.m. with wind speeds of 110 km per hour.<sup>8</sup>

**Impacts of Cyclone Aila.** The cyclone affected Bangladesh, India, and Myanmar. It also came ashore close to the landfall location of Cyclone Sidr in 2007. In addition to heavy rains and high winds, damage from Aila was associated with a significant storm surge. The Sundarbans World Heritage Site was very close to the center of Aila's landfall.

Accounts are mixed as to the adequacy of forecasts and preparations made in advance of Aila's landfall. According to accounts in the *Times of India*, radio broadcasts were released that a cyclone threat existed in the area. However, these broadcasts did not indicate the intensity of the storm. Instead, the radio messages simply advised fishers not to go to sea.<sup>9</sup> The *Times of India* also reported that in some areas government preparations were inadequate, and alert levels were raised after the event.

“Pradip Haldar, block development officer of Patharpratima, said the administration went on alert only after a major breach was reported in the embankment at Mithapukur in Gopalnagar village on May 21. Haldar rushed to the spot with other officers and found water gushing into the village. Sunderbans affairs minister Kanti Ganguly also arrived. It was only after an emergency meeting at the block office that Ganguly asked Haldar to issue a warning” (*Times of India* report).

Over 5 million were affected in some capacity in India, and over 3 million in Bangladesh.<sup>10</sup> Fishing boats, croplands, and rice paddies were also damaged or destroyed throughout the region.<sup>11</sup> The impact associated was about US\$550 million with a loss of more than 300 lives, with over 8,000 persons missing.<sup>12</sup>

### 3.2.3 Cyclone Nargis: April–May 2008, Myanmar

**Meteorological history.** The IMD first classified the storm that was to become Cyclone Nargis as a depression on April 27, 2008. At that point, it was approximately 1,000 km southeast of Chennai, India. The following day, April 28, both the JTWC and the IMD classified the event as a cyclone. The storm increased in strength on April 29 and was classified as a severe cyclone by the IMD (windspeeds of 160 km per hour). At that point in time, the IMD forecast the tropical cyclone to strike Bangladesh or southeastern India. However, later that day, the storm became disorganized and began redirecting to the northeast. May 1 found the storm rapidly increasing in strength and heading due east toward Myanmar. On May 2, as it approached the coast of Myanmar, the JTWC reported that it reached its maximum strength, with winds approaching 215 km per hour (category 4). Cyclone Nargis made landfall on May 2, 2008, in the Ayeyarwady Division of Myanmar.<sup>13</sup>

**Impacts of Cyclone Nargis.** Cyclone Nargis is considered one of the most devastating storms in recorded history. While the high winds and heavy rains of the cyclone caused considerable damage, the greatest impacts were a result of the associated storm surge. The cyclone (and surge) destroyed much of the Ayeyarwady delta, as well as Yangon (Myanmar's primary city) (Fritz et al. 2009). In the Ayeyarwady delta, over half the fishing fleet was destroyed, three-quarters of the livestock was killed, 700,000 houses were destroyed, and 1 million acres of rice paddies were degraded due to saltwater infiltration from the storm surge. The Government of Myanmar reported that over 135,000 people were killed, and the United Nations reported that 2.4 million were severely affected by Cyclone Nargis. Among those, 1.4 million were in dire need of clean water, food, shelter, and medical aid in the weeks following the cyclone's landfall.

<sup>7</sup>See <http://www.climate.org/PDF/Bangladesh.pdf>

<sup>8</sup>JTWC and IMD sources; see also [http://en.wikipedia.org/wiki/Cyclone\\_Aila](http://en.wikipedia.org/wiki/Cyclone_Aila).

<sup>9</sup>See [http://articles.timesofindia.indiatimes.com/2009-06-03/kolkata/28170288\\_1\\_warning-sunderbans-bdo-office](http://articles.timesofindia.indiatimes.com/2009-06-03/kolkata/28170288_1_warning-sunderbans-bdo-office).

<sup>10</sup>Data derived from the Centre for Research on the Epidemiology of Disasters (<http://www.cred.be/>).

<sup>11</sup>See <http://www.nytimes.com/2009/05/28/world/asia/28cyclone.html>.

<sup>12</sup>See [http://en.wikipedia.org/wiki/Cyclone\\_Aila](http://en.wikipedia.org/wiki/Cyclone_Aila).

<sup>13</sup>JTWC and IMD sources; see also [http://en.wikipedia.org/wiki/Cyclone\\_Nargis](http://en.wikipedia.org/wiki/Cyclone_Nargis).

Despite continual warnings from the IMD, the JTWC, and the Climate Forecast Applications Network (CFAN),<sup>14</sup> the Myanmar authorities responsible for issuing forecasts and warnings failed to notify the people of the Ayeyarwady delta of the impending tropical cyclone and storm surge. In fact, the official forecast was delivered in the following bulletin in the *New Light of Myanmar*, May 2, 2008:

“Storm News (issued at 9:00 hours MST on 1-5-2008). According to observations at (18:00) hrs MST today, the severe cyclonic storm (NARGIS) over the Bay of Bengal is centered at about (310) miles Southwest of Gwa. During the past (12) hrs, it has intensified and moved Eastnortheast. It is forecast to cross the Coast between the Southern Rakhine State and Northern Ayeyarwady Division during the next (36) hours commencing noon today. Under the influence of this storm, rain and thunder storms will be widespread in Rakhine, Mon, Kayan, Shan and Kayah States, Ayeyarwady, Yangon, Bago and Taninthayi Divisions, isolated to scattered in Shan and Kayah States, Mandalay Division. Frequent squalls with rough seas will be experienced off and along the Mandalay coast. Surface wind speeds may reach (50) mph [80 kph]...”

At that stage, IMD, JTWC, and CFAN all had the tropical cyclone moving westward along the east–west Ayeyarwady delta coast. The Myanmar authorities had forecast the storm to landfall further north and underestimated the strength of the wind by 80–95km per hour. Furthermore, there was no mention of a potentially severe storm surge. Clearly, the international forecasts had either been ignored or misinterpreted.

Significant international controversy was raised after the Government of Myanmar refused to allow international assistance in the immediate period after the landfall of Cyclone Nargis and closed evacuation camps and centers early, requiring some groups to return to what remained of their communities.<sup>15</sup>

### 3.2.4 Cyclone Sidr: November 2007, Bangladesh

**Meteorological history.** The storm that was eventually to become Cyclone Sidr was first detected as an area of disturbed weather on November 9, 2007, over India’s Andaman Islands. The JTWC issued a tropical cyclone formation alert on November 11. Later that day, the JTWC labeled it a cyclone. The IMD did the same the following day (November 12). It was upgraded by the IMD to a very severe cyclone on November 13. The JTWC found that its wind speeds reached 260 km per hour on November 15.

It made landfall in Bangladesh later that day. After appearing over the land it quickly weakened, with the last advisories issued the following day.<sup>16</sup>

**Impacts of Cyclone Sidr.** While Cyclone Sidr was extremely powerful, preparations made for its landfall by the Bangladeshi government and subsequent impacts stand in stark contrast to the experience of Myanmar with Nargis. Cyclone Sidr initially hit islands off the coast of Bangladesh, and then made landfall on the southern coast between Cox’s Bazar and Satkhira in the evening.<sup>17</sup> In the days leading up to landfall, and in its immediate aftermath, Bangladeshi officials recognized the storm as being one of the largest in years, comparable in strength to the 1991 cyclone that had resulted in 138,000 dead in Bangladesh. However, disaster management preparation policies put in place by the government provided a level of confidence about mitigating the impacts. At the time, the head of Bangladesh’s meteorological department, Samarendra Karmakar, said:

“It is not less severe than the 1991 cyclone, in some places it is more severe. But we are expecting less casualties this time because the government took early measures. We alerted people to be evacuated early.”

Preparations for Sidr included shutting down Bangladesh’s primary port at Chittagong, and evacuating 3.2 million residents in most of the coastal areas and central parts of the country into cyclone shelters. Significantly, Bangladesh mobilized over 40,000 volunteer emergency staff to help with the evacuations and disaster management preparations.<sup>18</sup>

Damage to Bangladesh was considerable. Rice paddies, property, and protective embankments were destroyed, and an estimated 10,000 people died.<sup>19</sup> Compared to the impacts of previous storms that had made landfall in the same area, and of Cyclone Nargis in Myanmar a year later, the incidence of death and destruction was much lighter,<sup>20</sup> even though many parts of Bangladesh had been repeatedly inundated by floods in the preceding months as a result of very intense monsoonal rains.<sup>21</sup> Also, the strong winds of Cyclone Sidr caused the destruction of many mobile phone towers, putting out of action an important means of disaster management communication.<sup>22</sup> Nevertheless, the relatively low levels of damage, and the ability to prepare for that damage, were a testament to the integrated disaster management system that had been put in place and implemented by the Government of Bangladesh.

<sup>14</sup>See <http://www.cfanclimate.com/>.

<sup>15</sup>See <http://www.nytimes.com/2008/06/03/world/asia/03myanmar.html?ref=cyclonenargis>.

<sup>16</sup>JTWC and IMD sources; see also [http://en.wikipedia.org/wiki/Cyclone\\_Sidr](http://en.wikipedia.org/wiki/Cyclone_Sidr).

<sup>17</sup>See [http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242\\_8921\\_1311\\_3478\\_1570](http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242_8921_1311_3478_1570).

<sup>18</sup>See [http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242\\_8921\\_1311\\_3478\\_1570](http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242_8921_1311_3478_1570).

<sup>19</sup>See [http://en.wikipedia.org/wiki/Cyclone\\_Sidr](http://en.wikipedia.org/wiki/Cyclone_Sidr)

<sup>20</sup>See <http://www.nytimes.com/2007/11/16/world/asia/16iht-bangla.html>.

<sup>21</sup>See [http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242\\_8921\\_1311\\_3478\\_1570](http://www.aisaid.gov.au/hottopics/topic.cfm?ID=7242_8921_1311_3478_1570).

<sup>22</sup>See <http://www.nytimes.com/2007/11/16/world/asia/16iht-bangla.html>.

### 3.2.5 Cyclone 04B: December 2000, Sri Lanka

**Meteorological history.** Cyclone 04B was first detected on December 21, 2000, in the Bay of Bengal. At that time it was a weak convective system. However, it quickly organized and began to move to the west. On December 23, the JTWC issued a tropical cyclone formation alert. The following day, on December 24, the IMD termed it a deep depression. A day later, after a period of brief weakening, the JTWC labeled it a cyclone and issued warnings for Sri Lanka, which was 250 km to the west of the storm at that point. The IMD upgraded the event from a deep depression to a cyclone later that day. On December 26, 2000, Cyclone 04B made landfall at Trincomalee, Sri Lanka. At that point, the JTWC determined that the winds were at speeds of 120 km per hour. Cyclone 04B weakened slightly over Sri Lanka, and entered the Gulf of Mannar as a tropical storm on December 27. It once again made landfall – this time in Kanyakumari, India – on December 28, with weakening wind speeds of 70 km per hour. It then made its way across southern India and entered the eastern Arabian Sea on December 29, 2000.<sup>23</sup>

**Impacts of Cyclone 04B.** Cyclone 04B made landfall in Sri Lanka following a month of significant monsoon rains. As a result, the high rainfall from the cyclone exacerbated flooding. While relatively minimal numbers of people were killed as a result of the cyclone, approximately 375,000 people were adversely affected.<sup>24</sup> Scores of fishing vessels, crops, and houses were damaged or destroyed. India received impacts from the storm, but they were relatively minimal.

### 3.3. The Sundarbans: A Region of Particular Vulnerability

The Sundarbans comprise the largest mangrove forest in the world, occupying a vast delta area at the northern end of the Bay of Bengal, spanning the border between India and Bangladesh. They comprise a vast network of coastal islands, mangroves, rivers, and tidal waterways – all a function of the confluence of the Padma, Brahmaputra, and Meghna Rivers. The Sundarbans area is made up of a number of different ecoregions. Inland, it comprises freshwater swamp forests, while on the coasts it is made up of mangroves. While huge tracts of the area have been logged and developed, it remains rich in biodiversity. As a result, it was designated a World Heritage Site in 1987 by UNESCO.

The Sundarbans is extremely rich in flora and fauna. Most of the area is populated by the plant species *Heritiera fomes* (known locally as “sundri”) and *Excoecaria agallocha* (“gewa”). Along the coast, UNESCO reports that 27 types of mangroves have been cataloged. The Sundarbans is a vital habitat for the endangered Royal Bengal tiger, and 49 mammal species have been documented in the area. However, of these, five are probably

extinct in the region (Javan rhinoceros, water buffalo, swamp deer, gaur, and hog deer). In addition, 53 reptile and eight amphibian species have been recorded in the Sundarbans, along with 315 avian species, including waterfowl, raptors, forest birds, kingfishers, and the white-bellied sea eagle. Over 3 million people depend on the Sundarbans and its ecosystem services for their existence.

Its location at the northern end of the Bay of Bengal makes the Sundarbans especially prone to cyclone impacts. This, in combination with development and resource extraction as a result of the extremely high human population nearby, has lowered the resilience of this very important ecological region and reduced its ability to recover from the impacts of cyclone landfalls in the area.

In recent years, the Sundarbans has been severely impacted by two cyclones: the cyclone of 1988, and Cyclone Sidr in 2007. During the 1988 cyclone, nine Royal Bengal tigers were documented as killed, in addition to several hundred deer (CEGIS 2007). The impacts of Cyclone Sidr – as a result of a very high storm surge and strong winds – were considered to be just as severe. Around 1,900 km<sup>2</sup> of area was damaged by the event, a significant proportion of the total area of the Sundarbans. The massive damage to the flora – upon which many other species depend – was expected to result in negative ripple effects across ecosystems. Similarly, a large number of mammalian, avian, and fish species were impacted by the cyclone and storm surge (CEGIS 2007).

Being part of a low-lying delta, the Sundarbans is susceptible to sea level rise associated with global warming and, along with the nearby coastal islands, deltas, and estuaries, it is expected to be subject to the increase in frequency and intensity of tropical cyclones that is projected for the North Indian Ocean (Webster et al. 2005; Elsner, Kossin, and Jagger 2008).

### 3.4. Disaster Preparation and Response

As illustrated by the earlier analysis, cyclone landings in the Bay of Bengal have had very significant impacts on populations living in the region, particularly rural communities. These communities are amongst the poorest and most vulnerable populations in the area, as they have few resources to support themselves, and governmental and institutional capacity to provide support systems is often inadequate. These communities and populations, lacking support to bolster their resilience to natural hazards, are therefore amongst those most impacted by cyclone landfalls.

In order to strengthen community resilience in the face of cyclones, countries in the region have begun to implement, to varying degrees, disaster risk reduction (DRR) strategies, which can be defined as:

<sup>23</sup>JTWC and IMD sources; see also [http://en.wikipedia.org/wiki/2000\\_Sri\\_Lanka\\_cyclone](http://en.wikipedia.org/wiki/2000_Sri_Lanka_cyclone).

<sup>24</sup>Data derived from the Centre for Research on the Epidemiology of Disasters.



“The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development” (UNISDR 2004).

The following section gives an overview of DRR strategies and risk communication systems, with an emphasis on the importance of community-level structures. The ensuing sections describe the DRR strategies and risk communication systems in place in Bangladesh, India, Myanmar, and Sri Lanka.

### 3.4.1 General Overview of DRR Strategies and Risk Communication Systems

Contemporary disaster management must ensure vertical integration of DRR and risk communication approaches. That is, there must be a mapped or planned structure that encompasses coordinated responsibilities and functions for various government institution types and levels (federal, state or district, local). In addition, it is important to recognize the necessary role played by communities themselves within an effective and modern DRR system. Because communities are both the immediate entities affected by a natural disaster and ideally the first responders on the scene, contemporary disaster management approaches recognize that “community action for disaster risk management is a crucial element in promoting a culture of prevention and creating safer communities.”<sup>25</sup> A top-down approach to disaster management (DRR and risk communication) cannot take full account of the needs and local contingencies of communities – thereby potentially exacerbating their vulnerabilities. Similarly, a sole focus on a top-down approach under values the resources and capacities that may be endemic to a community.

The United Nations World Food Programme notes: “[a] dollar invested today in disaster risk reduction saves four or more dollars in the future cost of relief and rehabilitation.”<sup>26</sup> Similarly, disaster management policies have transformed from reactive disaster response efforts to a broader, more proactive approach that emphasizes disaster planning as well as response activities. Contemporary DRR planning should involve, then, top-down (governmental) planning activities, as well as community-level planning structures and approaches.

The Asian Disaster Preparedness Center has indicated that the following elements must be present in an integrated disaster management structure:<sup>27</sup>

- Institutionalization of the community-based disaster risk management (DRM) in the policy, planning and implementation of the government ministries and departments and that of the donors in target countries;

- Implementation of innovative programs to explore new dimensions in the community-level preparation and response practice;
- Development of a frameworks and tools to support the work of decisionmakers and practitioners;
- Development of databases and publications to map the community-level preparation and response practices in various regions; and
- Development of new training tools to enhance the capacity of practitioners.

These basic elements were implemented in the CFAN flood forecast and warning system implemented operationally in 2007 in Bangladesh.

With specific regard to cyclones, however, effective disaster planning and risk communication in a DRR framework must include a weather forecasting element. Forecast information regarding cyclone formation, tracks, and landfall – disseminated through the disaster management system, and down to and through communities – is a central element to effective and successful community resilience to cyclone landfalls. In other words, a disaster management system and a risk communication structure are necessary – but not sufficient – elements of proper mitigation measures to counteract the impacts of cyclones.

A cyclone forecast system that is integrated as part of a disaster management and risk communication scheme will include the following elements:

- The ability to provide probabilistic information as to when and where a cyclone will make landfall, as well as its scale and intensity;
- Communication of the forecasts to communities using a prearranged system, and in a form that the recipient of the information can understand and use; and
- An indication of the appropriate types and levels of response that should be applied by communities, government institutions, and other stakeholders.

The culmination of this scheme will result in information being provided to communities in advance of a cyclone landfall whereby communities and community members can reduce the possibility of injury, loss of life, and damage to property and livestock.

### 3.4.2 Bangladesh: Disaster Management

#### Overview

Bangladesh has a vertically structured, community-oriented disaster management system that consists of both national and

<sup>25</sup>Asian Disaster Preparedness Center: <http://www.adpc.net/v2007/Programs/CBDRM/>.

<sup>26</sup>See <http://www.wfp.org/disaster-risk-reduction>.

<sup>27</sup>Asian Disaster Preparedness Center: <http://www.adpc.net/v2007/Programs/CBDRM/>.

local (community) preparation and response elements. While Bangladesh has certainly suffered horrendous losses from cyclones over time, its relatively small losses from Cyclone Sidr in 2007 (certainly in comparison to the damage inflicted on Myanmar by Cyclone Nargis in 2008) are an indication that the system in place has shown dividends in terms of lower property damage and loss of life.

The disaster management system that has been implemented by the Government of Bangladesh is a function of the government's realization of the country's particular geographic vulnerabilities, as indicated by its history of cyclonic events. The low-lying geography of Bangladesh makes it very vulnerable to cyclone landfalls and associated storm surges. The majority of the country has a very low-lying topography (elevations of 1 m or less along tidal floodplains, 1–3 m along estuarine floodplains and rivers, and 6 m in the northeast of the country). Bangladesh also has a relatively long Bay of Bengal coastline, which provides a significant opportunity for cyclone landfall along its borders. The country also has a very large and mostly poor population, estimated in 2007 at about 150 million, making it the seventh most populous country in the world. The combination of geographic features and large population has meant that Bangladesh has suffered significant negative impacts from cyclone landfalls (Riaz 2011).

### Disaster Management in Bangladesh

In response to the country's vulnerability to devastating cyclone impacts, the Government of Bangladesh has implemented an integrated disaster management system. This structure provides for coordination of government institutions and facilitation of community response efforts.

Bangladesh's Disaster Management Bureau provides some context for the structure and associated disaster management strategy that has been put in place:

"After the floods of late 1980s and the killer cyclone of 1991, the concept of acting only after the occurrence of disaster has been replaced by the concept of total disaster management involving prevention/mitigation, preparedness, response, recovery and development. The [Government of Bangladesh] has, therefore, total commitment towards reduction of human, economic and environmental costs of disasters by enhancing overall disaster management capacity. Efforts have been continuing for optimum coordination and best utilization of resources along with ensuring community involvement so that they are aware of what they can do for protecting their lives and properties against disasters. The plan and conduct of disaster management by [the government] involve preparedness, response, recovery and mitigation as key notes for building up self-reliance of the community people."<sup>28</sup>

Bangladesh has a number of interrelated disaster management coordination institutions: the Disaster Management and Relief Division; the National Disaster Response Coordination Centre; the Disaster Management Bureau; and the Comprehensive Disaster Management Programme. One of the principal tasks of the Disaster Management and Relief Division is the "[a]ssessment of disaster situation and recommendation to declare State of Disaster Emergency and issuance of evacuation notices and monitor disaster early warning dissemination."<sup>29</sup> Through data collection and analysis, the National Disaster Response Coordination Centre provides strategic and operational assessments of and guidance concerning a disaster. Information is provided to the Disaster Management and Relief Division for tactical responses. The Disaster Management Bureau is the technical services branch of the Disaster Management and Relief Division and coordinates all elements of disaster management from national to local level.<sup>30</sup> The Comprehensive Disaster Management Programme is a governmental project that seeks to "reduce Bangladesh's vulnerability to adverse natural and anthropogenic hazards and extreme events, including the devastating potential impacts of climate change. It will do so through risk management and mainstreaming... across thirteen key ministries and agencies."<sup>31</sup>

To achieve this goal of effective risk management, the Comprehensive Disaster Management Programme has identified a series of outcomes that must be met:

- Development of strong, well-managed, and professional institutions in Bangladesh that are able to implement a comprehensive range of risk reduction programs and interventions at the national level, as well as contributing to regional actions, international learning, and best practice;
- Reduced risk to rural populations through structural and nonstructural interventions, empowerment of rural communities, and improved awareness of, and planning for, natural hazard events, including the likely impacts of climate change;
- Reduced risk to urban populations through structural and nonstructural interventions, improved awareness of natural hazard events, and the piloting of urban community risk reduction methodologies targeting the extreme poor;
- Improved overall effectiveness and timeliness of disaster preparedness and response in Bangladesh by strengthening management capacity, coordination, and networking facilities at all levels;
- Better disaster proofing of development funding across 13 ministries by generating increased awareness of hazard risks and the provision of technical information, advisory services,

<sup>28</sup>Disaster Management Bureau strategy: <http://www.dmb.gov.bd/strategy.html>.

<sup>29</sup>Disaster Management and Relief Division: [http://www.dmr.gov.bd/index.php?option=com\\_frontpage&Itemid=1](http://www.dmr.gov.bd/index.php?option=com_frontpage&Itemid=1).

<sup>30</sup>Disaster Management Bureau: <http://www.dmb.gov.bd/>.

<sup>31</sup>Comprehensive Disaster Management Programme: <http://www.dmb.gov.bd/cdmp.html>.

and resources to stimulate positive changes in planning and investment decisions over the long term; and

- Effective management of community-level adaptation to disaster risks due to a changing climate.<sup>32</sup>

Bangladesh's central community-based element is the Cyclone Preparedness Programme. In 2009, it consisted of 49,215 cyclone response volunteers based in 13 coastal districts. Using radio networks, megaphones, hand sirens, and public address systems, the volunteers provide the public with the latest weather bulletin information in advance of a cyclone landfall. The volunteers will implement any Bangladesh government evacuation order and direct the public to established cyclone shelters. The volunteer networks also provide rescue, first aid, and emergency relief services.

Finally, Bangladesh has bolstered its national and community-based disaster management approach and institutions with enhanced forecasting capabilities. A grant from the Government of Japan has assisted in upgrading radar systems and establishing a satellite ground receiving station at the Storm Warning Centre, enhancing the capability of the Bangladesh Meteorological Department. In addition, substantial progress has been made in the expansion of flood forecasting and warning services with the help of the Danish Hydraulic Institute.<sup>33</sup>

In addition, extended flood forecasts for up to 10 days have been introduced by Climate Forecast Applications in Bangladesh.<sup>34</sup> These forecasts are now conducted in collaboration with the Flood Forecast and Warning Centre of the Government of Bangladesh<sup>35</sup> and the Regional Integrated Multi-Hazard Early Warning System (RIMES), an intergovernmental and international institution.<sup>36</sup> The forecasts enabled the successful evacuation of habitations along the Brahmaputra twice in 2007 and once in 2008 ahead of major flooding.

### 3.4.3 India: Disaster Management

#### Overview

India is very vulnerable to cyclone impacts, with a coastline of over 7,500 km, a low-lying topography in coastal areas, and high population densities. Of the two (western and eastern) coasts, India is more vulnerable along its eastern seaboard, adjacent to the Bay of Bengal.<sup>37</sup>

#### Disaster Management in India

Because of the country's long history of devastating cyclones, exposed topography, and high population densities in vulnerable areas, India has embarked on a number of efforts to prepare more thoroughly for cyclone landfalls.

The National Cyclone Risk Mitigation Project is a World Bank and Indian government project designed to “minimize vulnerability to cyclones and make people and infrastructure disaster resilient in harmony with the conservation of the coastal ecosystem in the cyclone hazard prone States and Union Territories of India.”<sup>38</sup> The project will achieve this objective through the following measures:

- Strengthening cyclone warning systems by improving the “last mile” connectivity for dissemination of early warnings and advisories from authorities to communities and to receive feedback from communities by the authorities;
- Construction and sustainable maintenance of multipurpose cyclone shelters;
- Construction of connecting roads and bridges;
- Construction of coastal embankments in selected places to stop saline ingress to protect crops, vital property, and populations;
- Shelterbelt plantation and mangrove plantation and regeneration;
- Detailed hazard, vulnerability, and risk assessment studies of coastal districts, provision of technical assistance for preparing high-priority risk mitigation investments, preparation of long-term training and capacity-building strategy, and strengthening institutional capacity for damage and loss assessment; and
- Strengthening community-level preparedness, building the capacity of communities to manage disasters as the first responders, identification of support and other stakeholders and building their capacities for coordinated and systematic response and mitigation measures, and awareness generation regarding preparedness and mitigation measures.<sup>39</sup>

The Indian government's National Disaster Management Authority is charged with implementing the National Cyclone Risk Mitigation Project, and administering related projects. The authority is a coordinating body, headed by the Prime Minister, that integrates disaster response activities across government agencies.

In order to properly implement the National Cyclone Risk Mitigation Project, India put into place the National Policy on Disaster Management in 2005. This comprehensive framework is vertically integrated in that it utilizes institutions at the national, state, and local government levels, as well as communities. The vision of the policy is “to build a safe and disaster resilient India by developing a holistic, proactive, multi-disaster oriented and technology driven strategy through a culture of prevention,

<sup>32</sup>See <http://www.dmb.gov.bd/cdmp.html>.

<sup>33</sup>See <http://www.dmb.gov.bd/practice.html>.

<sup>34</sup>See <http://cfab.eas.gatech.edu/cfab/cfab.html>.

<sup>35</sup>See <http://www.ffwc.gov.bd/>.

<sup>36</sup>See <http://www.rimes.int/>.

<sup>37</sup>See [http://ncrmp.gov.in/ncrmp/Cyclone\\_Impact.html](http://ncrmp.gov.in/ncrmp/Cyclone_Impact.html).

<sup>38</sup>See <http://ncrmp.gov.in/ncrmp/About.html>.

<sup>39</sup>See <http://ncrmp.gov.in/ncrmp/Aims.html>.

mitigation, preparedness and response” (GoI 2009). The policy’s approach consists of the following elements:

- Community-based disaster management, including last-mile integration of policy, plans, and execution;
- Capacity development in all spheres;
- Consolidation of past initiatives and best practices;
- Cooperation with agencies at national and international levels; and
- Multisectoral synergy.

The policy explicitly notes that communities, as first responders, are a significant part of India’s disaster management process. As such, the National Policy on Disaster Management mandates that capacity building in community disaster management capabilities is a central objective.

As for Bangladesh, the Indian approach to disaster preparedness includes a formal forecasting element. The National Policy on Disaster Management states:

“It is most essential to establish, upgrade and modernise the forecasting and early-warning systems for all types of disasters. The nodal agencies responsible for monitoring and carrying out surveillance, for specific natural disasters, will identify technological gaps and formulate projects for their upgradation, in a time bound manner. All States should provide to India Meteorological Department the required infrastructure for upgradation/establishment of meteorological observation systems. Partnership with the World Meteorological Organization (WMO), Pacific Tsunami Warning System and other regional and global institutions may also be considered. [Information and Communication Technologies] ICT tools need to be used for data receptions, forecasting and timely dissemination” (GoI 2009).

### 3.4.4 Sri Lanka: Disaster Management

#### Overview

Sri Lanka is susceptible to cyclones originating in the Bay of Bengal and making landfall on its eastern coast. Many of these continue on over the country and leave Sri Lanka on its western coast.

#### Disaster Management in Sri Lanka

Sri Lanka’s Disaster Management Center (in the Ministry for Disaster Management) was established in 2005 to plan for and coordinate responses to natural disasters, including cyclones. Following landslides and floods in 2003 and the 2004 tsunami, the Government of Sri Lanka recognized that it had to revisit its disaster management approach. The Disaster Management Center is intended to proactively provide risk reduction in advance of natural disasters, and to improve disaster response mechanisms (Government of Sri Lanka 2006). The primary shift in approach that took place was to move from reactive to proactive disaster

management. Under the legislation that established the Disaster Management Center, community-based disaster management approaches are encouraged, as are capacity-building and public awareness elements. As with Bangladesh, Sri Lanka is adopting a volunteer response system to aid its community response efforts. The approach uses a hierarchy of committees for planning and information dissemination at provincial, district, divisional, local, and village levels (Government of Sri Lanka 2006). As part of its risk communication strategy, the Disaster Management Center uses media outlets, phones, and early warning towers to provide information to communities.<sup>40</sup>

### 3.4.5 Myanmar: Disaster Management

#### Overview

As a result of its lengthy coastline along the Bay of Bengal, Myanmar is vulnerable to damaging cyclone impacts. The country had an estimated population of 56 million in 2007 (ADPC 2009). While the country is made up of a number of geographic zones, the coastal areas – the Arakan coastal lowlands – are densely populated and susceptible to cyclone landfalls, storm surges, and coastal flooding. The tidal Ayeyarwady delta is very exposed to cyclones and storms approaching from the southwest (the track of most cyclones that impact Myanmar). Between 1968 and 2008, six major cyclones hit Myanmar: Sittwe (1968), Patheingyi (1975), Gwa (1982), Maungdaw (1994), Mala (2006), and Nargis (2008) (ADPC 2009).

#### Disaster Management in Myanmar

Myanmar has a disaster management plan: the Action Plan on Disaster Risk Reduction, Preparedness, Relief, and Rehabilitation. It contains the following objectives (ADPC 2009):

- To formulate a program or action plan for DRR in a consolidated manner;
- To carry out search and rescue activities in a speedy manner in the aftermath of disasters and organize mock drills for improved disaster response;
- To undertake reconstruction and rehabilitation activities systematically; and
- To protect the resources of the nation effectively from disaster.

Under the action plan, Myanmar has instituted disaster management committees at various governmental levels, including the village tract level (a village tract comprises a number of villages). However, it is unclear as to the level of community engagement that takes place under the plan. The plan stipulates that the committees should “educate people on disaster preparedness & organize and implement programs for improvement to motivate people” (ADPC 2009). This aside, the plan seems to be a top-down disaster management model.

<sup>40</sup>See [http://www.dmc.gov.lk/A3\\_EarlyWarning.htm](http://www.dmc.gov.lk/A3_EarlyWarning.htm).



The plan calls for risk communication to take place through a number of formats, with the following aims:

- To educate people on disaster preparedness by various means, such as school curricula, printed media, television broadcasting, and radio transmission;
- To disseminate information to relevant communities during different phases, namely, before, during, and post disaster, and to release news after verification;
- To disseminate information on hazard-prone areas and communicate forecasts on likely situations; and
- To make arrangements for the timely communication of necessary disaster news and information to people in disaster-prone regions through printed materials, airplanes and helicopters, and radio broadcasts.

For the most part, however, cyclone warnings occur through radio and television. The local committees then provide guidance to local populations on preparedness measures. These measures are still influenced, nevertheless, by representatives from the central government: “Such operational measures are usually carried out at the township or district hit by any natural disaster, and at the same time the responsible personnel from the National Disaster Prevention, Relief, and Rehabilitation Committee come to the site immediately in order to give necessary instructions.”<sup>41</sup>

Myanmar does have some weather forecasting capability, although it has little or no numerical weather forecasting capability. The integration of Myanmar’s forecasting capability with its risk communication scheme is described as follows:

“Tropical cyclones surveillance and tracking works were effectively done after the installation 10 cm WSR 74 S Type Radar at Kyaukpyu in 1979 and of Automatic Picture Transmission (APT) System to obtain imageries from Meteorological Satellite Network at Kaba-Aye in 1973. Timely Storm Warnings are issued by the Department of Meteorology and Hydrology (DMH) and announcement to public is made through Myanmar Television and Broadcasting Station. The Department had developed an analytical and empirical prediction model for Storm Surge during 1980. In 1986, the prediction model was modified to predict not only the maximum surge height but also the surge envelope for the respective land fall point along Myanmar coast. However, in the absence of the direct observations of the storm parameters, reliable source of data and a better competing facilities, the method used recently in DMH will provide a valuable first guess for the prediction of Storm Surge within acceptable accuracy.”<sup>42</sup>

Unfortunately, most of these goals were not attained during the advent of Cyclone Nargis. As noted earlier, no surge forecast was made, and forecasts of wind and precipitation were inadequate.

### 3.5. Critical Evaluation of Current Tropical and Severe Local Convective Storm Forecasting

The complex meteorological and socioeconomic environment throughout the North Indian Ocean, and particularly in the Bay of Bengal, necessitates a warning system that provides several days of advance notice for tropical cyclone formation, movement tracking, intensity change, horizontal distribution of surface winds, and maximum coastal wave heights. Long lead times are necessary to allow the evacuation of large populations in hazardous regions with, often, only basic transportation systems and infrastructure. All of these requirements are fundamental to fuel the DRR systems developed by countries, as discussed extensively above.

To facilitate tropical cyclone forecasts, the WMO has designated six regional specialized meteorological centers (RSMCs)<sup>43</sup> across the global tropics to facilitate the forecasting of tropical cyclones. The RSMC that has responsibility for the North Indian Ocean is operated by the IMD.<sup>44</sup> However, the WMO only requires a small subset of this critical forecast information to be generated daily. In its RSMC capacity, the IMD provides the official forecasts and warnings for tropical cyclones.

The following observations may be made on the role of the IMD, as mandated by the WMO:

- The IMD RSMC is required to coordinate and release its forecasts daily to each member country within the North Indian Ocean. However, ultimate responsibility for forecast development and warning dissemination lies with each country’s national meteorological service;
- As part of the daily operational procedure, when a tropical cyclone is not present in the region, the IMD is required to prepare a daily tropical weather outlook, which assesses the possibility of tropical depression development in the Bay of Bengal and the Arabian Sea. Unlike the United States National Hurricane Center’s Tropical Weather Outlook, which provides the likelihood of tropical cyclone genesis during the next 48 hours (Rappaport et al. 2009), the WMO provides no time requirement for this outlook product, as the time period that is covered by this forecast is determined separately by each RSMC. In addition, the product does not provide any quantitative, probabilistic information about the potential for tropical cyclone formation;
- After a tropical cyclone has formed in the North Indian Ocean, the IMD begins issuing advisories that contain information about the cyclone, including its past movement, current location and intensity, and forecast information with

<sup>41</sup>See [http://www.adrc.asia/management/MMR/Myanmar\\_dm\\_program.html?Frame=yes](http://www.adrc.asia/management/MMR/Myanmar_dm_program.html?Frame=yes).

<sup>42</sup>See [http://www.adrc.asia/management/MMR/Myanmar\\_dm\\_program.html?Frame=yes](http://www.adrc.asia/management/MMR/Myanmar_dm_program.html?Frame=yes).

<sup>43</sup>See <http://www.wmo.int/pages/prog/www/tcp/Advisories-RSMCs.html>.

<sup>44</sup>See <http://www.imd.gov.in>.

regard to its future location, translation speed, wind intensity, maximum average surface wind speed, and highest surface wind gust. However, the WMO only requires that these tropical cyclone advisories and forecasts extend out to three days in the North Indian Ocean, even though most numerical guidance for tropical cyclone forecasting today spans a full five-day forecast window. As the average lifetime of a tropical cyclone in the North Indian Ocean is about four days, these limited outlooks do not provide enough leadtime for disaster preparation or evacuation;

- Also, even though this region has historical experience of devastating impacts from tropical cyclone-induced storm surges in the Bay of Bengal, the IMD does not produce storm surge forecasts, as these remain the responsibility of each country's national meteorological service. Unfortunately, many countries in the developing world do not have the capacity to make storm surge forecasts based on the numerical forecasts of the IMD. At best, based on the broad guidance from the IMD RSMC, empirical or statistical forecasts of cyclone-induced surges are made by regional countries. A case in point here regarding the limitations of this approach is the Myanmar response to Cyclone Nargis, discussed in detail above; and
- Until 2010, the JTWC tropical cyclone forecasts, often used as advisories by the IMD and regional countries, only produce forecasts up to three days. In 2010, these advisories were extended to four days. However, no forecasts of the genesis of tropical cyclones are made by either the IMD or the JTWC. Instead, forecasts are only made once there is observational evidence of a developed tropical system (Figure A3.3).

Both the IMD RSMC and JTWC produce only “deterministic forecasts” and do not take advantage of the ensemble-based approach. A deterministic forecast requires that the numerical

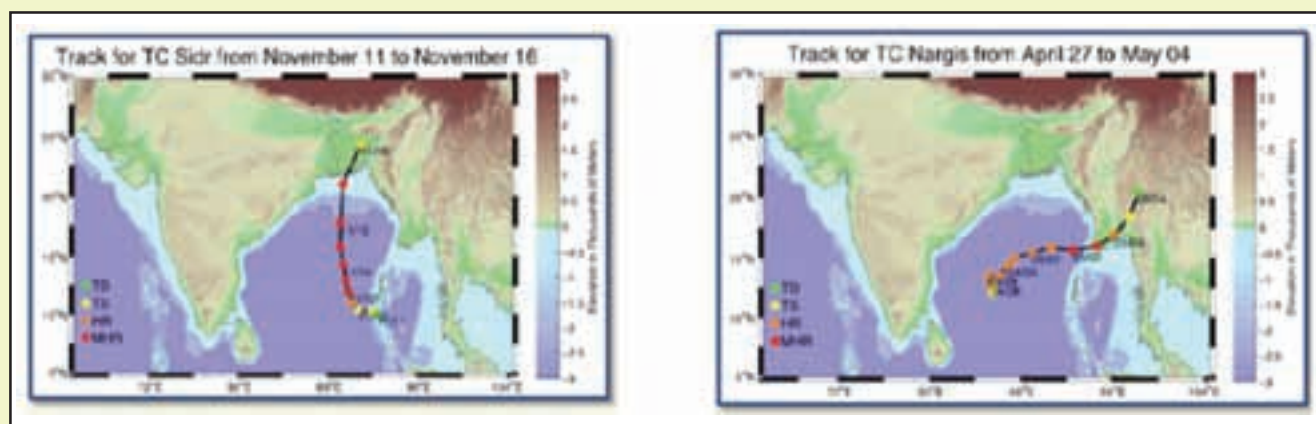
model be run just once, relative to a set of initial conditions. Advanced numerical weather systems (for example, the European Centre for Medium-Range Weather Forecasts (ECMWF), the U.S. National Center for Environmental Prediction, and the U.K. Meteorological Office) run models in ensemble mode, where the model is run multiple times with a perturbed set of boundary conditions or model physics. The ECMWF, for example, runs its global model 51 times twice per day. The ensemble approach is to test the uncertainties in the model and the initial data. From these computations, sets of 15-day forecasts are made. Most importantly, the use of ensembles allows the probability of an event occurring to be determined.

In addition, a central advantage of the probabilistic forecast made through an ensemble approach is the ability to determine the potential cost involved. If the cost of occurrence of an event is known (for example, the potential damage to a village, institution, industry, and so on) then the risk of an event can be determined, as risk is the product of probability and cost.

The current system used across the Bay of Bengal region fails to provide tropical cyclone forecasts with a long enough leadtime, nor with the probability of where and when the system will make landfall, and how strong it will be. Simply, the current forecasts fail to supply the national disaster reduction systems with sufficient information to be effective.

Currently, there does not exist an established forecasting strategy for severe local convective storms. At best, utilizing extended weather predictions makes it possible to denote that a region, during the next few days, may possess a higher risk of flash flooding. A number of countries (for example, Bangladesh) have networks of doppler radars. They are useful at this stage for aiding “now-casting,” which is the determination of where severe convective storms are occurring.

**Figure A3.3: JTWC Tracking of Cyclone Sidr and Cyclone Nargis**



The JTWC tracks of TC Sidr (left panel) and TC Nargis (right panel). Tracks start at the time of the issuance of a tropical storm advisory on November 11, 2007 and April 27, 2008, respectively. These dates denote when the IMD RSMC commenced their three-day numerical forecasts. Colors denote the observed intensity of the tropical cyclone.

### 3.6. Use of Extended Probabilistic Cyclone System in the Bay of Bengal

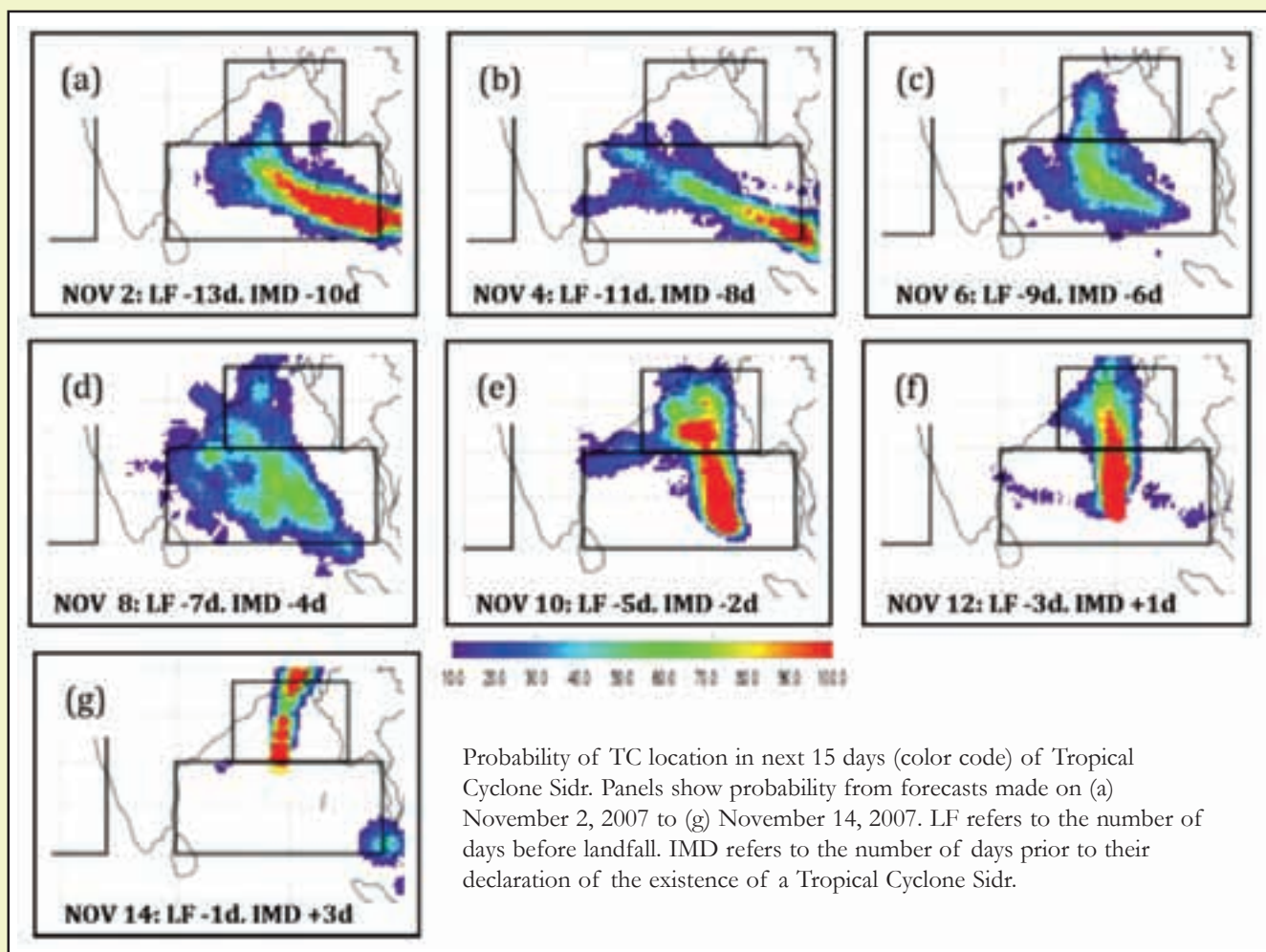
In this section, examples are given of the use of a probabilistic forecast system for tropical cyclones Sidr and Nargis, as discussed earlier in the text. The observed tracks of the two systems are shown in Figure A3.3. The first tropical storm advisory for Cyclone Sidr was given by the IMD RSMC on November 11, 2007, and landfall took place four days later on November 15. For Cyclone Nargis, the first IMD tropical storm advisory was given on April 27, 2008, six days before landfall in Burma on May 2.

Figures A3.4 and A3.5 show 15-day forecasts (initialized on the date in each panel), and the probability of a tropical cyclone occupying a particular area in the Bay of Bengal during that period for Cyclone Sidr and Cyclone Nargis. The probabilities are color coded relative to the color bar on each figure. The probability is deduced from forecast tropical cyclone tracks of the 51 ensemble members of the ECMWF model initialized on the date shown in each panel.

**Cyclone Sidr.** The IMD recognition date of Cyclone Sidr was November 11, 2007 (between panels e and f of Figure A3.4). However, the ECMWF ensemble system was suggesting a strong probability of mid-Bay of Bengal development nine days before the IMD designation and 13 days before landfall in Bangladesh (each panel is two days apart). By November 6, the probability of Bangladesh landfall had steadily increased as the tropical cyclone was forecast to recurve into the head of the bay. Clearly, the ECMWF system shows extended predictability of tropical cyclone formation and landfall, outperforming the IMD system by well over a week.

**Cyclone Nargis.** The IMD recognition date of Cyclone Nargis was April 27, 2008. But the ECMWF extended prediction system showed, as early as April 22, that there was a strong probability of landfall near or in Myanmar. Thus, given that the IMD recognition date also identified the time of formation of Nargis, the ECMWF system was showing a high probability of formation of the tropical cyclone six days before formation.

**Figure A3.4: Probability Forecasts for Cyclone Sidr**





In summary, the ECMWF system shows that there is exceptional predictability of North Indian Ocean tropical cyclones, far greater than experienced in the North Atlantic and somewhat longer than in the western Pacific. Furthermore, based on the evaluation period from 2007 to 2010, the ECMWF variable ensemble prediction system (VarEPS) for tropical cyclones demonstrates low false alarm rates and moderate-to-high probabilities of detection for leadtimes of one to seven days (Belanger, Webster, and Curry 2011).

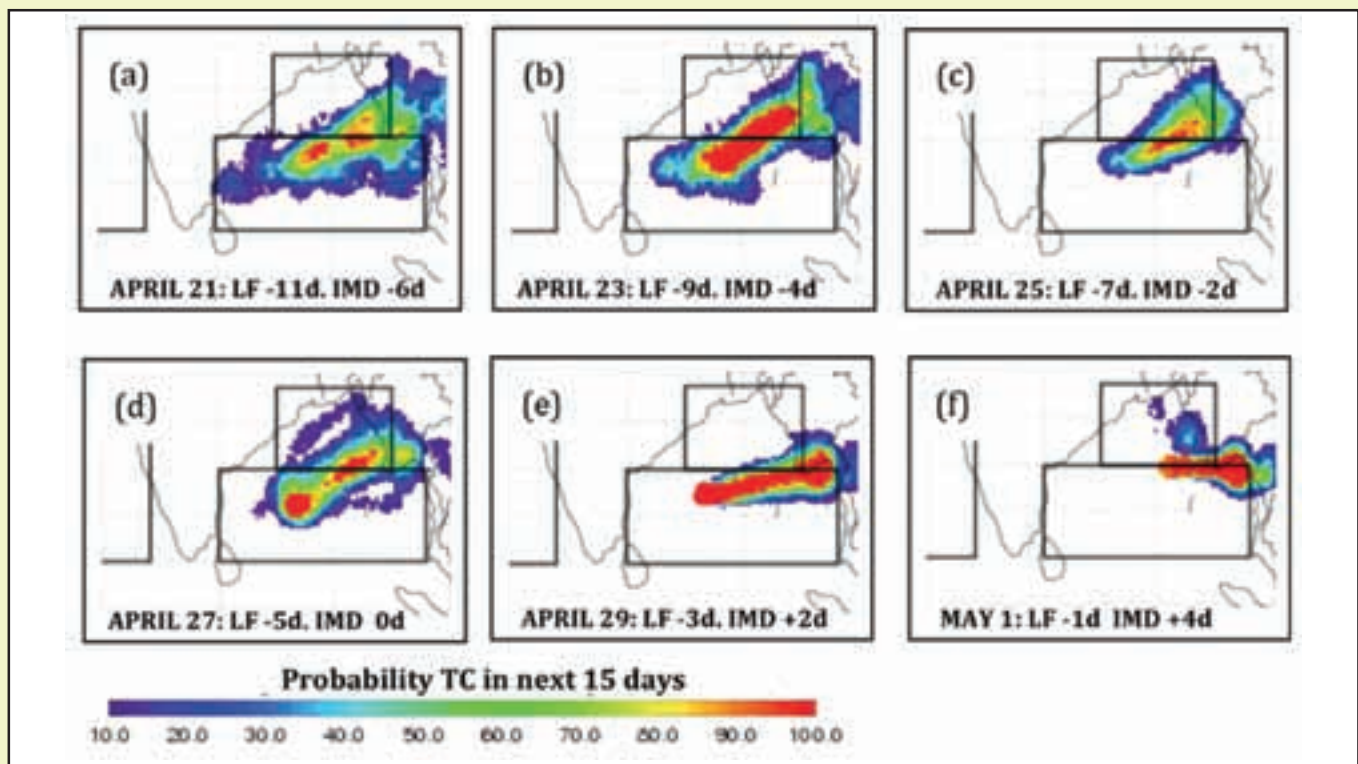
Finally, is predictability feasible at longer time scales? It has been shown that technical capability exists on the 30-day timescale, at least in the Atlantic Ocean, with accuracy depending very much on the phase of the intraseasonal variability in the Madden-Julian oscillation (Belanger, Curry, and Webster 2010). The analysis uses the ECMWF 30-day ensembles generated each week. Given that the maximum variance on intraseasonal variability occurs in the Indian Ocean, there is an intriguing possibility that predictability of these exist at extended time scale. Finally, there appears to be strong modulation of seasonal tropical cyclone activity in the North Atlantic Ocean (Kim, Webster, and Curry 2009) and the western Pacific Ocean (Kim, Webster, and Curry 2011) by the different forms that El Niño can take. El Niño and its form

(central or eastern warming) are predictable in advance of both the spring and fall tropical cyclone seasons. A natural extension of the two studies is to see if there is seasonal predictability in the North Indian Ocean by prediction of the form of the El Niño southern oscillation.

### 3.7. Bay of Bengal Tropical Cyclones and Climate Change

During the last 40 years, there has been considerable evidence that the intensity of tropical cyclones is increasing (Webster et al. 2005; Emanuel 2005). These analyses, conducted since satellite data have become available, show a consistent increase in tropical cyclone intensity over most of the tropical oceans. These increases in intensity are attributable to increases in sea surface temperature, consistent with increased concentrations of anthropogenically produced greenhouse gases in the atmosphere (Hoyos et al. 2006). Re-examination of satellite data has confirmed that an increase in intensity has indeed occurred and that the basin with the largest increase in intensity of tropical cyclones is the North Indian Ocean (Elsner and Kossin 2007).<sup>45</sup> Figure A3.6 shows the increase in intensity in the North Indian Ocean since 1980.

**Figure A3.5: Probability Forecasts for Cyclone Nargis**

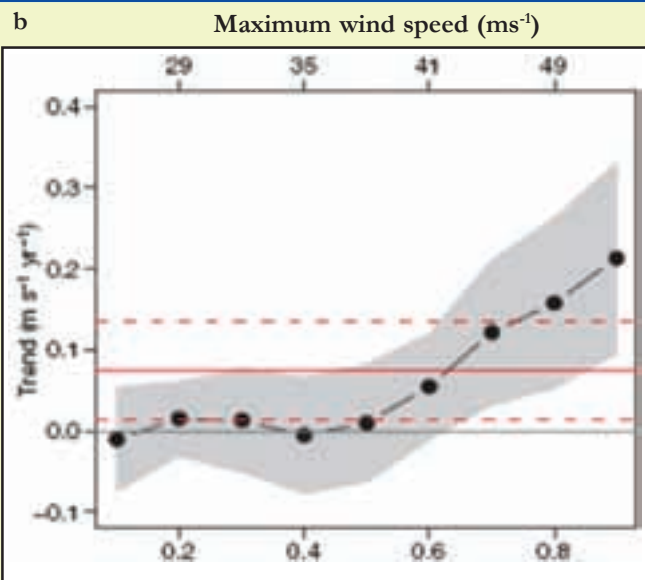


Probability of TC location in next 15 days of Tropical Cyclone Nargis. Panels show forecast probability from forecasts made on (a) April 21, 2008 through (f) May 1, 2008. LF refers to number of days before landfall. IMD refers to the number of days prior to the declaration of the existence of Tropical Cyclone Nargis.

<sup>45</sup>Elsner, James B.; James P. Kossin, Thomas H. Jagger, 2008: The increasing intensity of the strongest tropical cyclones. *NATURE*, 455, 7209, 92-95 DOI: 10.1038/nature07234.



**Figure A3.6: Trends in Intensity of Tropical Cyclones in North Indian Ocean**



Trends in tropical cyclones of various intensity in the North Indian Ocean (left weak, right very strong) since 1980. Major tropical cyclones (categories 4 and 5) have increased substantially during the last 30 years. The North Indian Ocean shows the largest trend. Red dashed lines indicate 95 percent significance. From Elsner and Kossin (2007).

Using the 1970–2010 period as a base, it is projected that the intensity of tropical cyclones in the North Indian Ocean will continue to increase through the 21st century. As discussed previously, the consequences of tropical cyclone activity can be dire for current conditions of climate and population in the Bay of Bengal region. With the prospect of increasing sea level, stronger tropical cyclones, and an increased population, the interaction of tropical cyclones and society could become significantly worse.

However, assuming that sea level rise and tropical cyclone intensity increases are gradual, there are steps that can be taken to prepare populations in peril as hazards increase. In Bangladesh, for example, the return time of major slow-rise floods of duration greater than 10 days is about a decade. Thus, each generation may expect to experience such a major flood perhaps twice. During the coming century, the return period of 10-day floods may half (Webster and Jian 2011). Similarly, in the coastal regions, return times of major tropical cyclones may also decrease. But this is why the building of a strong disaster reduction system (combining modern prediction techniques with planned responses) is so important. Simply, societies that have learned to mitigate the impacts of hazards in the present climate will prove to be most resilient to changes in climate during the next century.

### 3.8. Conclusions and Recommendations

Due to both demographic and physical factors, a tropical cyclone in the Bay of Bengal has the potential of causing great harm to the countries of the region. Bay of Bengal tropical cyclones are only a small percentage of the global number of tropical cyclones generated each year, but they have proven to be the most deadly in the total number of deaths they cause.

Because of the potential harm, regional countries of the Bay of Bengal have developed disaster reduction plans that use forecasts of impending landfalls of weather systems as the basis for specific warnings and actions. However, irrespective of how complete the disaster reduction response program is and how well the warning is communicated to the village level, the success of the strategy depends on the leadtime of a reliable forecast. Yet, current practices in the North Indian Ocean rely on forecasts of just three days in advance, the shortest lead time of any tropical cyclone forecast system on the planet. Unfortunately, because of logistical problems associated with evacuation and communication, the forecast leadtime in the developing world must be longer than the current three days.

In the following paragraphs some specific recommendations are made regarding best practices for forecasting and disaster reduction. In addition, suggestions are made about how these recommendations may be implemented. Further, recommendations are made about developing a forecast capability for tropical weather systems.

#### Recommendation 1: Upgrading of Tropical Cyclone Forecast System

In order to provide a greater lead time for forecasts for the Bay of Bengal and produce a more useful forecast product, the following measures are suggested:

- 1.1 Increase the lead time of tropical cyclone forecasts.** It is imperative that the Bay of Bengal region has access to modern extended tropical cyclone forecasts rather than those that are currently produced by the current North Indian Ocean RSMC managed by the IMD. High-resolution forecasts are available up to 15 days, and it has been shown that accuracy is feasible in tropical cyclone forecasts upto 10 days in advance and often well before genesis occurs (Belanger, Webster, and Curry 2011).
- 1.2 Increase the content of the forecasts.** The current three-day forecasts do not include storm surge forecasts, although surges are the prime cause of tropical cyclone deaths. At present, individual countries are responsible for the provision of storm surge forecasts, yet they do not have access to numerical data on which to base those forecasts.

**1.3 Produce probabilistic forecasts.** The current forecasts are deterministic (based on only one forecast each day). Modern numerical forecasting techniques use multiple integrations to determine the probability of track, intensity, and landfall, providing the basis for extended range forecasts. Only with probabilistic forecasts can the risk of an event occurring in a particular place, at a particular time, and with a certain intensity be calculated.

**1.4 Provide genesis forecasts.** The WMO, IMD, and JTWC should be encouraged to adopt procedures to forecast the genesis of tropical cyclones. Currently, these organizations do not commence forecasting until the identification of a tropical storm or tropical cyclone from observations. CFAN forecasts both genesis and postgenesis tracks and probabilities, as indicated in Figures A3.4 and A3.5.

### Measures to Accomplish the Recommendations

- It is suggested that the WMO encourage the IMD to use forecasting techniques that conform to at least the five-day standard used in most of the world;
- There should be an annual regional meeting to discuss best forecasting practices, perhaps organized by the WMO;
- Alternatively, a second forecasting product could be made available to the region. For example, RIMES, the international and intergovernmental center, receives the ECMWF VarEPS forecasts each day. Using the CFAN tropical forecasting techniques, RIMES is capable of producing forecasts with a 10–15-day lead time. The RIMES/CFAN/ECMWF forecasts could be offered as an additional product for the Bay of Bengal regional countries. RIMES currently has 29 member countries and strong associations with the national meteorological organizations in all of the countries fringing the Bay of Bengal. World Bank funding of this effort could be worthwhile;
- National meteorological and hydrological services require an interface institution to transform probabilistic forecasts into country-specific potential impact outlooks. This would enable the national services to provide user-friendly forecast information so that users could formulate response options well ahead of time. RIMES could perform this function initially and transfer this capacity to each member nation gradually; and
- Surge forecasts should be made at a central location (for example, IMD or RIMES) and disseminated to all countries of the region. If not, then numerical data from the forecast model should be disseminated to regional countries as the basis for producing in-country forecasts.

In summary, the RSMC concept that one organization makes regional forecasts has merit. Thus, either the WMO mandate for an RSMC must change to accommodate modern prediction

practices or another organization needs to be developed to render and disseminate forecasts of tropical cyclones made from the leading numerical prediction centers in the world (for example, the ECMWF, the U.K. Meteorological Office, the U.S. National Oceanic and Atmospheric Administration, or the U.S. National Center for Environmental Prediction).

### Costing

The technology for extended-range probabilistic forecasting already exists and is used experimentally in the North Indian Ocean by CFAN. The CFAN system uses the ECMWF forecasts as a base that is statistically rendered to produce 15-day forecasts twice per day. The highest-resolution data are not used in the experimental product and this would have to be purchased from ECMWF. In addition, CFAN uses a manual interface in producing the web-based forecasts. Some development work would have to be done to produce storm surge forecasts:

- Basic high-resolution twice per day 15-day forecasts with a dashboard web interface: US\$350,000 per year for four years;
- Data purchase: US\$50,000 per year;
- Development work for storm surge forecast: US\$75,000 per year for four years; and
- Daily forecast analysis and web-based written report: US\$50,000 per year.

This costing would also include forecasts of Arabian Sea tropical cyclones.

### Schedule

The base forecasts (one to 15 days twice per day) could be set up immediately. A storm surge module could be in place within a year.

### Hardware and Location

Currently, sufficient computer hardware exists at IMD, RIMES, and CFAN. Model development and experimental forecasts can be done at CFAN, for example, and transferred as a complete product to RIMES or the IMD within a year.

## Recommendation 2: Improvement of Regional DRR Strategies and Risk Communication Systems

DRR strategies and risk communication systems have been described for each of the Bay of Bengal countries. They vary in adequacy from country to country. Even those that are well established (for example, Bangladesh) are limited by the leadtime of the tropical cyclone forecasts. Assuming that Recommendation 1 is accomplished and the leadtime of the forecasts is extended and probabilistic forecasts are produced, there are certain improvements to DRR strategies and risk communication systems that can be accomplished. Approaches toward this improvement are listed below:

- 2.1 Evaluation of DRR programs.** A study is required to evaluate the effectiveness of DRR programs and their implementation in each of the countries located along the Bay of Bengal. The evaluations should identify best practices in DRR programs, as well as gaps in each country's programs and implementation practices.
- 2.2 Identification of strengths and weaknesses.** Given that ultimate responsibility for forecast development and warning dissemination lies with each country's national meteorological service, an evaluation of the effectiveness of each country's forecast development services is required, with an aim to identify strengths and weaknesses and disseminate findings and recommendations, while still acknowledging the individual differences between countries.
- 2.3 Develop transnational DRR strategies on a regional basis.** Given the common social, geographic, communication, and economic conditions that exist in cross-boundary locations, for example, the Sundarbans, a corresponding international DRR strategy and risk communication system would help in formulating a transboundary response to natural disasters.

## Measures to Accomplish the Recommendations

- Holding an annual regional workshop for representatives from Bangladesh, India, Myanmar, and Sri Lanka would help to identify approaches toward addressing gaps in DRR programs and implementation;
- A critical goal of the workshop would be matching DRR strategies and risk communication systems with the constraints of the forecast; and
- Plans should be developed for cross-boundary DRR strategies and risk communication systems.

## Costing

RIMES has 29 member countries and strong ties with national weather and hydrological services. Its members include the countries considered in this study: Bangladesh, India, Myanmar, and Sri Lanka. Bhutan and Nepal, both subject to severe convective events and flash floods, are also member countries, as is Pakistan. Given this representation, RIMES seems to present an ideal venue for a regional meeting and, at the same time, is qualified to conduct a survey of disaster management plans and make recommendations to improve, homogenize, and integrate the national plans. In particular, due to its international nature, it would seem wellplaced to assist development of transboundary plans, for example, between India (West Bengal) and Bangladesh in the Sundarbans.

Meeting and development costs are estimated at around US\$100,000 per year for five years.

## Location

RIMES, Bangkok, Thailand.

## Recommendation 3: Development of a Severe Convective Storm Forecasting Capability

A second form of destructive regional hazard, besides the tropical cyclone, was identified: the pre-monsoonal severe local convective event associated with mesoscale convective clusters. These events, almost equal in number to the tropical cyclone incidence, produce enormous damage and loss of life through associated flash floods and mudslides. Little attention has been given to the forecasting of these phenomena. Yet the tools (very high resolution numerical weather models) and necessary data (satellite and doppler radar) may be available to at least produce short-term probabilistic forecasts of these convective events. Both Bangladesh and Nepal place the development of a flash flood warning system as a very high priority.

The following measures are recommended:

- 3.1 Development of a climatology of severe convective events and flash floods.** The development of a detailed climatology of mesoscale convective clusters and their associated impacts should be encouraged. The use of doppler radar in Bangladesh, India, and Nepal should be central to the development of conditions conducive for their formation.
- 3.2 Basic prediction research.** Basic research into the forecasting of mesoscale convective clusters should be supported. Such forecasts should eventually be included in the forecasting and warning systems of the countries fringing the Bay of Bengal, although it is realized that, at best, the forecast will be regional and probabilistic.

## Costing

- Archiving of doppler radar and satellite data: US\$100,000 per year for five years;
- Development of mesoscale model and incorporation of data: US\$300,000 per year;
- Development of a web interface dashboard for visualization of the data and model output: US\$100,000; and
- Training of local meteorological agencies in the use of these data: US\$50,000 per year for two years.

## Location and Hardware

It is doubtful whether the complete data from the doppler radars in Bangladesh and Nepal have been archived. It is unlikely that either of these countries has the hardware capacity to archive these data or incorporate them into a high-resolution mesoscale

model. There are likely to be substantial information technology (IT) costs. It is recommended that initial research and model development take place either at CFAN or RIMES, with an eventual technological transfer at a later date.

## Recommendation 4: Study of Tropical Cyclones and Climate Change

Figure A3.6 provided convincing evidence that, during the last 30–40 years, in concert with warming sea surface temperatures, tropical cyclones have increased in intensity. Consideration of a number of models developed by the Intergovernmental Panel on Climate Change (IPCC) suggests that this increase will continue through the 21st century (Knutson et al. 2010). Given that this increase in intensity will probably coincide with a rise in sea level in the low-lying deltas around the Bay of Bengal and a substantial increase in population, a first priority will be the determination of the impact of these more intense tropical cyclones.

**4.1 Impact study.** It is recommended that a study be commissioned to determine what these impacts might be, how risks may change in the coming decades, and what type of mitigation measures may be necessary. Such a study may be of service for long-term national disaster planning, guiding the construction of levees and tropical cyclone shelters and their optimal location.

### Costing

Most information that exists about future climate comes from the IPCC model simulations. The latest iteration (version 5) contains simulations of sufficient resolution to identify and track tropical cyclones. Also, it is possible to nest much higher resolution mesoscale models of the Bay of Bengal region into these models. It is recommended that there are two parts to the suggested impact study: first, an examination of the IPCC simulations to determine the frequency and intensity of tropical cyclones in the future; and second, a series of workshops in which these findings would be integrated with other studies of future sealevel rise and changes in slow-rise floods (for example, Webster and Jian 2011)<sup>46</sup> with the aim of developing mitigatory strategies:

- Basic study of changes in tropical cyclone intensity and location: US\$250,000 per year for four years; and
- Regional workshops: US\$50,000 per year for five years.

### Location and Hardware

Much of the model output examination would have to be done where there is significant IT support, principally because of the sheer volume of the data. Furthermore, if model nesting is deemed necessary, this would also have to be done remotely.

However, regional input is critical and it is suggested that funding should accommodate partnerships with scientists in the developing world.

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# Annex 4.

## Disaster Risk Management for Addressing Immediate Needs<sup>1</sup>



### Abstract

The inhabited areas of India's Sundarbans are characterized by severe poverty, which both contributes to and arises from the vulnerability of the populations to a growing range of natural hazards. Resilient systems are those that have a capacity to adapt when faced with persistent stresses, but the adaptive capacity of those residing in the Sundarbans has been undermined on an ongoing basis. Isostatic sea level rise, saltwater intrusion, flooding, and nutrient loss in local soils have all conspired over the past century to render this one of the most hazardous areas in the Indian subcontinent. Ironically, the embankment system, initially constructed to protect these inhabitants, has itself become a liability: it provides a false sense of security while being increasingly prone to erosion and failure in the face of multiple stresses. Natural stresses have been recently compounded by stresses due to human activity, which include reductions in freshwater flows and an expansion in tidal water aquaculture. The future will provide no respite: eustatic sea level rise coupled with predicted increased storm intensity will further increase hazards to local residents. This annex describes the interventions necessary to reduce the threats and manage risks with a view to building the adaptive capacity of local residents. The interventions described here include: (a) long-term *threat reduction through estuary management* commitments such as embankment realignment, mangrove restoration, and salinity management; and (ii) near-term *disaster risk management* interventions such as early warning systems, emergency preparedness, and cyclone shelters. These interventions are not intended to provide a permanent solution. They will, however, provide a significant and essential added measure of safety to the residents of the Sundarbans over the next 50-plus years during which human capacity can be built through targeted programs of poverty reduction and livelihood enhancement. Ultimately, however, the intent is that much of the transition zone between the natural Sundarbans mangrove forest and the more stable inland areas of the mature delta will be depopulated.

### 4.1. Introduction: Adaptation and Climate Change in India's Sundarbans

The specter of climate change is seen by many as a significant potential threat to the welfare of the over 4.4 million inhabitants of India's Sundarbans. And indeed it is. But even in the absence of future climate change impacts, development prospects in the Sundarbans are constrained by a basket of hazards that include a mix of natural and human-induced phenomena (Table A4.1). The inhabitants of the Sundarbans have been living with extreme weather events, rising sea levels, changing natural environments, and other stresses for centuries. Lifestyles and livelihoods have been regulated by the monsoons, floods, and tropical cyclones since the area was first settled. The protective system of embankments has been in place since the 19th century, and has permitted the establishment of sedentary livelihoods relying on long-term cropping patterns. Even the mangrove system itself has survived some 100 m of sea level rise over the past 10,000 years as it slowly shifts and adapts to changing geomorphology. Through all of this change, the people, their cultures, and their habits have adapted to permit ongoing survival within an inherently hostile realm.

More recently, human interventions have contributed to salinization as rivers have been diverted, and to severe erosion as tidal-based aquaculture has expanded far from the Bay of Bengal. Ironically, the one historical intervention that was intended to protect people – the 4,000-km system of ring embankments around various islands – may also have become one of the greatest liabilities. Its protection attracted people to the area, while also preventing natural geomorphological adaptive processes from sculpting the delta. As a consequence, the area termed here as the “transition zone” has become one of the most unstable and riskiest areas to settle in. It finds itself between two relatively stable areas: one is the natural Sundarbans forest, which has been largely free of massive

<sup>1</sup>This Annex was prepared by Jack Ruitenbeek based on stand-alone reports and notes prepared by John Pethick and Jack Ruitenbeek.

intervention and has adapted continuously to geomorphological shifts and sea level rise; the other is the more mature and stable inland delta, which — through natural sedimentation trends and human efforts — is a less hostile and risky area for human settlement. This study seeks to summarize the nature of the hazards and risks, including those associated with anticipated climate change.

Within a risk management framework, the study identifies how a combination of direct long-term threat reduction investments and immediate DRM efforts can combine to build the resilience of the local population. Threat reduction efforts focus on estuary management, which includes embankment realignment interventions complemented by restoration of mangrove bioshields; some interventions can also mitigate impacts of saltwater intrusion. DRM interventions focus on early warning systems, emergency preparedness, and cyclone shelters. The study also describes various alternative options that were considered, and — for the most significant investments — also provides complementary economic analyses to guide investment decisions and priorities relating to embankment realignment.

## 4.2. Risk Management, Climate Change, and Adaptation

Humanity has always faced natural hazards, taken risks, and adapted. But what is so different now in the new order of “climate change?” In fact, there is nothing that is different about the hazards except the time scales and absolute magnitudes of change. Storms are becoming more frequent and severe. Regional sedimentation patterns have become more complex because of human intervention in major river basins such as those of the Ganges and the Brahmaputra. Sea level rise from thermal expansion of the oceans will also accelerate the historical geomorphological trends, contributing to moderate but persistent subsidence of much of the Sundarbans system. Most significant perhaps is the magnitude

of the linkages between the physical environment and expanding human population: mangroves have been cleared, river courses have been altered, and water requirements for agriculture and aquaculture have altered hydrology and contributed to salinization. Also, the old embankment system — while protecting inhabitants and their assets — has itself changed natural adaptive processes and created disequilibria, which are now weakening these same embankments. Coupled with all of this is the fact that inhabitants remain among the poorest people in the region; their means for ongoing adaptation are limited, the risks are rising, and potential social, cultural, and personal impacts are now at a scale that could never have been imagined just a century ago.

Fundamentally, the required policy response to this situation falls into the realm of one of the most complex DRM exercises ever undertaken in the region. Although DRM traditionally addresses emergencies and hazards through various specific interventions, the modern toolkit of DRM is much more comprehensive. Indeed, according to the United Nations Framework Convention on Climate Change (UNFCCC), DRM now potentially encompasses every possible adaptation and mitigation measure that might be undertaken in response to climate change in the next century. This position is echoed by other United Nations agencies responsible for disaster reduction (UNISDR Secretariat 2004; see also Sperling and Szekely 2005):

Disaster risk management tries to address hazard risks as an integral part of development. Consequently, it is less events and more process focused. It is based on a continuous assessment of vulnerabilities and risks and involves many actors and stakeholders, such as governments, technical experts and local communities (UNISDR Secretariat 2004).

The World Bank also acknowledges, through its DRM work, that modern DRM strategies must include a comprehensive set of interventions, and that DRM is as much an ongoing process

**Table A4.1: Summary of Hazards in the Sundarbans**

Iss	Magnitude
Isostatic sea level rise	Localized sinking of the delta causes an implicit annual sea level rise of 3–8 millimeter (mm) depending on location, translating to 30–80 centimeter (cm) per century
Eustatic sea level rise	Global thermal expansion of the oceans from climate change is forecast to result in up to 59 cm of sea level rise in the coming century
Cyclonic storms	The region experiences about nine cyclonic storms every decade, with a third classified as “severe;” these are expected to increase in energy intensity by 15 percent over the coming century
Saltwater intrusion	All 19 blocks of the Sundarbans have seen persistent saltwater intrusion, which limits drinking water availability and decreases soil fertility
Tidal flushing from aquaculture	Inland tidal aquaculture over expanses of more than 40,000 ha creates a daily tidal flushing, which erodes embankments and channels seaward
Embankment undercutting and channel erosion	Historical embankment alignments have prevented natural geomorphological processes from creating wider channels and larger meanders to accommodate long-term easterly migration of the delta. As a consequence, embankments have weakened. A century of neglect has contributed to fragility. Almost 1,000 km of the 3,500-km system were destroyed by Cyclone Aila (2009)
Embankment overtopping and failure	



that reduces vulnerability<sup>2</sup> as it is any given specific item such as a cyclone shelter, an effective early warning system, or an insurance program.

This NLTA similarly takes the approach that any strategy must be comprehensive. Following these leads, it distinguishes among different types of responses: (a) long-term investment responses; (b) near-term investment responses; and (c) ongoing processes that reduce vulnerability. Long-term investments in the Sundarbans context might encompass strategies such as embankment realignment, clustering of islands through channel closures, and complementary infrastructure to accommodate resultant changes in transportation modes, communications requirements, and basic services such as water supply, energy, education, and healthcare. The near-term investments within this context encompass what many regard as the traditional DRM interventions, such as emergency shelters, early warning systems, relief systems, and insurance schemes, and similar safety nets. Interwoven through all of this are two parallel processes. The first process involves development of policies that reduce long-term socioeconomic vulnerability: these might influence migration, education, provision of livelihoods, or incentives to reestablish beneficial natural processes (such as restoration of mangrove bioshields). The second process involves policies that address shorter-term needs in DRM through identifying and supporting appropriate institutional changes, developing emergency plans for multihazard incidents, creating incentives to promote redundant (duplicate) systems, and introducing risk reduction measures such as preparedness simulations. Paramount through all of these interventions and policies is that one must never presume that it is possible to drive risk to zero. In fact, emergency planners have found that those who think they are safe are often among the most vulnerable, as they are

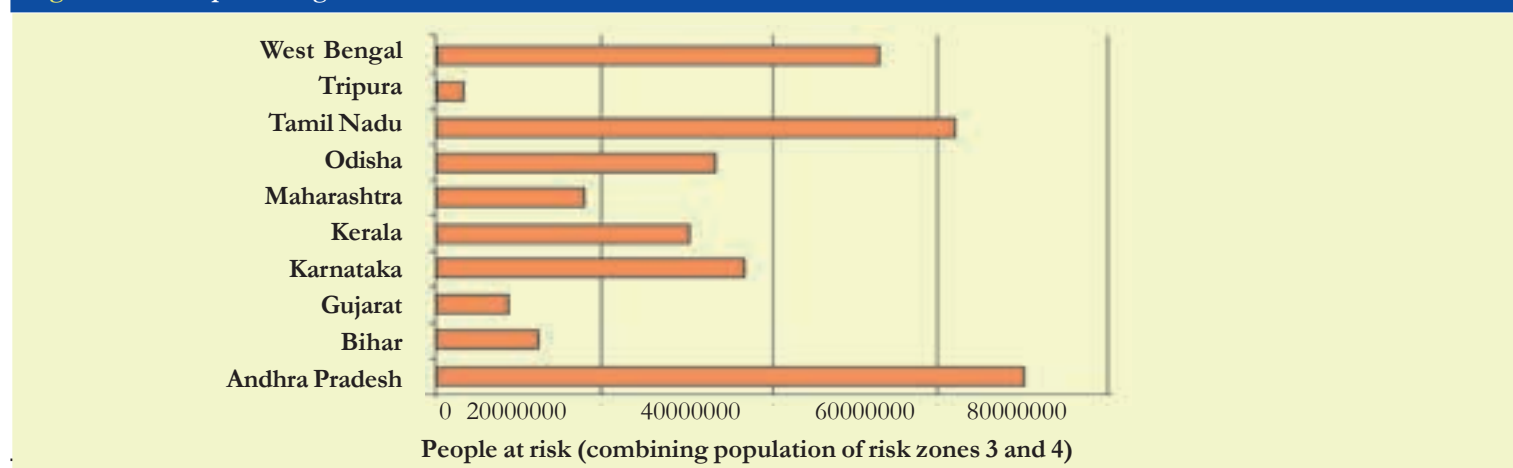
not prepared psychologically or practically for some severe event.

This entire approach is characterized as one of “building resilience.” Resilience is traditionally an ecological concept but it applies equally well to any natural or human system. Resilience is often thought of as the opposite of vulnerability, but it goes a step beyond because it also emphasizes the need to reinforce the adaptive capacity of a system. Poor people are vulnerable because their adaptive capacity is undermined; lack of education, health, and accessibility to information and social networks can all prevent them from adapting to any external stress. But even before this long-term human capacity can be strengthened, there is a prerequisite to protect lives and existing productive assets. The following sections focus on how to achieve that prerequisite.

### 4.3. Hazards: Cyclones, Sea Level Rise, Flooding, and Salinization

Of all of the natural hazards, cyclones are the most severe and routine occurrences striking the Sundarbans. While cyclones forming in the Bay of Bengal constitute only 5–6 percent of the global total number of cyclones, they are the deadliest of all the cyclones, accounting for roughly 80–90 percent of global loss of human life and property.<sup>3</sup> The Sundarbans is in the most cyclone-prone region in India, having experienced 90 cyclonic storms between 1891 and 1994, of which 35 were classified as “severe.” Between 1970 and 1996, 41 cyclones were formed in the Bay of Bengal (Table A4.2), and six of them had severe impacts in the Sundarbans region (highlighted in the table). Because of high population density, exposure to cyclones in the Sundarbans is relatively high, and West Bengal is ranked as the third highest based on the number of vulnerable people at risk at the state level (Figure A4.1).

**Figure A4.1: People at High Risk in Different Indian States**



Source: Hossain and Singh 2006.

<sup>2</sup>“The World Bank’s Disaster Risk Management Team aims to reduce human suffering and economic losses caused by natural and technological disasters. [It promotes ...] the integration of disaster prevention and mitigation efforts into the range of development activities” (IEG 2006).

<sup>3</sup>Chowdhury (2002) provides this global estimate. More recent valuation efforts that pertain just to the Sundarbans (conducted under this NLTA) considered economic losses across a number of categories – cyclones, by-catch losses, carbon revenue losses, salinization, biodiversity loss – and showed that cyclones alone account for about 45 percent of all losses in the Sundarbans. The estimated total cost of environmental damage associated with ecosystem degradation and biodiversity loss in the region is about INR 6.7 billion annually, accounting for about 5 percent of the estimated Sundarbans GDP in 2009.

**Table A4.2: Historical Records of Severe Cyclones Forming in the Bay of Bengal and Making Landfall at the Eastern Coast of India, 1970–1996 and 2009**

Date	Landfall/Consequences
September 7–14, 1971	Crossed southern Odisha (then Orissa) coast and adjoining northern Andhra Pradesh coast on September 10 and moved up to eastern Delhi. Ninety people died and 8,000 cattle perished. The system caused considerable damage to crops, houses, telecommunications, and other property in the coastal districts of Odisha, namely Ganjam, Puri, and Cuttack
September 20–25, 1971	Crossed southern Odisha coast near Gopalpur on September 22. Caused considerable damage to crops and houses due to floods and heavy rain at Vamsadhara village in Srikakulam and Koraput districts
September 27–October 1, 1971	Crossed West Bengal coast near the Sundarbans. Continued its movement toward the northwest, weakened into a low over Bihar on October 1. Sixty people died and thousands of houses were destroyed in West Bengal
October 26–30, 1971	Crossed Odisha coast near Paradip early in the morning of October 30. Maximum wind speed recorded was 150–170 km/hour. Lowest pressure recorded was 966 hectopasca (hPa) near the center of the storm. Ten thousand people died and more than 1 million were rendered homeless; 50,000 cattle perished; 800,000 houses were damaged
September 7–14, 1972	Crossed the extreme northern Andhra Pradesh coast near Baruva on the afternoon of September 10. Maximum wind speed recorded at Puri was 175 km/hour. Maximum wind speed estimated from the satellite picture was 204 km/hour. One hundred people died and 8,000 cattle were lost. Nearly 200,000 people were affected by the system. Heavy damage to crops and other property was reported from Ganjam, Puri, and Cuttack districts of Odisha, the worst affected being Ganjam district
September 20–25, 1972	Crossed extreme southern Odisha coast near Gopalpur on the afternoon of September 22 and weakened into a depression by the morning of September 23. Maximum wind speed recorded was gust of 136 km/hour at Gopalpur on the morning of the 22nd. Caused damage to crops and houses. No loss of life was reported
November 15–23, 1972	Crossed extreme southern Andhra Pradesh coast near Sriharikota island during the early part of the night on November 22. Maximum wind speed reported was 111 km/hour, gusting to 167 km/hour. Lowest pressure recorded near the storm center was 983 hPa. Eighty people killed. Many trees were uprooted and several thousands of people were rendered homeless
December 1–8, 1972	Crossed Tamil Nadu coast close to and north of Cuddalore at 23:30 on December 5 and was within 50 km west-northwest of Cuddalore at 03:00 on December 6. Maximum wind speed recorded at Cuddalore was 111–148 km/hour between 22:30 on the 5th and 02:30 on the 6th. Eighty people killed and 30,000 rendered homeless in Chennai (then Madras) due to flood. Total loss INR 400 million
November 3–9, 1973	Crossed Odisha coast close to and north of Paradip on the early morning of November 9. It weakened rapidly and lay as a trough over Odisha the same day. Maximum wind speed reported was 100 km/hour at Paradip and Chandbali. The cyclone caused some damage to standing crops in the coastal districts of Odisha between Paradip and Chandbali.
August 13–20, 1974	Crossed West Bengal coast near Contai at about 07:00 on August 15 and remained a cyclonic storm over land until August 17. Maximum wind speed was 139 km/hour. The storm caused floods in parts of the districts of Midnapore, Hooghly, and Howrah and affected 24 districts of West Bengal
September 6–19, 1976	Crossed coast near Contai around noon of September 11 and reached southeast Madhya Pradesh as a cyclone on the morning of September 13. Maximum wind speed 160 km/hour was reported in gusts. Forty people died and 4,000 cattle perished. Crop damage was around INR 125,000.
November 3–6, 1976	Crossed Andhra Pradesh coast north of Machilipatnam on the night of November 4. It maintained its intensity over land up to the morning of November 5, when centered 50 km southeast of Hyderabad. It weakened into a depression, emerging into the Arabian Sea off the northern Maharashtra coast by the 6th. Twenty-five people killed and 25,000 huts damaged; 13 fishers were missing

**Table A4.2 (continued): Historical Records of Severe Cyclones Forming in the Bay of Bengal and Making Landfall at the Eastern Coast of India, 1970–1996 and 2009**

Date	Landfall/Consequences
November 15–17, 1976	Crossed southern Andhra Pradesh coast between Nellore and Kavali on November 16 at midnight, weakened thereafter and lay as a deep depression over southern Andhra Pradesh coast and adjoining Rayalaseema on the morning of November 17. Maximum wind speed was estimated to be 222–259 km/hour. Thirty people died and 10,000 houses were damaged, 24 country boats also damaged. Total loss of property was estimated to be INR 39 million. Kavali and Kavur, Nellore district, were most affected by the cyclone
October 27–November 1, 1977	Crossed southern Andhra Pradesh coast near Kavali between Nellore and Ongole around noon on October 31. Weakened into a depression over the interior parts of Karnataka by morning of November 1 and emerged into the Arabian Sea as a low. It caused huge damage to property and telegraph posts over an 80 km stretch from Kavur to Singarayakonda
November 8–12, 1977	Crossed Tamil Nadu coast 10 km to south of Nagapattinam early in the morning of November 12. Weakened into a cyclonic storm by that evening over interior parts of Tamil Nadu and emerged into Lakshadweep (then Laccadives) off northern Kerala coast on the morning of 13th as a deep depression. Maximum wind speed recorded about 120 km/hour on the morning of the 12th at Thanjavur, Tiruchirapalli, and Pudukottai. Five hundred and sixty people died and 1 million people rendered homeless; 23,000 cattle perished. Total property damage estimated to be INR 1,550 million.
November 14–19, 1977	Crossed near Chirala in Andhra Pradesh at midday on November 19 and weakened into a low on the evening of the 20th. It dissipated over southeast Madhya Pradesh and adjoining Odisha by the evening of the 21st. Maximum wind speed recorded was 193 km/hour on board ship at 10:30 on November 17. Ten thousand human lives reported lost and 27,000 cattle perished. Damage to crops and other property estimated to be INR 3,500 million
November 19–24, 1978	Crossed between Kilakarai and Ramanathapuram, Tamil Nadu, on the evening of November 24 as a severe storm and emerged into the Arabian Sea off the Kerala coast as a deep depression on the morning of November 25. Maximum wind speed reported was 145 km/hour. In India 5,000 huts were damaged and total damage was estimated to be around INR 50 million. In Sri Lanka, 915 people died and 1 million people were affected, and 100,000 houses were damaged
May 10–13, 1979	Crossed near Ongole in Andhra Pradesh early morning on May 13. Nellore reported wind speeds of 100–160 km/hour. The storm surge was 4 m above mean sea level at Pedaganjam. Some coastal villages of Kavur were affected. Seven hundred people killed and 300,000 cattle perished. Nearly 4 million people were affected and 700,000 houses damaged.
September 24–28, 1981	Crossed Odisha coast near Puri on the early morning of September 26 and weakened into a depression on that evening over interior Odisha and adjoining eastern Madhya Pradesh. Five launches were lost in the bay and many houses were damaged in Midnapore, West Bengal, and Cuttack, Odisha.
December 4–11, 1981	Crossed West Bengal coast near Sagar Island around 13:00 on December 10 and weakened into a depression on the morning of December 11 over Bangladesh and into a low the same evening over Assam and Meghalaya. Two hundred people died and 1 million were affected in 24 Parganas district of West Bengal.
May 31–June 5, 1982	Crossed on June 3 near Paradip, Odisha. High tides caused damage all along the coastal stretch. The cyclone caused heavy damage in the coastal districts of Puri, Cuttack, and Balasore
October 11–17, 1982	Crossed Andhra Pradesh coast and adjoining Telangana as a low on the morning of October 17. Heavy rainfall caused damage to roads
October 16–21, 1982	Crossed between Sriharikota and Dugaraja Patnam (Andhra Pradesh). Sixty people died and 300–400 huts were damaged
October 9–14, 1984	Crossed northern Odisha coast near Chandbali in the forenoon of October 14. The system caused some damage in Cuttack and Balasore districts of Odisha and Midnapore district of West Bengal
November 9–14, 1984	Crossed between Sriharikota and Dugaraja Patnam between 08:00 and 09:00 on November 14. Seawater inundation occurred in the village of Dugaraja Patnam on the 14th and reached 3 km inland from the coast. Fifty-four lives were lost in Tamil Nadu; 90,000 livestock perished and 320,000 buildings were completely destroyed in Andhra Pradesh

**Table A4.2 (continued): Historical Records of Severe Cyclones Forming in the Bay of Bengal and Making Landfall at the Eastern Coast of India, 1970–1996 and 2009**

Date	Landfall/Consequences
November 27–30, 1984	Crossed southern Tamil Nadu coast near Nagapattinam on the afternoon of December 1. About 35,000 people were affected in East Thanjavur and South Arcot districts of Tamil Nadu. In Thanjavur, 50,000 acres of land was submerged
September 17–21, 1985	Crossed on September 20 close to Puri, Odisha. Chilka and Tangi submerged for three days due to inundation of seawater.
October 13–17, 1985	Crossed near Balasore, Odisha, on October 16. High tidal wave of over 5 m was observed
October 31–November 3, 1987	Crossed north of Nellore, Andhra Pradesh. Fifty people died and 25,800 livestock perished in Andhra Pradesh; 68,000 houses damaged, and 680,000 people affected
November 23–30, 1988	Crossed 20 km west of India-Bangladesh border in West Bengal. At midnight on November 30, it lay centered near Dhaka. Two thousand people killed, 6,000 reported missing in Bangladesh
May 23–27, 1989	Crossed 40 km northeast of Balasore, Odisha. Sixty-one persons died in Odisha and West Bengal, 1,000 cattle perished in West Bengal
November 1–9, 1989	Crossed near Kavali, Andhra Pradesh. Sixty-nine people died and 7,100 cattle perished. Loss of property estimated to be INR 140 million
May 4–9, 1990	Crossed 40 km southwest of Machilipatnam; 967 people died, 3.6 million livestock perished, 1.43 million houses damaged
April 24–30, 1991	Crossed Chittagong (Bangladesh) across Sandwip Island, where 13,200 people died. Colossal loss of property. One of the most devastating cyclones to affect Bangladesh
November 11–15, 1991	Crossed Tamil Nadu coast north of Karaikal; 185 people died and 540 cattle perished. Sixteen people died in Andhra Pradesh
November 11–17, 1992	Crossed near Thoothukudi (then Tuticorin), Tamil Nadu; 175 people died and 160 reported missing. Damage to standing crops due to flood reported
December 1–4, 1993	Crossed on December 4, 30 km north of Karaikal. A hundred people died in Tamil Nadu
April 29–May 2, 1994	Crossed near Teknaf in Bangladesh around midnight on May 2. Loss of life was limited to 188 due to timely and adequate cyclone warning issued by Bangladesh Meteorological Office
November 7–10, 1995	Crossed northern Andhra Pradesh coast south of Ichchapuram on morning of November 10. Ninety-three persons died and 81 boats were affected; 2,631 houses damaged; 153 fishers were reported to be missing
November 5–7, 1996	Crossed Andhra Pradesh coast 50 km south of Kakinada around 16:00 on November 6; 978 persons died, 1,375 persons reported to be missing, 1,380 villages affected in Andhra Pradesh, 6,464 boats lost at sea
November 28–December 6, 1996	Crossed near Chennai around 2100 on December 6. The cyclone persisted for nine days, a very long life for the Indian Ocean. It caused severe damage to life and property.
May 23–26, 2009	Cyclone Aila developed as a tropical depression on May 23 in the North Indian Ocean, south of West Bengal, India. Aila reached its maximum sustained wind speed of around 120 km/hour on May 25, becoming a severe cyclonic storm (equivalent to an Atlantic category 1 hurricane) prior to landfall near the India-Bangladesh border later that same day. The storm brought heavy rain and strong winds to parts of eastern India and Bangladesh, claiming the lives of over about 1,000 people and leaving half a million homeless. As the storm moved inland toward Bangladesh it weakened, though torrential rain continued to wreak havoc in the region. The storm caused rivers to burst their banks, prompting floods and landslides that damaged crops, roads, and houses. The storm not only affected residents but also affected the Royal Bengal tigers located in the Sundarbans. The forest officials feared that more than a dozen of the endangered tigers perished during the storm. The storm dissipated by May 26. (Sources: Associated Press/BBC News/Reuters/ <i>Times of India</i> .)

Sources: Indian Meteorological Department <http://www.imd.gov.in/section/nhac/static/cyclone-history-bb.htm>;

National Climatic Data Center <http://www.ncdc.noaa.gov/sotc/index.php?report=hazards&year=2009&month=5>.



Cyclones are most deadly when the peak storm surge occurs at the time of high tide; this was the case with Cyclone Aila in 2009, which made landfall during one of the highest tides of the year. The devastation affected more than 1 million people in India and reduced rice productivity for up to three years due to saltwater intrusion (Table A4.3).

Relative sea levels are rising in the Sundarbans – partly from eustatic processes but mainly due to land subsidence caused by various natural and anthropogenic processes.<sup>4</sup> The sea is estimated to be rising at a rate of 3–8 mm per year in the Sundarbans; parts of the coast due south are, in fact, rising because of uplift, which illustrates that impacts are not necessarily homogenous and differ according to varying geological processes. Seismic events, such as that causing the 2004 tsunami, and their subsequent aftershocks can also shift land levels by a meter or more over a period of a few days. But most change is gradual and a frequent response is simple inundation

and loss of land; the 4 km<sup>2</sup> of Ghoramara Island (part of Sagar Block) will probably be completely submerged in the coming decades and the island is already largely uninhabitable. Two nearby islands totaling a similar area are already submerged at high tide.<sup>5</sup> Moreover, the subsidence and inundation also lead the way for more routine flooding, which contributes to salinization of soils and freshwater resources.

Flooding from storm surge remains a significant hazard even when embankments are present, as natural disasters are capable of wiping out embankments. Given the relatively flat landscape, hazard mapping suggests that a 45-cm rise in sea level would destroy 75 percent of the Indian and Bangladeshi Sundarbans. Mangrove systems themselves are inherently adaptable and are, thus, intrinsically not necessarily at risk. In areas of accretion (such as in the upper Matla estuary), some mangroves have taken root spontaneously, but overall they are in decline because the rapid

**Table A4.3: Damage Details in West Bengal as of June 2, 2009**

S. No	District	No. of block affected	No. of ward/ municipality affected	No. of villages affected	Population affected	No. of human lives lost	No. of cattle/ livestock lost	Cropped area affected (in ha)	Estimated damage of crops (in Rs Lakh)	No. of houses damaged	
										F	P
1.	Cooch Behar	15	6	1,453	295,356	1		26,766		5,353	13,046
2.	Jalpaiguri			133	16,500		75		710	1,223	
3.	Darjeeling	8	4	425	950,00	26	40		4,500	12,000	
4.	Uttar Dinajpur			1,430	321,120			43,370		14,339	20,144
5.	Dakshin Dinajpur	8	2	305	21,702				1,518	2,966	
6.	Malda		3,501	270,000	2			15,000	35,000		
7.	Murshidabad	4		130	18,675	3			3,020	4,512	
8.	Nadua	17	1		308,250	4		21,667		5900	10,477
9.	North 24 Parganas	20	9	1,967	1,255,074	27	2,196	121,501	2,127	76,184	66,925
10.	South 24 Parganas	14	7	1,737	1,190,321	34	1,443	4,371	2,457	116,486	126,644
11.	Kolkata					5					
12.	Howrah	14			80,820	9				11,910	24,643
13.	Hooghly	18		810	600,028	5		9,206		19,648	45,385
14.	Bardhaman	10	5		200,000	4				7,447	26,670
15.	Birbhum	10		200,000	2					850	1,300
16.	Bankura	14	2	5,187	97,500	1	1	410	150	10,752	13,632
17.	Pachim Medinipur	29	7	6,310	628,545		6			37,537	79,348
18.	Purba Medinipur	25	5	2,964	1,058,534	3	27	9,223	3,301	29,781	64,889
	<b>TOTAL</b>	<b>206</b>	<b>48</b>	<b>26,352</b>	<b>6,657,515</b>	<b>126</b>	<b>6,713</b>	<b>236,609</b>	<b>27,125</b>	<b>360,935</b>	<b>546,804</b>

Source: United Nations Situation Report, Cyclone Aila, June 2, 2009 [http://reliefweb.int/sites/reliefweb.int/files/resources/E98F917FD21A0B1D492575CA00087C2F-Full\\_Report.pdf](http://reliefweb.int/sites/reliefweb.int/files/resources/E98F917FD21A0B1D492575CA00087C2F-Full_Report.pdf).

<sup>4</sup>Battacharya, S., J. Pethick and K. Sarma (2013). Managerial response to sea level rise in the tidal estuaries of the Indian Sundarbans: A geomorphological approach. Water Policy. In Press. 2013.205.

<sup>5</sup>These shoals correspond to census units 607 and 651 in Sagar block. Ghoramara has two census units – 605 and 606 – but census unit 605 is already treated as abandoned.

changes in estuary dynamics have reduced the transport mechanism for wild mangrove propagules (seeds). Land use change and other shifts in the habitat are thus placing even the normally resilient mangrove ecosystem at risk.

Drinking water quality varies depending on location, but salt water intrusion is an ongoing challenge in the provision of drinking water. Typically, the source of piped water supply schemes is a tubewell. The depth of tubewells is about 300 m, where nonsaline water is usually available. Extensive river-based surface water schemes cannot be employed in the context of tidal rivers. Hence, only a few such schemes have been implemented in the Sundarbans. A few pond-based surface water schemes have been constructed, but most of them have been affected with saltwater intrusion linked to the effects of Cyclone Aila. All 19 blocks within the Sundarbans are affected by salinity, but information on the exact population affected by salinity is not available. A few habitations are also affected by arsenic, and they are provided with safe water by the PHED through an arsenic mitigation plan, which also incidentally addresses the salinity issues in those areas.

#### 4.4. Embankments: Part of the Solution or Part of the Problem?

Embankments play a key role in the Sundarbans as systems of defense against cyclonic storms and sea level rise, but the structural integrity of many embankments is poor. The widths of estuarine channels in the Sundarbans have changed and will continue to change because of natural and anthropogenic factors; the changes involving increases in channel width have undermined the structural integrity of embankments. To understand why changes in channel width take place, it is necessary to recognize conditions under which estuaries erode sediments from their banks in contrast to conditions under which they deposit sediments, a process known as “accretion.” Whether an estuary erodes or deposits sediments depends on whether the estuarine channel is in an equilibrium in which it neither erodes nor deposits sediments. This equilibrium depends on the velocity of water flow. If velocity is “too fast” in comparison to an equilibrium case, channel bank erosion will occur and the channel cross-section will become larger; with a larger cross-section, flow velocity will be reduced, as will the levels of erosion. In contrast, if velocity is “too slow”, the estuary will deposit sediments. This has the effect of reducing the cross-sectional area and increasing the flow velocity. In equilibrium, these opposing trends balance so that, over a particular time period, the channel neither erodes nor deposits. An important variable affecting the velocity (and thus the erosion and accretion processes) of tidal channel flows is the “tidal prism,” defined as the volume of water that flows into and out of a channel during a complete tidal cycle (excluding upland freshwater discharges). If the tidal prism is made larger – for example, by extending the reach of tidal flows so that upstream fishponds are recharged with estuarine waters – the velocity of tidal flow increases. In contrast, if upper portions of a channel are cut

off from an estuary to create reservoirs of fresh water, the tidal prism is made smaller and thus tidal velocity is reduced.

Some tidal channels have been eroding their banks while the banks of other channels have been subject to accretion. Studies conducted as part of the analytic work for this NLTA<sup>6</sup> identified three main factors that have affected the size of tidal prisms and, therefore, discharge velocities and erosion or accretion of channel banks: (a) the sea level rise of 0.2–1.6 m that has taken place in the Sundarbans during the past 100–200 years; (b) the increasing prevalence of aquaculture ponds, which are periodically recharged by creating networks of channels that can deliver estuary water upstream so ponds can be recharged with saline water periodically; and (c) the creation of freshwater impoundments on the upper reaches of channels and closures that restrict upstream estuarine flows. The first two of these factors have increased the size of tidal prisms and the third has decreased their size.

The current system of embankments is ineffective in the sense that continual channel erosion is expected increasingly to threaten the structural stability of embankments in many tidal channels. Sea level rise at levels expected over the next century will result in the widening of many tidal channels with the consequence that embankments along those channels will fail structurally and be breached, especially during surge events such as those that occurred during Cyclone Aila. Even without future sea level rise, embankments will continue to be undermined because tidal flows will continue to erode the banks of many channels. In short, channel bank erosion processes, independent of sea level rise, will continue unimpeded in many locations and, unless embankments are relocated further away from the channel banks (“retreated”), they will continually fail. In areas of erosion, measures such as concrete reinforcements or planting of buffer mangrove bioshields will not impede the deep undercutting that contributes to eventual embankment failures. As detailed in the recommendations later, it is technically and economically feasible to defend some *but not all* of the productive areas within the Sundarbans by a strategy that involves systematic retreat of existing embankments.

Past experience has thus shown that embankments, by their immovable nature, can be both part of the solution and part of the problem. They prevent flooding and protect households and their assets. But they cannot stand up to long-term natural processes that will eventually undermine some sections. As such, they may be a solution but, on long-term planning time scales, they remain a temporary solution at best.

#### 4.5. Modern Prescripts of Disaster Risk Management: Implications for Adaptation

As described previously, large tracts of the Sundarbans buffer area are already below the high-tide line and protected by poorly maintained and obsolete embankments, many of which are

<sup>6</sup>See Annex 5.

undermined by erosion of the banks of tidal channels and by hazardous weather events. Cyclone Aila damaged nearly 1,000 km of embankments in the Sundarbans. Embankments were destroyed in over 80 places in Patharpratima block. On Ghoramara Island in Sagar block, over 3 km of embankments were washed away. Tidal waves also destroyed embankments in Namkhana block. The foundations of others have gradually eroded away, making it likely that many will collapse in the storms to come. Embankment rehabilitation and reconstruction has been very slow in some parts of the Sundarbans. Moreover, embankment reconstruction work has mostly been carried out by local residents, many of whom are inexperienced and untrained in this type of work. In late 2010, the first contracts for embankment realignment were tendered by the Irrigation Department; these acknowledged the findings of this NLTA that embankment retreat was both inevitable and beneficiary, and the processes also provided allowances for compensation to those who would lose land as a consequence of the retreat.

The recent real scenario has underlined the need for improved DRM. As described previously, DRM is more than simply lending relief after disaster strikes, although relief efforts are certainly an important component of any DRM strategy. Numerous lessons have been compiled of relevance to DRM, and a number of key prescripts or concepts are of particular relevance in the Sundarbans. These concepts are as follows:

- **Redundant systems are important.** One event that inevitably happens during a disaster is that a potentially critical part of the disaster response system itself is affected and not functional. This applies to human resources, institutions, and physical assets. In infrastructure, communications systems and energy networks are often vulnerable to impacts but are critical in any response. Duplication and overdesign are, therefore, completely justifiable if DRM is to be effective. European embankment systems, for example, typically have two lines of defense, with people living only behind the inner system;
- **Information is even more important.** Everyone is familiar with the idea of early warning systems, but equally important are the information networks that feed into these systems. The information can be about the hazard (such as impending storms and their likely tracks) or the assets potentially affected (such as the locations of vulnerable populations or ecosystems). Information also comprises scientific monitoring data relating to basic information such as tide levels and storm surges. An underappreciated approach to data collection is simple monitoring work conducted at the local level by people likely to be affected by any severe event;
- **Failing to plan for multihazard incidents is inexcusable.** Naïve planning often attributes probabilities to various hazards, and then puts emergency planning protocols in place to address them. A common error in such planning is to believe that the risks and hazards are uncorrelated.<sup>7</sup> But correlated risks are often the rule, rather than the exception, in severe incidents. After Cyclone Aila, emergency response teams and doctors were also faced with water shortages and disease outbreaks that made matters worse and also counted relief workers among the victims. Storms and oil spills go hand in hand, but are often planned for only as separate emergencies. As earthquakes are followed by aftershocks, embankment breaches are followed by floods, which will repeat with every high tide until the breach is contained. All of these are examples of correlated risks that add to damages and burden response networks;
- **Practice makes perfect.** Emergency coordinators routinely conduct simulations to test response systems. What is often missed, however, is that these simulations are effective because they build confidence, create new skills, and reinforce parallel social networks and systems on which they depend. A corollary to this is that those closest to the hazard (that is, those directly affected) often have a significant adaptive skillset of their own because of their (perhaps unwilling) participation in past real events. In earthquake-prone areas, it is well known that small shocks or tremors keep people vigilant; the worst incidents are often in areas not prone to such hazards and are thus so much more catastrophic because of the lack of capacity. In the Sundarbans, much greater use can and should be made of local knowledge and capacity at all levels in the DRM strategy;
- **Risk is never eliminated.** Partially, this is because it is impossible to harden targets perfectly or to reduce vulnerability completely. But it is equally true that the mitigation and adaptation strategies that are adopted may, in turn, contribute to new types of problems. The architects of the original embankment system would never have guessed that the embankments themselves would, over a few centuries, contribute to their own destruction. We can plan for what we know, but we can never plan perfectly for what we do not know; and
- **Process is fundamental in overcoming the most entrenched and difficult challenges.** The above lessons all point inevitably to the importance of implementing DRM within the context of an adaptive process that permits learning and experimentation. There are numerous difficult challenges (identified in the United Nations Office for Disaster Risk Reduction (UNISDR) Secretariat 2004): dealing with uncertainty (and resisting conservative approaches of doing nothing in such circumstances), augmenting information, relying on short-term thinking, depending on outdated or entrenched institutional structures, and developing appropriate financing frameworks. Not one of these challenges can be overcome through a single action, which is why adaptive processes must be adopted.

<sup>7</sup>The 2011 Japanese tsunami and subsequent nuclear disaster are a tragic example of how presumed uncorrelated risks of tsunami, nuclear meltdown, and power outages created a disaster without precedent that completely overwhelmed response systems.

## 4.6. Current Approach to Disaster Risk Management in the Sundarbans

Preliminary findings show that the current approach to DRM in the Sundarbans does not reflect the foregoing precepts, and even falls far short on traditional grounds of disaster planning, preparedness, and response. Cyclone shelters are few and far between. Responses are mismanaged, late, or uncoordinated. Communication systems may work reliably from a technical standpoint, largely because cellphones are now accessible to even the poorest inhabitants, but information flowing through such networks is of mixed quality. At a higher level, there is no formal, synchronized DRM policy to protect the Sundarbans from cyclones and other natural disasters. Moreover, notwithstanding the potentially disastrous medium- and long-term impacts of sea level rise, the Sundarbans does not have a program for adaptation.

Vulnerability to cyclonic storms is increased in the Sundarbans by the paucity of emergency cyclone shelters. The availability of and access to appropriate cyclone shelters in the event of an emergency are a key line of defense to reduce vulnerability to damage from cyclones, but the Indian Sundarbans lacks adequate shelters (both in terms of quantity and quality). Studies have shown that, unless a cyclone shelter is within 1.6 km of residences, it may be too far for coastal residents to reach during an emergency (Paul 2009); less than 5 percent of rural residents in the region has access to the handful of shelters that are currently in place.<sup>8</sup> One shelter typically serves 2,000 residents, implying that one would require at least 2,000 shelters to serve the over 4.4 million people living in the Sundarbans. But a May 2010 report puts the current number of cyclone shelters in the coastal areas of North and South 24 Parganas and Midnapore East at 315 (Basu 2010). The quality of shelters is also mixed, with some not meeting basic design standards that would address the specific needs of women, the sick, the elderly, or those with livestock.

Vulnerability to extreme weather events is also increased because the Sundarbans lacks an effective early warning system. Expanding the network of shelters should be a high priority in any vulnerability reduction strategy. IMD issues warnings of impending cyclones and storm surges through television and radio. Warnings are conveyed to the State Disaster Management Department in West Bengal, relevant districts, Zila Parishad authorities, and to state media and newspapers (Jadavpur University 2009). However, government warnings often reach residents many hours or days after a storm. A 2009 field visit conducted by the Jamsetji Tata Centre for Disaster Management in the Hingalganj and Gosaba blocks of North and South 24 Parganas districts revealed deficiencies in the warning system for Cyclone Aila. Interviews revealed that the warning for Cyclone Aila given over the radio did not adequately explain to residents what a cyclone was or specify where the landfall was expected to occur. Moreover, the cyclone warnings were expressed in such general terms that residents already accustomed to experiencing severe weather events did not feel the

need to evacuate. Evacuations that did take place were not systematically organized and some communities were unable to evacuate to safer locations (Sinha and Bhattacharyya 2009).

The Jamsetji Tata Centre 2009 field study found that, because of deficiencies in the warning system for Cyclone Aila, many people had only 10–15 minutes of reaction time available to gather children and the elderly, pack essential belongings, and evacuate to higher ground. The majority of respondents interviewed said that their major concern was either locating to higher ground or to concrete structures nearby. Moreover, respondents unequivocally stated that they did not want to evacuate without taking their belongings. As a result of the lack of time to prepare for evacuation, individuals suffered from three major types of losses: (a) all forms of documentation (ration cards, BPL certificates, MGNREGA work cards, birth and death certificates, proofs of school enrollment, and other documentation); (b) livestock, such as cattle and poultry (Mookerji 2009); and (c) money and food grain reserves (both for consumption and for selling in the market). Those interviewed during the 2009 study also felt that the agencies responsible for assuring that the warning messages were disseminated fell short of their responsibilities.

One of the weakest links in early warning dissemination was the inability of local authorities, such as GPs, to send warnings effectively to coastal communities. Warnings, if sent at all, did not clearly explain what actions communities needed to take. Not all coastal districts are well equipped to disseminate early warnings down to the communities in a timely and effective manner. This greatly increased the vulnerability of coastal communities during the Cyclone Aila emergency and will continue to do so unless changes are made. The Jamsetji Tata Centre's 2009 field study also found that there was an absence of any role played by officeholders at the Panchayat level in organizing or implementing a systematic evacuation plan; providing relief shelters, food supplies, and medical aid; or organizing health workers to give assistance during the aftermath of the cyclone (Sinha and Bhattacharyya 2009).

Relief distribution efforts are also poorly coordinated. There is generally a lack of safe water, sanitation services, and medical aid for cyclone-affected residents; no system of emergency preparedness is in place. The study of the effects of Cyclone Aila by the Jamsetji Tata Centre for Disaster Management revealed that temporary shelters and relief camps for flood victims had inadequate sanitation, hygiene, and safe water availability. Following the cyclone, hundreds of cases of diarrhea were reported. There was a shortage of government-run medical camps in all districts of the Sundarbans (Sinha and Bhattacharyya 2009). Other complaints recorded in the study included mosquito infestation and lack of mosquito nets; provision of uncooked food items such as rice and lentils, even though the residents had neither water nor pots for cooking; and irregular supply of drinking water, especially in Gosaba block. Many residents were also unaware of the type of services that NGOs were providing (Sinha and Bhattacharyya 2009).

<sup>8</sup>Nature, Environment and Wildlife Society, Kolkata: personal communication, 2010.



## 4.7. Some Alternatives: A General Overview of Possibilities

Building resilience to current and future hazards is not a straightforward matter, given the complexities of the system and linkages involved. In identifying a potential strategy of interventions, a number of alternatives were broadly considered. First, a “Business-As-Usual” (BAU) approach is generally regarded as untenable. This, in essence, involves ad hoc approaches to embankment repair, dysfunctional disaster response, and tolerance of destructive practices (such as improperly managed tidal aquaculture) while paying no heed to the fact that the population at risk is, in fact, growing on an annual basis.<sup>9</sup> Doing nothing is not an option.

One option that has frequently been mooted politically is the reinforcement of the current embankment system through the use of pilings, cement construction, and armoring to a crest height that would withstand predicted levels of sea level rise for the next century. Cost-benefit studies (conducted for this NLTA) quickly dismissed this as infeasible on economic grounds; construction costs using cement and pilings are 10 to 30 times greater than in traditional methods using local material, and are no stronger when addressing issues such as undercutting or toe erosion. At current land productivity levels, very few islands justify the expense of such costly ring embankments because the area of land is too small relative to the perimeter of the island. Even a fivefold increase in net land productivity would still result in fewer than 20 percent of the islands qualifying for such protection, but no interventions identified in this NLTA could consistently realize such productivity. Sagar Island would qualify, and some others would qualify if currently separated islands were clustered together to be protected by a single circle embankment. But in addition to the lack of economic viability, the technical basis for the strategy is regarded as flawed because of the inherent inability of such structures to survive undercutting; realignment is thus the preferable strategy, and local materials are the most cost-effective means for constructing new embankments.

A second option that was considered and may still, in fact, be useful in some limited areas, is land warping. Warping is a very old land reclamation method that involves the deliberate flooding of land on a recurrent basis within an embanked area, with a view to letting sediment settle out and – over time – raising the land level. Land is flooded on high tides, enclosed using sluices, and water is released on the low tide. The practice is common in the Sundarbans Impact Zone in Bangladesh, and the tidal management schemes implemented within the polder system in Bangladesh have generated land build-up of as much as 1 m over three to seven years. While the technology appears simple and transferable, there are critically important differences between the systems in Bangladesh and those in West

Bengal that make it technically problematic for the West Bengal Sundarbans. First, warping will take longer in West Bengal because of lower starting land levels; the India embankments are about 150 years old while the polders in Bangladesh are of recent design and construction (1960s to 1980s). Second, sediment concentrations in Bangladesh are higher: measurements taken during this NLTA confirm this and, more obviously, accretion and sedimentation are two of the greatest problems in Bangladesh, whereas erosion is the dominant management issue in India. Third, even in Bangladesh, the warping is done only in small areas and can be implemented only in rotation because – during warping – residents are temporarily displaced (for five years on average). Fourth, social acceptance of the warping remains mixed in Bangladesh: firstly, because of the temporary displacement, and, secondly, the compensation requirements for these five-year periods strain local resources or (more frequently) compensation is not paid in full. Transferring this experience to India as a potentially wide-ranging solution was thus rejected, especially because the warping process would take longer.

A third option would be to reclaim new land from unused and uninhabited land, and embark on a modernized system of polders and enclosures that could be built to higher standards over a time period that does not involve displacing people. While technically this is feasible, the only area available is the Sundarbans Reserve Forest. The mandate of the NLTA did not consider conversion of the Sundarbans Reserve Forest for settlement purposes; such settlement is regarded as incompatible with the goals of biodiversity conservation and hence the option was not explored. Even if it were possible, it is noted that such conversion would not solve the more immediate poverty and vulnerability issues of those living in the transition zone.

In consideration of the above, the favored strategy involves some form of progressive abandonment of high-risk areas of the delta (notably the transition zone and selected hot spots within that zone). The pace of abandonment can be very quick (less than five years) or relatively slow (multigenerational). The reference case selected was, in fact, the multigenerational model, largely because of human and institutional capacity constraints rather than technical issues. The multigenerational model is socially less disruptive as it permits voluntary migration over a longer period of time, but it also places a greater need and emphasis on supporting those within the high-risk transition zone. Hence, there is a need both for reducing the potential threats (through estuary management interventions) and for addressing, more effectively, the treatment of disasters when they do occur (in the context of DRM). The recommendations below involve two styles of intervention: (a) threat reduction investments, including embankment realignment and upgrading, mangrove bioshield restoration, and salinity management investments; and (b) DRM

<sup>9</sup>Preliminary results from the 2011 India Census became available at state and district levels during the preparation of this report, although information at the block level was not available at the time of completion of the NLTA. The preliminary results, however, suggest that the aggregate population growth of the Sundarbans blocks over the previous decade was about 16 percent. The state of West Bengal had a decadal growth rate of 13.9 percent, and for India as a whole the growth rate was 17.6 percent. The population of Kolkata, in fact, declined by 2 percent over the decade, showing net out-migration. South 24 Parganas recorded an 18 percent decadal growth rate and North 24 Parganas a 13 percent decadal growth rate. The estimated 16 percent decadal population growth for the Sundarbans region corresponds to an annualized population growth of approximately 1.5 percent.

measures that address immediate needs through early warning systems, emergency preparedness, and cyclone shelters.

#### 4.8. Building Resilience through Estuary Management: Recommendations

Estuary management primarily involves embankment realignment and upgrading, with supportive expenditures on mangrove bioshield restoration and salinity management. In this section, a number of design and economic issues are presented.

**A US\$5 billion investment is required just to handle embankment realignment.** Many of the embankments have suffered substantially from ongoing erosion, and recent storm events have caused their collapse. Relatively inexpensive reconstruction efforts have focused on protecting land and livelihoods and, in many places, this has already resulted in retreat of embankments. The retreat has relied on use of local materials (mud), frequently borrowed from the estuary side of the embankment or through dismantling of the outer embankment. In some areas, villagers are now voluntarily rebuilding the original outer embankment in an attempt to reclaim the area between the embankments for traditional aquaculture. While these temporary measures will have the desired immediate impact of protecting village lands, these are not regarded as long-term sustainable solutions for a number of reasons. First, realignment is occurring on an ad hoc basis and is likely to be inadequate. Second, destruction of outer embankments and mining of mud from the estuary side will reduce protection; material can also be taken from the landward side without unduly undermining the overall economic viability of the operation. Finally, promotion of traditional aquaculture in the areas between the embankments could contribute to long-term erosion elsewhere; such areas are better suited to plantation or rehabilitation of mangrove bioshields. A more comprehensive realignment strategy is expected to cost about US\$5 billion over the next decade to retreat embankments in critical areas, followed by a reconstruction and rehabilitation of the rest of the system to accommodate sea level rise and increased cyclone intensity. The favored material is mud coupled with mangrove bioshields; the economic analyses suggest that use of concrete will add substantially to costs without decreasing vulnerability.

**The embankment investment is economically viable.** The overall viability of any protective circle embankment depends primarily on three factors: (a) building material; (b) area and shape of land under protection by an embankment; and (c) size of the population being protected and productivity of that area. The economic studies show that concrete as a building material would only be viable for very large expanses of the order of 1,000 km<sup>2</sup>, and that a concrete embankment would not normally provide greater security than a mud embankment. Benefit–cost analyses were undertaken to calculate break-even points that also reflected typical retreat distances from current alignments. Results indicated robust positive net benefits as long as agricultural productivity could double over the next 10 years and that enclosed areas were

greater than about 20 km<sup>2</sup>. Such agricultural productivity improvements are potentially available through extending current best practices or through adopting new aquaculture methods. As noted elsewhere, though, aquaculture must be more aggressively managed to ensure that externalities associated with embankment erosion do not arise.

A loss of protected land will accompany the realignment of embankments; local social concerns will need to be addressed to ensure proper compensation. Managed realignment will result in the loss of significant areas of agricultural land, and this indicates a need for enhanced investments to improve agricultural productivity such that basic food needs can be met. The area of land involved in the eroded segments is estimated to be 15,000–25,000 ha, or a maximum area approximately equivalent to that of Sagar Island. This can potentially be offset by reclamation of lands under accretion or by channel closures, which will also make available new land.

**The newly unprotected lands should be used to develop a mangrove bioshield to attenuate wave energy.** New mangroves should be allowed to recolonize portions of the newly unprotected lands. However, the size of this new mangrove area should be carefully controlled. Benefit–cost analyses of mangrove afforestation show marginally positive net benefits; this is significantly constrained by regulations that do not permit local use of mangroves even if there are sustainable uses. Most of the planted greenbelt mangroves will not contribute significantly to in situ biodiversity over the foreseeable future, and their sustainable management would provide additional livelihood benefits while also providing incentives to local populations for their wise use. As a carbon sequestration method, some 5,000 ha are currently being targeted in the Sundarbans through private and community-based initiatives with a potential area for this an order of magnitude greater. Such activities would, however, be optimized in a system that permitted sustainable harvesting on a 10–15-year cycle (consistent with the maturation period of the dominant *Avicennia* species) that also provides incentives to local communities to manage the carbon asset. It is important to note that an excessive area devoted to mangroves as a management technique may unnecessarily increase the tidal prisms, thereby exacerbating difficulties associated with augmented channel velocities which consequently increase erosion.

**Management controls should be implemented to regulate recharge of aquaculture ponds with estuarine waters.** The construction of canals allowing estuarine waters to reach aquaculture ponds for recharge purposes has significantly worsened channel bank erosion problems in many locations. This points to the need for controlling the location of aquaculture ponds and timing of recharge activities so that erosion problems do not continue to be exacerbated.

Clustering of islands, sluicing of smaller tributaries, or closing portions of channels can also serve as viable erosion control management techniques. Cutting off upstream portions of existing channels to create freshwater reservoirs provides a potentially

effective erosion control strategy. Reduction in erosion is possible because of decreases in the size of tidal prisms. This will also address a more general problem of ongoing vulnerability of small areas; such parts of the Sundarbans have a high ratio of perimeter to protected productive area and do not justify the investments required for embankments. Areas of about 20 km<sup>2</sup> in size are at a vulnerability threshold that does not warrant protection on economic grounds (depending on shape factors and land productivity). On the other hand, their complete abandonment may, in some circumstances, exacerbate problems if such abandonment significantly increases the tidal prism. Connecting these areas into a larger cluster provides protection while also improving the overall economic benefit–cost ratio. Within the study area, a total of 70 areas were defined in the Sundarbans complex of inhabited blocks in North 24 Parganas and South 24 Parganas districts.<sup>10</sup> The clusters ranged from 2.62 km<sup>2</sup> to 246 km<sup>2</sup> in area. Larger clusters are generally more cost-effective to protect and are more resilient, and it is clear that a number of these clusters fall below the “minimum economic size” demonstrated in the benefit–cost analyses. In addition, however, cluster “shape factors” are calculated for each of the 70 clusters; convex areas closest to a shape factor of a circle will have higher overall cost-effectiveness, while clusters with multiple concavities along the perimeter will be more vulnerable and costly to protect. It is noted that 13 of the clusters are less than 20 km<sup>2</sup> in area; 42 clusters are less than 50 km<sup>2</sup> in area. The detailed analyses provide guidance on which clusters are most vulnerable and merit aggregation with others.<sup>11</sup>

Saltwater intrusion is a problem throughout the Sundarbans and is most cost-effectively addressed in the short term through improved freshwater management. Tubewell sources (used in both piped and spot source systems) are becoming saline due to persistent saltwater intrusion, especially during cyclonic storms and floods. Problems are exacerbated by poor drainage due to low land levels: spot source tubewells are often submerged and inaccessible during floods. The PHED is implementing a program to raise the height of tubewells used as spot sources by 3–4 m. The floor levels of pump houses of piped systems also need to be raised to prevent submergence during floods. In addition, pond sources need to be protected by raising bunds around the ponds to prevent saltwater intrusion during floods. A number of alternative technology options exist, and small-scale community-based rainwater harvesting schemes show some promise. Desalinization is technically feasible but costly; a desalinization plant

with reverse osmosis has been implemented and is working well. Although it is expensive, reverse osmosis provides a technically feasible basis for providing salt-free water.

To summarize, the primary recommendations concerning estuary management include:

- **Realign embankments.** Embankment realignment is a cost-effective solution in areas where undercutting occurs; such undercutting can only be accommodated by retreat. Use of local materials will keep costs manageable if crest heights are gradually increased over a 100-year timeframe;
- **Do not abandon headwater areas.** Even small areas or islands that may not seem economically viable perform an important system function through decreasing the tidal prism and preventing erosion in areas closer to the Bay of Bengal. Preferentially these areas should be connected to adjacent areas;
- **Encourage mangrove fringes.** In areas of accretion, mangroves will tend to grow in any event. But where erosion is occurring, the planting of mangroves can be an important component of a strategy of embankment retreat. Mangroves themselves will not prevent the erosion and undercutting that is threatening many of the embankments in the Sundarbans, but planting or restoration of mangroves between old (abandoned) embankments and new (retreated) embankments will contribute to long-term system stability and also provide a basis for livelihood improvement;
- **Prepare complementary investments.** An investment in embankments is a core requirement in protecting the Sundarbans against isostatic and eustatic sea level rise. Other investments are, however, also critically important. High-priority candidate investments include: (a) improved management of aquaculture to reduce erosion elsewhere in the system; (b) selected investments to improve availability of freshwater, and freshwater storage; (c) modified transportation and communication infrastructure to accommodate embankment realignment; and (d) strategic sluicing and channel closures in headwaters; and
- **Build institutional capacity.** The nature of estuary dynamics and future potential hazards requires that adaptive management practices be adopted. This will involve ongoing monitoring of biophysical conditions that feeds into appropriate decision-making processes. Institutional capacity to adopt such methods

<sup>10</sup>Although historical background documents for the inhabited Sundarbans areas routinely mention “54 islands,” this specification was difficult to operationalize during the studies because of historical changes relating to channel closures, changes in estuaries and rivers, and other natural and anthropogenic influences. The analytical unit was thus redefined to specific “designated areas” (some of which were islands, others being multiple islands or existing low-lying polders within circle embankments). In total, 70 designated areas (or “clusters”) were digitized, with each cluster linked to the 2001 Census database related to villages; this also permits links to more aggregated block profiles that contain more recent economic data for blocks. The general operational definition of a “cluster” is an area encircled completely by a system of embankments, or by a system of embankments and high ground not directly vulnerable to tidal influences. Some areas are quite small while others are spread over two or more community development blocks; the 70 separate areas have a total area of 4,275 km<sup>2</sup> and a total perimeter of 2,833 km. The database links 1,071 distinct villages to the 70 clusters within 13 blocks in South 24 Parganas district and six blocks in North 24 Parganas district.

<sup>11</sup>No areas have been identified for immediate resettlement or abandonment beyond those already designated (in some cases) as “abandoned” or “uninhabitable” within current government mappings. There are, however, about 20 marginal areas where their size is too small to warrant long-term defenses by themselves but vulnerable populations require near-term support.



in the Sundarbans is weak, especially as it relates to intersectoral coordination and spatial planning. Any long-term strategy necessarily requires substantial institutional capacity-building efforts.

## 4.9. Building Resilience through Disaster Risk Management: Recommendations

DRM primarily involves addressing immediate needs through early warning systems, emergency preparedness, and cyclone shelters. In this section, a number of the design issues are presented.

**Recent disasters in the Sundarbans have demonstrated that storm surge losses still remain huge in many areas.** Thus, it is recommended that GoWB give priority to initiating several additional measures, which adequately prepare and protect coastal residents against the effects of tropical cyclones and associated storm surges. By allocating additional resources to decrease vulnerability to cyclonic events, losses of life and assets could be significantly reduced. The need for disaster preparedness along vulnerable coastlines is particularly important in the Sundarbans as climate scientists project increases in the intensity and frequency of cyclonic events for the region. Ideally, setting a new course to reduce vulnerability would be informed by a better understanding of expected changes in storm surge patterns in the future, and associated damages and adaptation costs.

**A disaster response and management scheme that will reduce vulnerability to natural events should be put in place.** This integrates an enhanced warning system, emergency shelters, disaster relief services, and a coordinated decision-making emergency management scheme. It is essential to have an effective and efficient warning system that reaches all segments of the population in a timely manner and that clearly and explicitly describes the nature of the event and landfall location. In addition, there should be an adequate supply of cyclone-resistant emergency shelters that are accessible to all Sundarbans residents. Proper disaster relief services are also needed, including access to adequate quantities of clean water and medical supplies. To serve as a blueprint for implementing the various disaster relief measures, GoWB should create an integrated and coordinated decision-making emergency management plan involving the relevant ministries and public agencies from national, state, and local governments, NGOs and volunteers, and segments of the military and coastguard. The plan should clearly outline specific directives, duties, and responsibilities prior to, during, and after an emergency.

It is essential to create a strong knowledge base for prediction as well as a communications network for use during emergencies caused by cyclonic events. The knowledge base should enable improved forecasting of cyclonic events, and the communication network (including warning systems) should allow for the efficient transmission of information and coordination among the national, state, and local levels in the Sundarbans during natural disasters. An effective emergency response plan should include improved ability to forecast the location and intensity of cyclonic events as well as outreach efforts to make all residents aware of the need for proper and timely evacuation. The plan should also make residents aware of specific evacuation plans and the locations of and routes to emergency shelters (as they are developed). The warning systems need to reach the coastal communities through dissemination from local governments, and should reach user agencies, health administrators, relief and rehabilitation authorities, and NGOs via methods such as television, megaphones, mobile phones, and even house-to-house contacts (especially for villages that do not have access to televisions or mobile phones).

**An adequate number of cyclone shelters should be created.**

The existing shelters cannot accommodate the vulnerable populations of the Sundarbans in case of an emergency. Action is needed to bridge the existing gaps. The effectiveness of these shelters depends on a number of variables, such as location, accommodation capacity, durability, maintenance, and availability of resources such as medical aid and safe water supplies. The number of cyclone shelters to be built and their accommodation capacity depend on the number of likely users and their locations. Clearly, areas with high population density are likely to need more shelters with greater accommodation capacity than areas with relatively lower population densities. An example of an adequate cyclone shelter project is one that includes the creation of a network of multipurpose cyclone shelters with elevated space for livestock and overhead water storage. During times other than emergencies, when cyclone shelters would otherwise not be used, they can be put into service as primary schools or office space. Such shelters can typically be built in six to nine months at a construction cost of about US\$100 per person accommodated in the shelter.<sup>12,13</sup>

## 4.10. Summary

This annex reviewed a number of findings and recommendations arising from the NLTA work, related specifically to natural and anthropogenic hazards. Fundamentally, all potential responses to climate-related hazards – which include sea level rise, increased storm strength and incidence, salinization, and channel evolution leading

<sup>12</sup>Dasgupta et al. (2010) observe that a World Bank-funded multipurpose cyclone shelter currently costs about US\$214,000 and can accommodate 1,600 people.

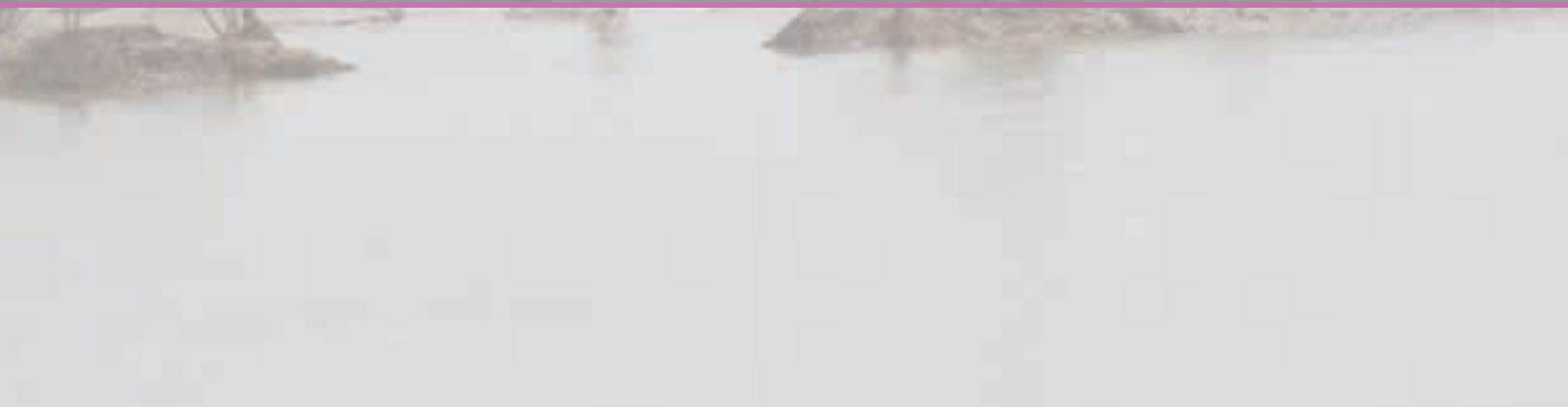
<sup>13</sup>Background documents for the NLTA contain proposed and current cyclone shelter projects for the Sundarbans and information about their designs. An 850 - km<sup>2</sup> shelter capable of housing 2,000–2,500 people and their livestock for four to five days was constructed in late 2010 as a pilot project for a community-based multipurpose shelter in the Sundarbans at a cost of approximately US\$200,000 based on designs by architects at Jadavpur University (NEWS, pers. comm.).



to embankment failure – require some form of adaptive response. All such responses can more generically be regarded as DRM, but a distinction is made between the long-term adaptive investments that must be made (such as embankment realignment) and more conventional near-term investments that relate directly to specific hazards. Cyclones represent the most direct threat, but planning should also reflect a broader integrated approach that plans for multiple coincidental emergencies (such as cyclones followed by epidemics), relies on redundant systems, and improves information resources. The presentation has not focused on a number of obvious but equally complex adaptive strategies, which rely on improvements in livelihoods, changing migration patterns, reestablishing or protecting critical biodiversity, or implementing comprehensive institutional reforms in key sectors. These and related complementary topics are treated in other parts of this NLTA.

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# Annex 5.

## Management Practices in Addressing Sea Level Rise, Floods, and Erosion<sup>1</sup>



### Abstract

Tidal estuaries constrained by embankments in the Sundarbans have failed to respond to a sea level rise of 0.2–1.6 m over the past 100 to 200 years since the construction of embankments. This has led to a disequilibrium morphology leading to channel erosion, undermining embankments and resulting in mass failure, breaching, and subsequent flooding during surge events. Predicted future sea level rise will exacerbate this trend and managed realignment of embankments will be needed to stabilize the situation. Management practices have, however, modified the underlying process of erosion. The increasing practice of severing tributary channels from the main channel using flap sluices in order to create freshwater storage ponds has, in many cases, reduced tidal flow in the main channels so that they are not only accreting rather than eroding but capable of accommodating future sea level rise without erosion. In contrast, the rapid spread of saltwater aquaculture in the Sundarbans, flooding previous paddy land, has led to an increase in tidal discharge and accelerated erosion of embankments in estuary channels conveying water to the ponds. Existing management practices may, therefore, have a more significant impact on flooding in the Sundarbans than the predicted sea level rise due to global warming.

### 5.1. Introduction

The Sundarbans region of West Bengal, India,<sup>2</sup> forms part of the delta of Ganges, Brahmaputra, and Meghna Rivers, which extends eastward from the Hooghly River (a distributary of River Ganga) to the Brahmaputra in Bangladesh. Much of the area of the West Bengal Sundarbans has been reclaimed for agriculture during the past 200 years but a significant seaward fringe of natural mangrove forest still exists.

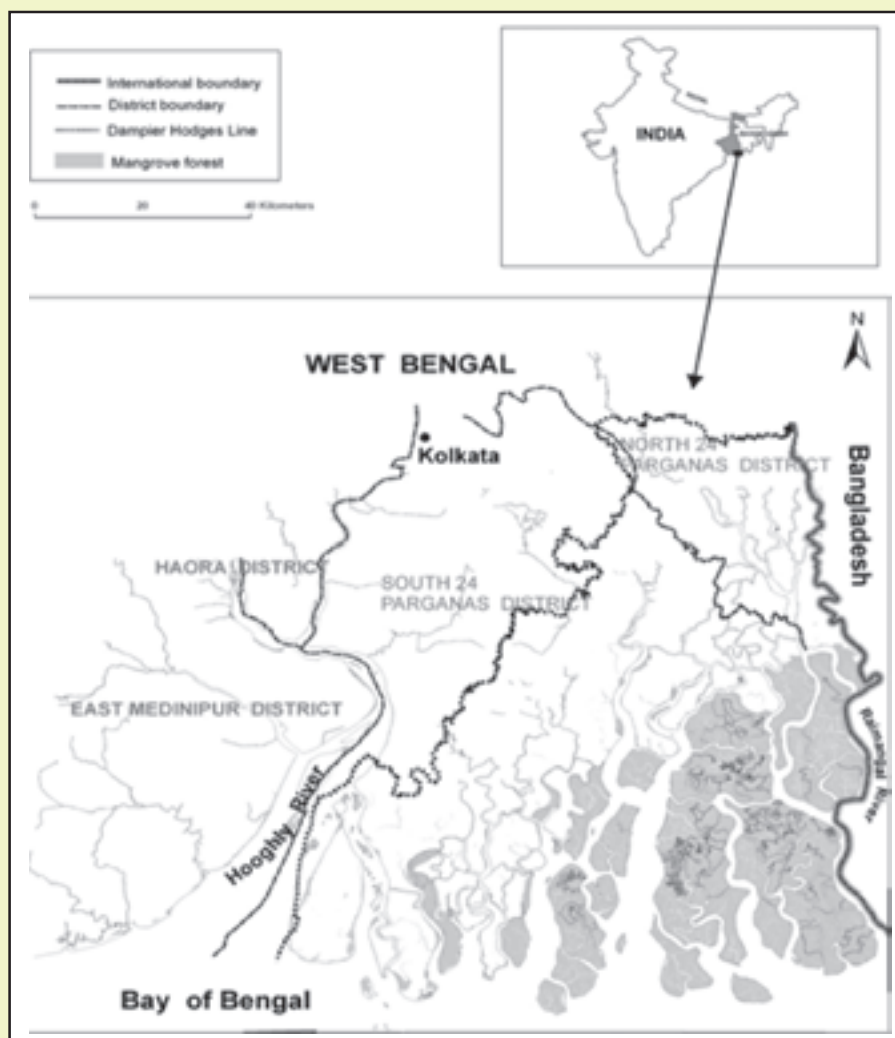
As a result of tectonic movements over the latter part of the Holocene epoch, the Ganges-Brahmaputra has moved eastward, so that today the fluvially active delta lies in Bangladesh, while the westward section in West Bengal, between the Hooghly and Hariabhanga Rivers on the India-Bangladesh border, receives no major fluvial contribution (Mukhopadhyay 2005). Nevertheless, this western section of the former fluvial delta has six major estuaries (Muri Ganga, Saptamukhi, Thakuran, Matla/Bidya, Gosaba, and Raimangal/Hariabhanga), which have large tidal volumes and which contribute suspended sediment to the extant intertidal areas. Consequently, despite the lack of fluvial input, this area of the delta cannot be regarded as fossil or abandoned. Indeed, as most of the sediment input to this area is moved landward by monsoonal influences, surge events, and estuarine flows (Allison and Kepple 2001), the western Sundarbans must be regarded as an integral part of the active delta. Thus it is misleading, both geomorphologically and from a management perspective, to consider this area a series of moribund islands whose ultimate fate must be to submerge beneath rising sea levels. Rather, it must be viewed as a series of active estuaries whose dynamics should inform the management of this densely populated zone.

The Sundarbans mangrove forest initially colonized this western area of the delta around 9,000 years ago, extending south as the delta front prograded (Sarkar et al. 2009). A temporary hiatus in mangrove development occurred around 4,500 years ago due to the mid-Holocene sea level high stand, but readvanced in the latter Holocene to a line now known as the Dampier and Hodges line after two surveyors who mapped the northern extent of the forest in 1831 (Figure A5.1). Reclamation of this original mangrove began in the late 18th century and reached a peak in the late 19th century under the colonial regime, which encouraged the *zamindar* landowners to construct embankments (Richards and Flint 1990) and clear forests to allow paddy cultivation. These clay

<sup>1</sup>This Annex was prepared by John Pethick, Tapas Paul, Somenath Bhattacharya and Kakoli Sen Sharma based on various reports and analyses prepared by John Pethick, Jack Ruitenbeek and the Institute of Environmental Studies and Wetland Management.

<sup>2</sup>The term “Sundarbans” is used in Bangladesh to define the area of natural mangrove forest in the seaward area of the Ganges-Brahmaputra-Meghna delta and excludes the landward reclaimed areas; however, in India the term is used to include both the mangrove forest and the reclaimed delta area.

**Figure A5.1: The Indian Sundarbans**



embankments have prevented siltation on the former intertidal surface so that their elevation has fallen relative to the rising sea levels (Stanley and Hait 2000).

## 5.2. Sundarbans Embankments

Relative sea levels in the Sundarbans are rising, due partly to eustatic processes but mainly due to land subsidence resulting from autocompaction, tectonic activity, and anthropogenic processes, including water abstraction from tubewells. Estimates of rates of subsidence vary from 3 mm per year (Khan and Islam 2008) to 5 mm per year (Stanley and Hait 2000). Those estimates, when added to estimates of eustatic sea level rise, means that relative sea level rise in this area of the delta varies from 2 mm to over 8 mm per year. For example, the Kolkata tide gauge at the landward edge of

the delta shows a relative sea level rise of 8.8 mm per year over the period 1932 to 1999, while the Sagar Island gauge at the seaward edge shows a 3.6 mm per year sea level rise over the same period.<sup>3</sup> This means that, over the past 100 to 200 years, since embankments were first constructed, there has been a rise in relative sea level of between 0.2 m and 1.6 m.<sup>4</sup> The impact of this increase in sea level on the embankment crest levels has been progressively offset by regular maintenance, carried out by local labor using in situ estuarine clay and silts; an arduous but cost-effective process.

More problematic is the impact of surge events on the embankments. The raised water levels and waves caused by surges, especially during cyclones, result in embankment overtopping in some cases, but more serious are the breaches in embankments, which lead to widespread flooding. For example,

<sup>3</sup>Permanent Service for Mean Sea Level website: <http://www.psmsl.org/>.

<sup>4</sup>Embankments were constructed between 100 and 200 year ago. Hence, the minimum is 0.2 m (100 x 0.002 m) and the maximum is 1.6 m (200 x 0.008 m).



Cyclone Aila, in May 2009, led to multiple failures of the embankments resulting in catastrophic flooding and loss of life, domestic animals, and crops. Observation of the causes of embankment breaching immediately after the cyclone indicated that the majority of breaches were the result of mass failure rather than overtopping or wave erosion. Such mass failures are the result of two factors: oversteepening of the embankment face by long-term channel erosion, and increased pore pressure within the clay structure due to water penetration during the surge event. Slope mass failures occur as a result of preparatory factors, such as slope profile steepening, and triggering factors, such as large storms or heavy rainfall (Fookes, Lee, and Griffiths 2007). In the case of the Sundarbans clay embankments, the slope profile includes the embankment face and also the intertidal zone on which it rests. If the estuarine channel erodes the intertidal area on which the embankment rests, then the overall embankment slope face steepens and the factor of safety is reduced so that the embankment is potentially unstable. The triggering factor for failure then occurs during high water levels such as surge events, when the embankment material becomes saturated, pore pressures become positive, and factor of safety for the already increased slope angle falls below 1.0. The key to embankment failure, therefore, rests with the mechanism whereby channel erosion undercuts the embankment intertidal footings, leading to increased slope angles and potential instability, which is then triggered during surge events. It is the process of embankment mass failure that is the focus of attention here and, in particular, the estuarine processes that have led to the undercutting of embankments causing the mass failures, breaches, and floods that have so often devastated the communities of the Sundarbans.

### 5.3. Sundarbans Estuaries: Tides and Channels

One of the most pressing needs for the India Sundarbans is to set up a comprehensive database upon which management decisions may be based. Of all the data requirements perhaps the most important is tidal and surge information; however, such data are almost entirely absent at the moment. Apart from the Delta Project report of 1968 (Delft Hydraulics 1968), there appears to be no published accounts of tides or surge frequency. The only permanent tide gauge is located at Sagar Island in the Hooghly estuary and although records have been kept there since 1937, these are made using a visual staff record operating only during daylight hours and are therefore incomplete.

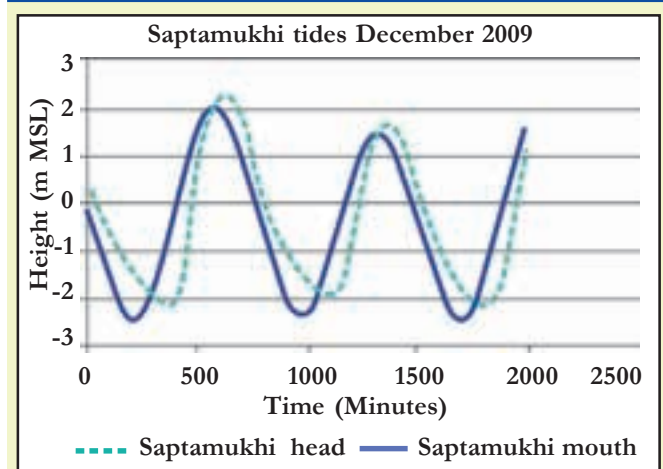
A limited tidal record was obtained for the present study in the Saptamukhi estuary using a temporary tide gauge deployed during a two-day spring tide period at the mouth and head of the estuary. Figure A5.2 shows that the tides at the mouth are semidiurnal and symmetrical, with a range of 4.5 m. However, 40 km landward at Milan More, the tide has become markedly asymmetric, with flood tide duration reduced to 4.3 hours, although the tidal range remains at 3.5 m. Such a marked flood

asymmetry in the landward reaches of the estuary suggests that sediment is moved landward in a relatively deep, narrow channel with limited intertidal areas (see, for example, Brown and Davies 2009; Pethick 1994), such as that shown in Figure A5.3 at the mouth of the Kalchara channel.

Bathymetric surveys of the Sundarbans channels are similarly lacking in the published literature. Surveys carried out for this study of the Kalchara channel, a major branch of the Saptamukhi estuary, demonstrate the range of channel morphology that exists. Figure A5.3 shows a comparison between the cross-sections at the mouth of the Kalchara at its junction with the eastern Saptamukhi estuary and that at the head of the Kalchara. The bathymetric data show mean depths decreasing from 12 m at the mouth to 4 m at the head, and similarly both the width: depth ratio and hydraulic radius decrease systematically landward (Figure A5.4). This morphology is typical of most macrotidal muddy estuaries and suggests that, despite the major modifications to the Sundarbans in the 18th and 19th centuries brought about by extensive reclamation and embankment construction, the estuarine geomorphology has adjusted rapidly to such change and now exhibits what appear to be stable forms.

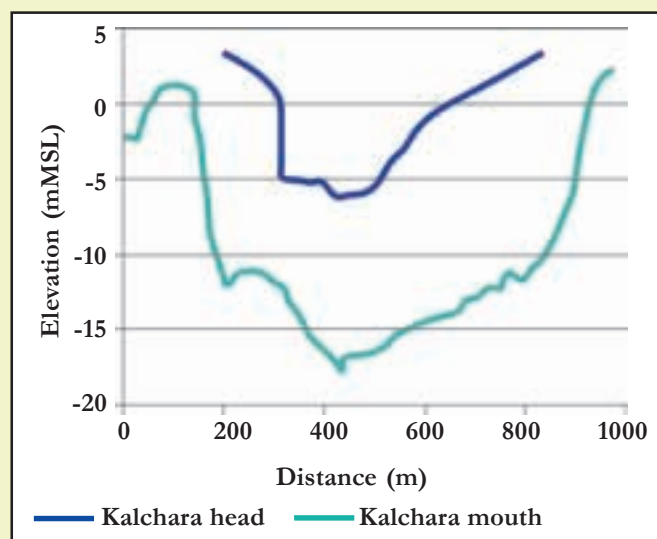
Such a general conclusion of estuarine stability must, however, be modified in the light of many problems affecting the management of these estuaries. These problems range from excessive accretion in many of the landward channels, impeding both freshwater drainage and navigation, to erosion of intertidal areas in other more seaward estuarine channels.

**Figure A5.2: Tidal Curves for Saptamukhi Estuary**

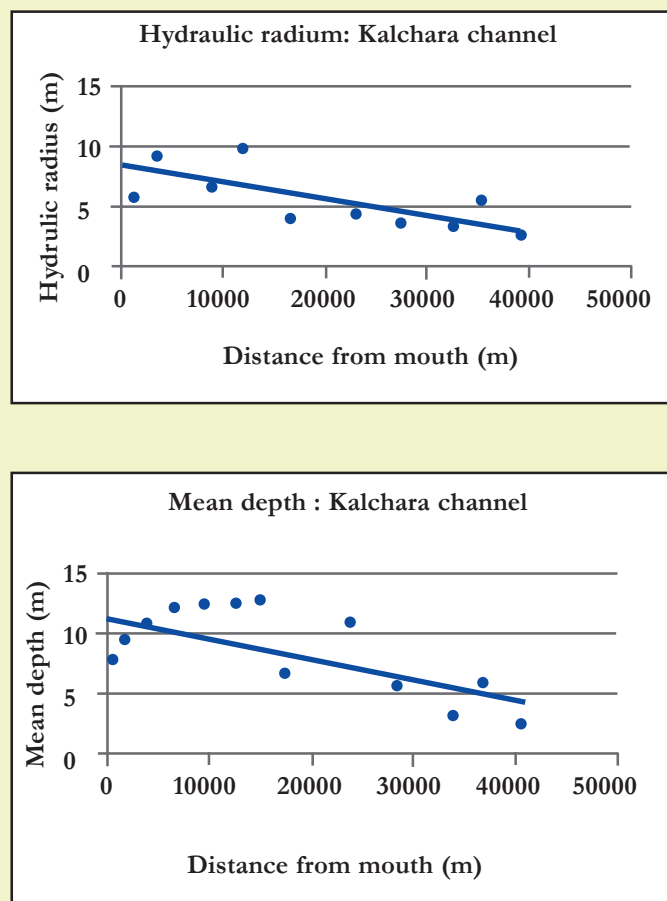


A general account of the Sundarbans estuarine geomorphology, based on these indicators of channel morphology, would suggest that, having lost their former sediment inputs from fluvial sources, the estuaries have now adjusted to a reduced sediment input, principally derived from marine sources. However, as intertidal sediment-receiving areas have been hugely reduced by reclamation over the past 200 years, all of the sediment input to the estuaries is carried landward by increasingly flood-dominant flows and is accreted in the smaller landward channels.

**Figure A5.3: Channel Cross-sections from Head and Mouth of Kalchara Channel, Saptamukhi Estuary (Vertical Exaggeration x10)**



**Figure A5.4: Mean Depth and Hydraulic Radius Variation with Distance Upstream, Kalchara Channel**



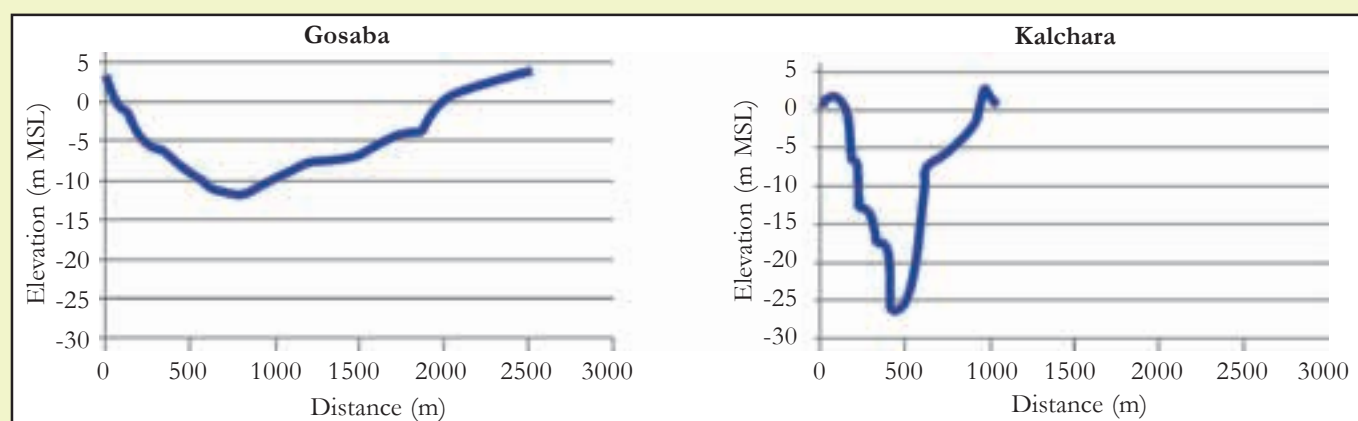
Offsetting this accretionary process is the impact of relative sea level rise. As the majority of embankments were constructed between 100 and 200 years ago, sea level rise since their construction could range between 0.2 m and 1.6 m depending on their location within the Sundarbans. The overall impact of such sea level rise will have been to increase intertidal cross-sectional areas, especially in the larger seaward channels where intertidal accretion is slow, causing undercutting and failure of embankments. This latter process of channel erosion is exacerbated by the presence of the embankments themselves which, despite their construction of intertidal silts and clays, nevertheless act to constrain channel development. This is shown in Figure A5.5, which compares an embanked channel, the Kalchara, with an unembanked estuary, in this case the lower Gosaba, which is bounded by natural and extensive mangrove. Although the channels have approximately similar cross-sectional areas, it can be seen that the embanked channel has eroded vertically, resulting in narrow intertidal areas with steep slope gradients of 1:10 compared with 1:100 for the unembanked Bidya channel. The result is that the factor of safety for embankments is reduced to a point at which an increase in pore pressure during surge events can cause failure and catastrophic flooding.

#### 5.4. Sundarbans Estuaries: Impact of Sea Level Rise

The impact of sea level rise on estuarine form depends, to a large extent, on its preexisting morphology and, in particular, the width and slope of the intertidal zone. In a rectangular channel cross-section with little or no intertidal surface area, sea level rise will have no morphological impact; assuming that the tidal frame rises at the same rate as sea level rise, the tidal prism will remain constant. For a trapezoidal channel section with a wide intertidal zone, however, sea level rise will increase the depth of water in the intertidal zone as well as causing an increase in the surface area of the intertidal flow. As a result, the tidal prism of the channel will increase, forcing a temporary increase in flow velocity leading to erosion, an enlarged channel cross-section, and a reduction in flow velocity: a homeostatic mechanism often referred to as “regime”. It should be noted that sedimentation on the intertidal surface would reduce or even cancel out these impacts, depending on the relative rates of sea level rise and sedimentation.

The Gosaba channel cross-section shown in Figure A5.5 illustrates the type of morphology that would maximize the impact of sea level rise. In this natural channel flowing through extensive mangrove, the wide intertidal zone with slope gradients of 1:100 means that sea level rise results in an increased tidal prism and, thus, the channel will erode to accommodate the increased flow. For example, an annual sea level rise of 1mm in this cross-section of the Gosaba estuary, assuming zero sedimentation on the intertidal surface, would result in an increase of  $2,500 \text{ m}^3 \text{ a}^{-1}$  for each 1 km channel length. The tidal range in the Gosaba is 6 m, cross-section mean intertidal depth 4.2 m, and width 2,500 m, so that the existing tidal prism is approximately  $10.5 \times 10^6 \text{ m}^3$  per km length; a sea level rise of 1 mm per year would, therefore, result in

**Figure A5.5:** Comparison between Cross-sections from an Embanked Channel (Kalchra Channel, Saptamukhi Estuary) and an Unembanked Channel (Gosaba Estuary) (Vertical Exaggeration x10)



a 0.02 percent increase in tidal prism per year. The resultant increase in channel cross-sectional area, although small, will be achieved mainly by width increase, as depth is relatively conservative with regard to tidal discharge (for example, Langbein 1963). Thus an annual sea level rise of 1 mm in this 2,500-m-wide section of the Gosaba estuary might be expected to result in bank erosion of 0.5 m per year. Sea level rise in the Sundarbans is, however, estimated above to range between 2 mm and over 8 mm per year, so that erosion rates for the Gosaba could range from 1 m to over 4 m per year. Such erosion rates characterize many Sundarbans estuaries where bank erosion is ubiquitously seen as recession of low intertidal cliffs.

In contrast, the Kalchra channel section shown in Figure A5.5 is bounded by embankments and flows through reclaimed paddy lands. Immediately after embankment construction in the 18th or 19th century, this channel would, most probably, have had a cross-section similar to the natural channel of the Gosaba today, so that the relative rate of response to sea level rise would have been approximately the same. Thus, a 1 m rise in sea level over the past 100 to 150 years would have resulted in an increase of over 10 percent in channel width, causing erosion of the intertidal zone and formation of the steep-sided cross-section seen today. The widened channel section shown in Figure A5.5 has undercut the embankments so that the factor of safety of these embankments is now reduced to the point of incipient failure.

The impact of future sea level rise on severely eroded channel cross-sections such as that shown for the lower Kalchra will, paradoxically, be minimal compared to the response of the natural mangrove channels such as that of the Gosaba. In such eroded cross-sections, the intertidal slope gradients of 1:10 or less are now so steep as to minimize any increase in tidal prism as sea level rises. Thus, a rise in sea level of 1 mm per year in the future would result in 0.02 m per year of horizontal erosion in the Kalchra compared to 0.5 m in the Gosaba. However, although further morphological change will be small, the impact of an increase in water levels on such steep-sided channels will be to cause increased water pore

pressure within the embankments and thus further reduce their factor of safety, resulting in mass failures.

The impact of future sea level rise on the smaller headwater channels such as that shown for the upper Kalchra in Figure A5.3 must also be considered. In these channels, accretion on the intertidal zone is rapid as a result of flood-dominant flow (Figure A5.2), leading to the development of wide intertidal areas with associated low slope gradients, often with mangrove colonizing the upper tidal levels. In such channels, the impact of future sea level rise is predicted to be similar to that outlined above for the unembanked section of the Gosaba: an increased tidal prism leading to enlargement of the cross-section in order to accommodate the increased flow. However, this process may be offset by the sedimentation on the intertidal area. If intertidal sedimentation rates can keep pace with the rate of sea level rise, then no increase in tidal prism will be experienced. Intertidal sedimentation rates of greater than 0.01 m per year are commonly experienced in these channels, so that a predicted rise in sea level of 0.5 m (as, for example, IPCC 2008) over the next 100 years would have no impact on channel morphology. However, if sea level rise over the next 100 years exceeds 1 m then it is probable that some morphological accommodation will occur.

It is clear from this brief summary of the impacts of sea level rise on Sundarbans channels that predictions of accelerated sea level rise due to global warming will have a potentially devastating effect on the integrity of the embankments, particularly in the larger, seaward channels. As these channels have widened in response to sea level rise over the past century, in many if not most cases, embankments are already at the point of incipient failure. Further increases in sea level accompanied by increased surge frequency will increase channel widths and depths, and lead inevitably to embankment failure with widespread flooding of agricultural lands whose surface elevation is more than 1 m below that of highwater spring tides.

Management response to such predictions must first consider the possibility of relocation of the embankment – so called managed

realignment— in order to allow accommodation of the increased flow regime brought about by sea level rise (Townend and Pethick 2003). Such realignment necessarily involves loss of agricultural land and must, therefore, be kept to an absolute minimum. The prediction of an optimum location for embankments in view of future sea level rise predictions is therefore a matter of some urgency.

## 5.5. Embankment Realignment: A Modeling Approach

In order to provide a prediction of optimum embankment location in response to sea level rise, a rapid regime-modeling approach has been used to derive equilibrium morphology for an estuarine channel based upon two major attributes: change in tidal prism due to sea level rise, and bed sediment characteristics. Sea level rise is assumed to result in an increase in tidal prism but only if intertidal sedimentation fails to keep pace with the rate of sea level rise, as discussed above. However, for the purposes of the model a worst-case scenario is assumed in which no intertidal sedimentation takes place. The increase in tidal prism resulting from sea level rise is then dependent on the specific intertidal morphology of the estuary under review, as outlined above. This worst-case assumption of a maximum impact of sea level rise on tidal prism results in prediction of estuarine width and, thus, embankment location that provides a margin of safety.

### 5.5.1 Sea Level Scenarios

Three sea level rise scenarios were input to the model:

- **No sea level rise.** Prediction of estuarine morphology is compared to existing, observed, morphology to allow model verification and error margins to be calculated;
- **Relative sea level rise of 1 m by 2100.** This is based on the prediction for a sealevel rise of between 0.26 m and 0.59 m by the year 2100, given in the IPCC Fourth Assessment Report prediction using the most pessimistic scenario family (A1F1) but excluding the impact of melting ice sheets (IPCC 2008). However, the Sundarbans is already experiencing isostatic relative sea level rise due to deltaic sinking of between 0.002 m per year and 0.008 m per year, a rise in sea level which, together with the eustatic sea level rise predictions of IPCC, implies a total relative sea level rise of between 0.46 m and 1.39 m by 2100; and
- **Relative sea level rise of 2 m by 2100.** An extreme forecast including the impact of ice sheet melting, based upon several published sources (for example, Pfeffer et al. 2008; Vermeer and Rahmstorf 2009).

### 5.5.2 Regime Modeling

Regime models are based on a semi-empirical approach in which estuarine cross-sectional area is related to tidal prism or discharge through the section. Simple power laws connecting discharge and

channel morphology have been used for many years in fluvial geomorphology, where they are known as hydraulic geometry (for example, Leopold, et al. 1964). In the coastal case, O'Brien (1931, 1976) and Escoffier ((1940, 1977) related tidal discharge or tidal prism ( $\Omega$ ) in coastal inlets to mouth area,  $A_m$ , using expressions of the type:

$$A_m = k\Omega^n$$

This approach was applied to a large sample of estuaries by Gao and Collins (1994), who derived empirical values for the  $k$  and  $n$  components of the basic power relationship. The approach has also been used by Spearman et al. (1998) and Pethick and Lowe (2000). Regime models are reviewed in Wallingford et al. 2007.

The approach in this study utilizes the basic hydraulic geometry relationship, calibrated using samples from the United States of America from Jarrett (1976), and the worldwide sample established by Gao and Collins (1994). The tidal prism for each estuary, included in the model runs, was calculated using remote-sensed satellite imagery, supplemented with bathymetric field survey, of high water and low water marks along each channel together with tidal range information established from field deployment of tide gauges. Tidal prism was calculated for 250-m increments of distance along each estuary.

Once the cross-sectional area had been predicted for a given section, the mean depth of the section was estimated using the classic Lacey equations for steady regime flow in alluvium channels (Lacey 1930), which was found to give reasonable prediction of mean channel depth in Bangladesh tidal rivers by Rahman and Haque (2004). Lacey's equation includes an estimate of channel bed sediment grain size and this was obtained from sediment samples from each estuary included in the model. Once cross-sectional area and mean depth are established, channel width is then calculated for each 250-m increment along the estuary. This equilibrium channel width for each sea level rise scenario indicates the optimum location for the flood embankments.

### 5.5.3 Study Area

The study area includes all of the India Sundarbans between the Hooghly estuary and the border with Bangladesh. However, within that area, the work focused on specific major estuarine systems and their associated tidal channels, namely:

- Saptamukhi system: Kalchara, Gobadia, Ghughudanga Gang, Banstala Gang;
- Matla estuary;
- Bidya system: Pathanakhali Nadi; and
- Raimangal system: Bhanga Khal/Jhila River.

Only the embanked lengths of each of these estuaries was included in the study; the seaward lengths of each estuary with no embankments and normally enclosed by mangrove forest were not included. The Thakuran estuary was not included in the study due



to lack of data. Figures A5.6 and A5.7 show the estuaries and channels included in the study. Where major braided channels occur, as in the Bidya/Pathanakhali Nadi and Bhanga Khal, these adjacent channels have been incorporated into the model. Although this coverage does not include many important channels, it does give a broad indication of the geomorphology of the Sundarbans estuaries and their embankments.

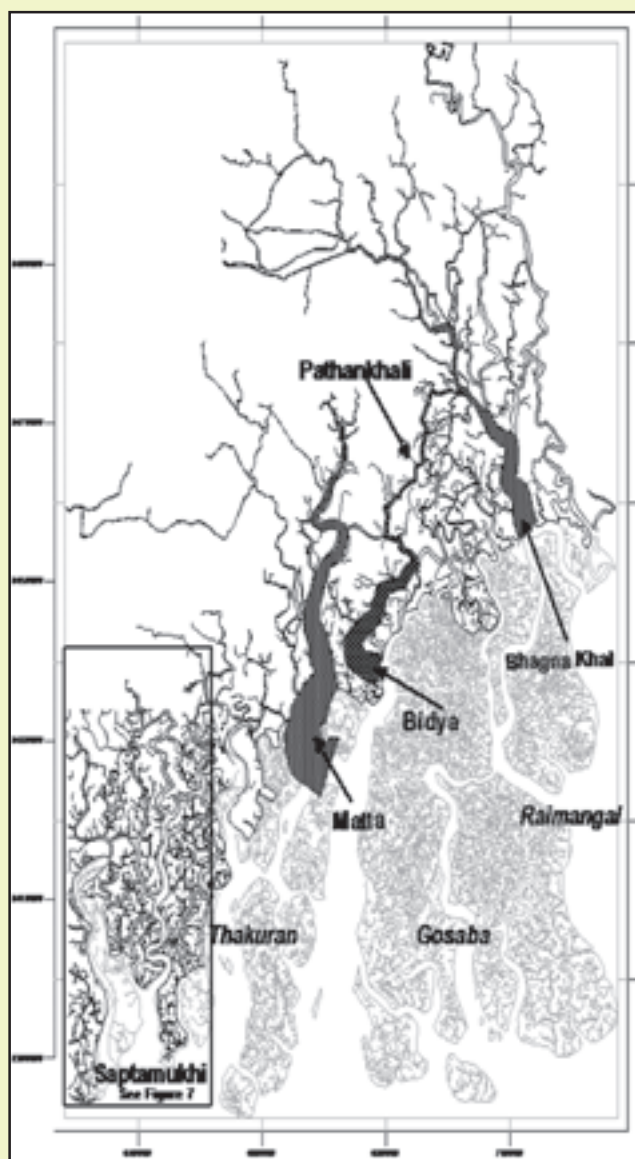
The study included a detailed field survey of the Kalchara channel in the Saptamukhi estuarine system, including bathymetric survey and tidal measurements. These field data were then used to provide verification of the model predictions before model application to the remaining estuaries.

#### 5.5.4 Model Verification

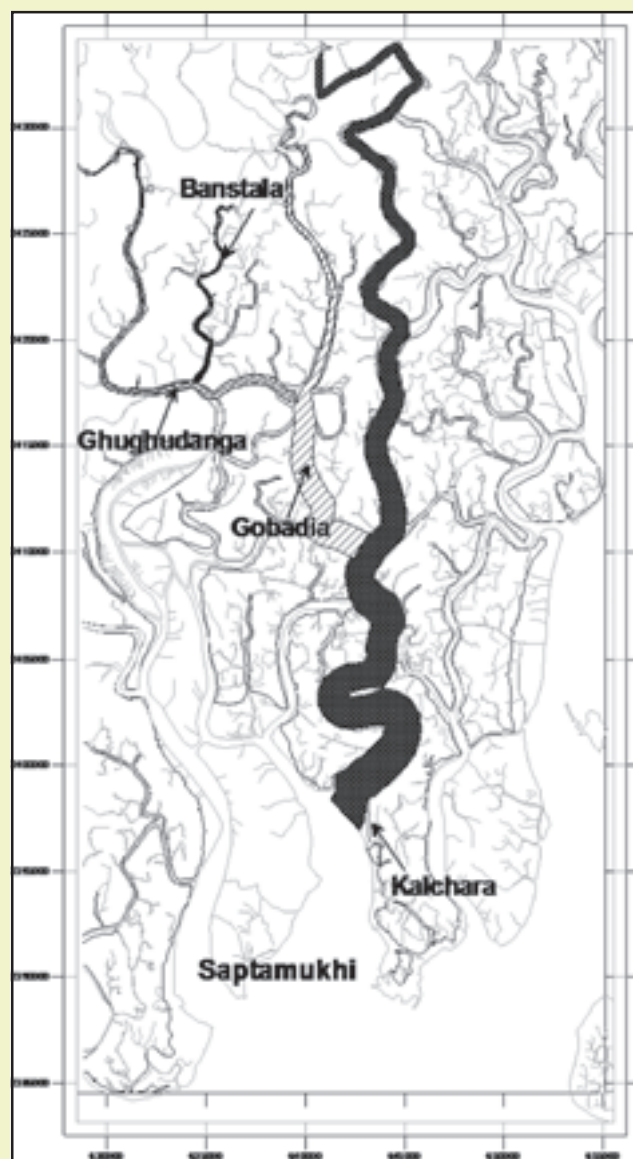
Model verification was achieved using measurements of channel width and depth obtained from field surveys of the Kalchara channel in the Saptamukhi estuary, and these were compared with model outputs for that channel.

Channel mean depth was surveyed along the 50-km-long Kalchara channel of the Saptamukhi estuary. Bathymetry was surveyed using echo-sounding equipment linked to a Global Positioning System (GPS) location and locally deployed tide gauges. Model prediction of mean depth using the Lacey equation was then compared to the field data (Figure A5.8). The regression coefficient

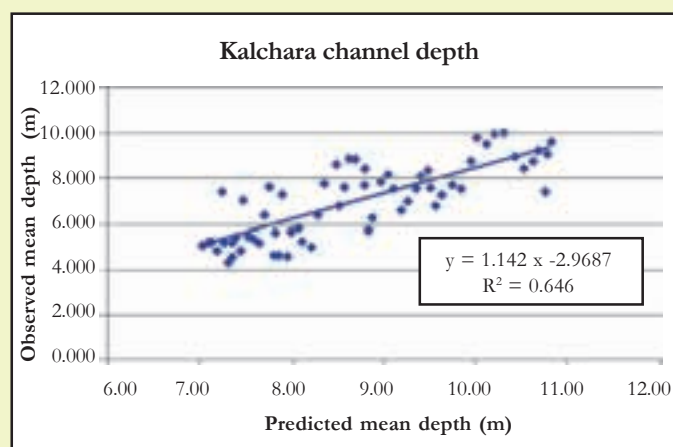
**Figure A5.6:** Study Area Showing Estuaries Referred to in Text



**Figure A5.7:** Study Area Showing Channels of Saptamukhi Estuary

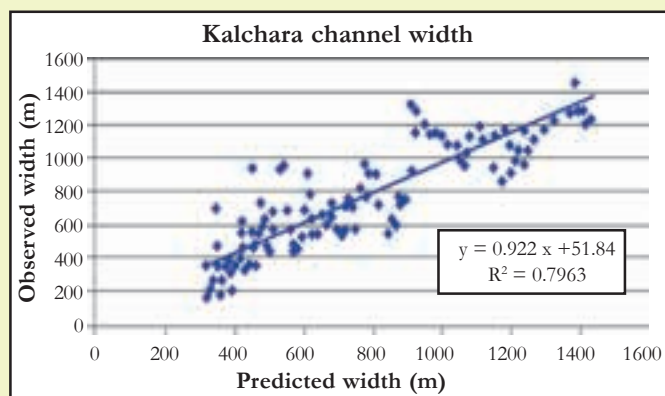


**Figure A5.8: Comparison of Observed and Predicted Channel Mean Depths**



*Note:* A best-fit regression line to the data is shown together with the regression equation and  $R^2$  values.

**Figure A5.9: Comparison of Observed and Predicted Channel Width**



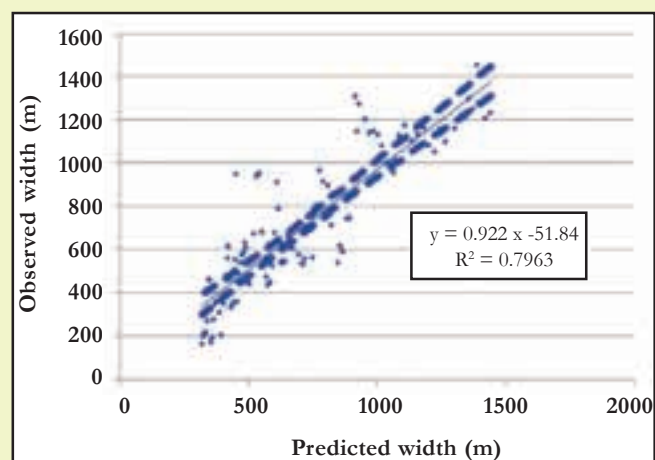
*Note:* A best-fit regression line to the data is shown together with the regression equation and  $R^2$  values.

for the relationship is 1.14 and the  $R^2$  value is 0.67. The correlation coefficient of 0.82 indicates that this is a highly significant statistical relationship ( $P < 0.0001$ ).

Model predictions of channel width, based on the existing tidal prism, were derived from the channel mean depths and predictions of cross-sectional area at increments of length along the Kalchara channel. These model predictions were compared to field measurements of channel width. Figure A5.9 shows that the regression coefficient for this relationship is 0.92 and the  $R^2$  value is 0.796 with an associated correlation coefficient of 0.89 and  $N = 64$ , again indicating a highly significant statistical relationship.

The 95 percent confidence (standard error) limits for the predicted versus observed width data (Figure A5.10) show that the confidence limits for the predicted channel width is 4 percent for average channels but increases to 10 percent for channels wider than

**Figure A5.10: Comparison of Observed and Predicted Channel Cross-section Areas with 95 Percent Confidence Limits (Dashed Lines) Superimposed**



1.5 km or narrower than 250 m. This means that predictions for a channel of 1,000 m width will have confidence limits of  $\pm 40$  m, increasing to 200 m for a channel 2 km wide, while those for a channel 200 m wide will have confidence limits of  $\pm 20$  m. These error margins are taken into account when defining optimum embankment location.

## 5.6. Results

Discussion of the results of the modeling distinguishes between three channel types:

- **Existing channel morphology.** In many cases, this morphology has not yet adjusted to existing environmental conditions;
- **Equilibrium channel morphology.** This refers to the predicted equilibrium morphology adjusted to existing environmental conditions (present-day sea level and management practices) but does not include any future sea level rise; and
- **Future equilibrium morphology** after a sea level rise of 1 m or 2 m.

The prediction of equilibrium morphology or of changes in channel widths as a result of future sea level rise, using a regime modeling approach, is time independent, in that it assumes that sufficient time will have elapsed to allow equilibrium morphology to develop. The model, therefore, does not provide any indication of processes, such as the rates of accretion or erosion that may lead to the development of a final, equilibrium or steady state morphology.

Model predictions of equilibrium channel morphology based on existing environmental conditions, assuming no sea level rise, show a wide disparity between the degree to which estuaries have attained such an equilibrium. Small channels such as the Banstala Gang and Ghughudanga Gang (for location, see Figure A5.7) are predicted

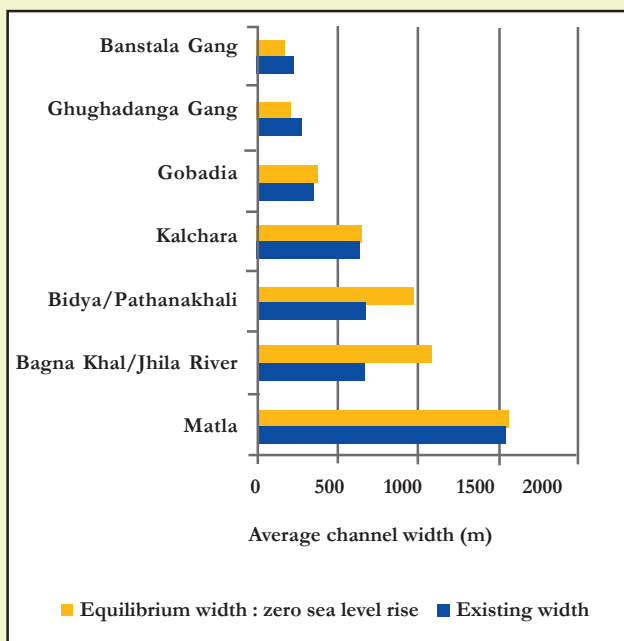
to be oversized on average, while larger estuaries such as the Bidya are significantly undersized (Figure A5.11). The Kalchara channel and Matla estuary, however, are both approximately in morphological equilibrium despite their wide disparity in size.

If the predictions for width in response to a future 1 m sea level rise are compared to the predicted equilibrium values for zero sea level rise (Figure A5.12), the differences are seen to be relatively small: on average, for all estuaries, the increase in channel width necessary to accommodate the 1 m sea level rise is 30 m, and 54 m for a 2 m sea level rise.

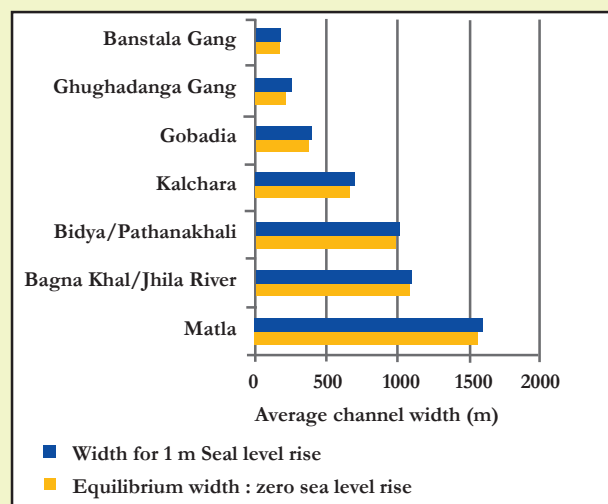
In contrast, the differences between the predicted widths in response to a 1 m sea level rise and existing channel widths are relatively large (Figure A5.13). The average increase from the existing value to the equilibrium width for a 1 m sea level rise for all estuaries in the study is 133 m. This large discrepancy is due to the adjustments necessary to bring existing estuary channels into equilibrium with present-day conditions as well as adjusting to a future 1 m sea level rise. The possibility that these present-day conditions may include management interference with the channel morphology, as well as changes in sea level in the recent past, is discussed below.

It may be concluded, first, that the morphological response to predicted future sea level rise is, on average, less than that needed to bring estuarine morphology into equilibrium with the existing environmental conditions; and second, that a wide disparity exists between the morphological status of each of the Sundarbans estuaries.

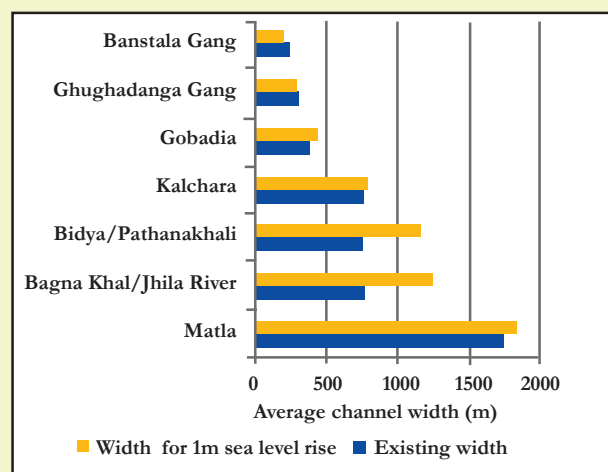
**Figure A5.11: Existing Average Width of Estuarine Channels Compared to Predicted Equilibrium Values for Zero Sea Level Rise**



**Figure A5.12: Response to 1 m Sea Level Rise Compared to Equilibrium Width**



**Figure A5.13: Comparison between Existing Channel Widths and Predicted Width after 1 m Rise in Sea Level**



## 5.7. Discussion

One of the most important outcomes of the modeling has been the identification of a wide morphological disparity between the Sundarbans estuaries. While some are accreting, others are eroding; while some are undersized compared to their equilibrium channel dimensions, others are oversized. It is difficult to attribute these fundamental differences merely to environmental variation across the Sundarbans, as the tidal, sedimentological, and ecological environment is relatively uniform throughout the study area. The differences may, however, be due to anthropogenic impact on estuarine morphology. All of the estuaries in the study have been embanked so that they are all, to some extent, artificial. In particular, the widths of the channels are constrained by the embankments and, in many cases, measurement of channel width between the high tide marks is, in fact, the width between the embankments on either bank.

One major environment change since embankments were constructed in the 18th and 19th centuries is a rise in sea level associated with an increase in the tidal prism of the estuaries. This could explain why many channels are predicted to be undersized – that is, their observed widths are narrower than those predicted by the model. As discussed above, evidence from tide gauges shows that the historical rate of sea level rise in the Sundarbans has ranged from 0.002 m per year to 0.008 m per year: a total of between 0.3 m and 1.2 m over the past 150 years. However, modeling results indicate that a sea level rise of 1 m would lead to an increase in width of between 10 m and 63 m, depending on the channel under review. Even if the larger figure is considered, this fails to explain the discrepancies of 300 m to 400 m between observed and predicted widths shown by the Bhanga/Jhila and Bidya estuaries. Thus, although past sea level rise may be a contributing factor to the present-day undersized channels, it cannot be the only factor involved.

In contrast, many smaller channels are shown to be oversized, that is, their observed channel widths are larger than the model predictions. In the Banstala Gang, for example, channels are predicted to be over 100 m wider between their existing embankments than their predicted equilibrium morphology. This means not only that these channels are already developing extensive mangrove on their upper intertidal margins but that they will be capable of accommodating future sea level rise of over 1 m without any impact on embankment integrity.

Finally, several estuaries appear from the model results to have present-day widths that are in agreement with predicted values: that is, neither under- nor over-sized. These include the Gobadia and Kalchara channels in the Saptamukhi estuarine system and the embanked section of the Matla seaward of Canning, as shown in Figure A5.13. This apparent equilibrium status is however ephemeral as, in each case, the intertidal areas of these channels are extensively eroded and their embankments are at the point of collapse, so that there is little, if any, accommodation space.

To summarize, it appears that three classes of estuary channel may be identified in the Sundarbans:

- **Oversized.** Channels significantly wider than predicted for the present-day tidal regime (for example, Banstala, Ghughudanga): large accommodation space;
- **Equilibrium.** Channel widths approximately in agreement with predicted values but at incipient erosional stage (for example, Kalchara, Matla): zero accommodation space; and
- **Undersized.** Channels significantly narrower than predicted for the present-day tidal regime (for example, Pathanakhali Nadi, Bhanga Khal/Jhila River): negative accommodation space.

## 5.7.1 Oversized Channels

One explanation for the oversized channels in these upper reaches of the Saptamukhi estuary may be the management practice of constructing sluices across the mouths of the first-order tributary creeks in order to prevent tidal ingress and thus form freshwater reservoirs. This practice appears to have increased dramatically over the past few decades and has resulted in a significant reduction in the tidal prism of the major channels that formerly fed tidal water into these first-order tributaries. Consequently, the major channels are now oversized and are experiencing accelerated accretion, especially on their upper intertidal areas, which are becoming colonized by mangrove vegetation.

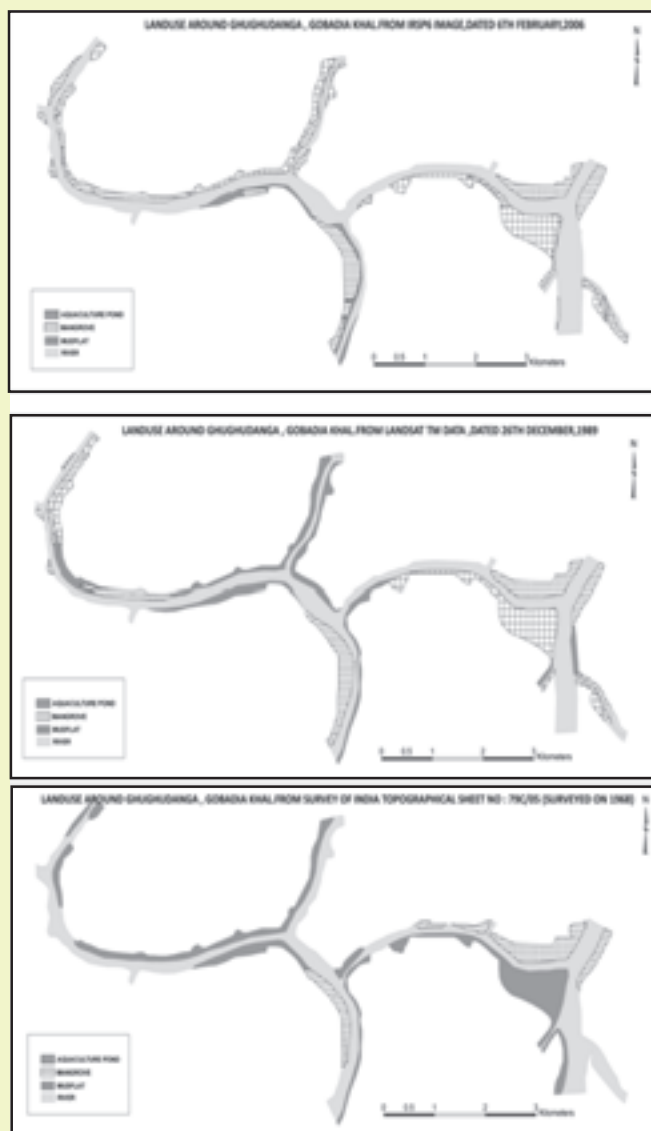
To test this hypothesis, satellite imagery of the upper Saptamukhi was examined, including the Gobadia, Banstala, and Ghughudanga channels from 1989 (Landsat TM) and 2006 (IRS-P6) to map the mangrove and mudflat intertidal areas. These maps were compared with the Survey of India topographic map dated 1968 (Figure A5.14). Results indicated that, whereas the surface area of the estuary channels at high water decreased from 661 ha to 446 ha during this period, the area of mangrove increased from 102 ha to 185 ha (Figure A5.15). This is indicative of a decrease in tidal prism, but to investigate this further the length of creeks upstream of sluices was mapped using satellite imagery from 2006 and compared with the Survey of India topographic map from 1968.

Results showed that, during the past 42 years, these channels – Banstala, Ghughudanga, and Gobadia – have experienced major loss of tidal tributary creeks due to the conversion of upper creeks to fresh water by sluice construction. The total length of creeks thus separated from tidal flow in the three estuarine areas amounts to 95.6 km, with an estimated loss of tidal prism to the main channel of  $19.7 \times 10^6 \text{ m}^3$ . The total tidal prism of the three estuary channels today is  $60.9 \times 10^6 \text{ m}^3$ , so that the loss of these upper creeks to tidal flow resulted in a 24 percent decrease in tidal prism within the main channel.

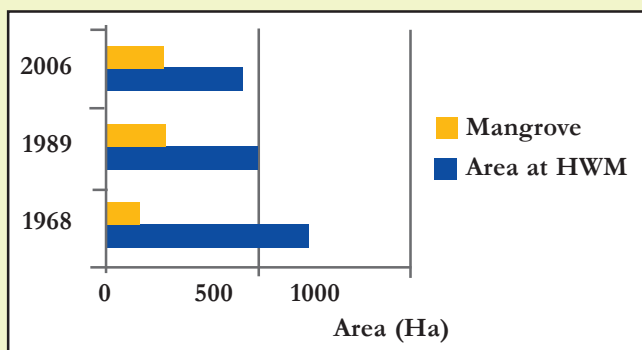
The impact of this loss of tidal prism may be seen in the regime model prediction for the width of the Banstala channel compared to the predictions for the Kalchara channel. Figure A5.16 shows that the equilibrium width for the Banstala channel is predicted to be approximately 30 percent narrower than the actual width as measured between embankments. In contrast, the larger Kalchara channel, with a total tidal prism of  $267 \times 10^6 \text{ m}^3$ , has been relatively unaffected by the loss of  $19.7 \times 10^6 \text{ m}^3$  due to sluice construction in its upper reaches – a reduction of only 7 percent compared to the 24 percent loss to the smaller upstream channels. This is reflected in the predicted widths for the Kalchara channel (Figure A5.17), which, as discussed above, closely match the observed values.



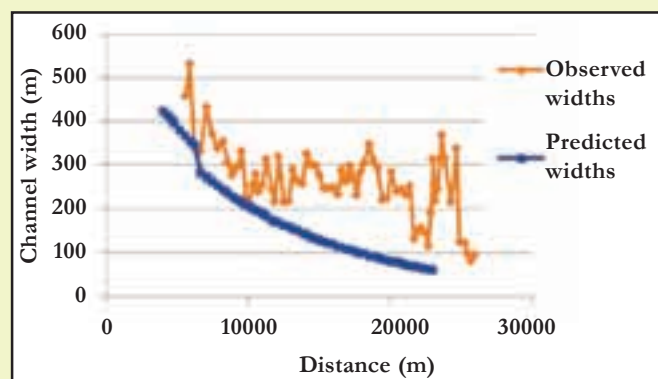
**Figure A5.14:** Changes in Mangrove, Intertidal Mud Flat, and Low Water Surface Areas in 1968, 1989, and 2006



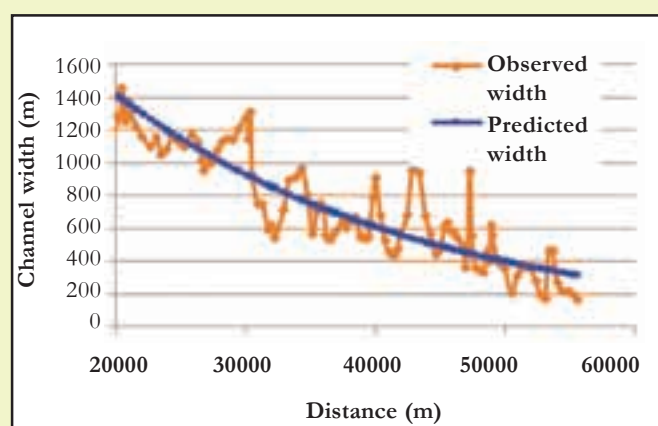
**Figure A5.15:** Changes in Estuary Water Surface Area at High Tide and Mangrove Area in 1968, 1989, and 2006



**Figure A5.16:** Predicted Compared to Observed Channel Widths for Banstala Channel, Saptamukhi Estuary



**Figure A5.17:** Predicted Compared to Observed Channel Widths for Kalchara Channel, Saptamukhi Estuary



*Note:* Increase in width at 10.8 km from the mouth due to junction with the Walsh Channel.

The reduction in tidal prism in the upper reaches of the Saptamukhi estuary may also explain the variation in the responses to future sea level rise shown in Figure A5.13. If the progression downstream from the Banstala through the Ghughudanga and Gobadia to the Kalchara is followed in Figure A5.13, comparing existing widths to predicted widths after a 1 m sea level rise, it can be seen that, in the upper reaches, a sea level rise of 1 m will be accommodated within the existing Banstala and Ghughudanga channels, which are predicted to be 100 m wider than necessary, so that these channels are predicted to accrete despite sea level rise. However, in the seaward reaches of the Gobadia and Kalchara, channel widths are predicted to be 80 m narrower than needed to respond to a 1 m sea level rise, so that these channels are predicted to erode in response to sea level rise.

### 5.7.2 Equilibrium Estuaries

Several estuaries in the study area appear to be in equilibrium with

their tidal environment. These include the Kalchara and Gobadia within the Saptamukhi estuary system and the Matla estuary in its embanked sections. The predicted widths of these estuaries for the existing seal level are shown (Figure A5.13) to be in agreement with the existing widths, suggesting that they have attained equilibrium morphology. However, inspection of cross-sections for the lower Kalchara channel (Figure A5.3) indicates that its intertidal zone has been extensively eroded so that it is narrow and steep and its embankments are undercut to the point of incipient collapse, suggesting that the apparent equilibrium here is merely superficial. Although bathymetric data are not available for the embanked Matla, field observation suggests that, in the most seaward sections, the embankments are similarly undercut.

It is concluded that these estuaries have experienced sea level rise over the past 100 to 150 years since embankments were constructed, resulting in gradual widening of the channels. Model predictions indicate that channels would have widened by between 10 m and 60 m for a 1 m sea level rise. As the channels are constrained by the embankments, this widening has resulted in loss of intertidal area and channel bed scour, as shown in Figure A5.3. This means that there is no accommodation space within these channels and that any further sea level rise will result in embankment collapse.

### 5.7.3 Undersized Channels

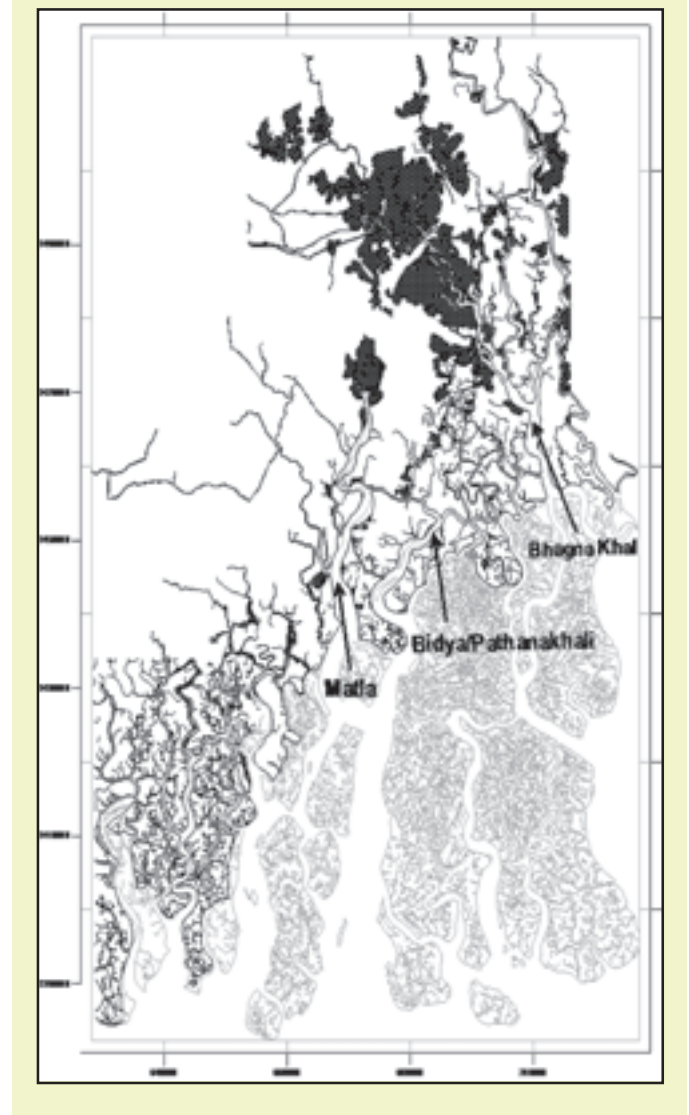
The model predictions for the estuaries in the east of the study area – the upper Bidya and Raimangal – contrast with those from the Saptamukhi estuary in the western Sundarbans. The two channels known as the Pathanakhali Nadi and the Bhanga Khal/Jhila River are both significantly undersized when compared to their predicted equilibrium morphology. The Pathanakhali Nadi in the upper Bidya is 340 m narrower than its predicted equilibrium, while the Bhanga/Jhila in the upper Raimangal estuary is 420 m narrower.

One possible explanation for this discrepancy might be failure of these channels to erode quickly enough to keep pace with the rise in sea level since embankment construction. However, as pointed out above, a rise of 1 m in sea level over the past 150 years would only account for a potential maximum increase of 60 m in channel width and could not explain the 300–400 m discrepancy noted for these estuaries. Instead, a radical alternative explanation is proposed: that an increase in tidal prism in these eastern estuaries has been caused by the recent proliferation of aquaculture in the region.

Aquaculture is an increasing landuse practice within the Sundarbans. Over much of the area, this is carried out using low-intensity management techniques, with open ponds flushed and recharged by tidal water usually on a two-week, spring tide cycle. The water for this recharge is derived from the estuaries connected to each pond by a complex system of feeder canals. This recharge constitutes a demand for tidal water ultimately derived from the sea and conveyed to the ponds via the estuary channels. The resultant increase in the tidal prism of the channels causes them to erode.

The extent of aquaculture in the Sundarbans, mapped from satellite imagery (Figure A5.18), shows that the major areas of aquaculture are directly connected to the Pathanakhali Nadi and Bhanga Khal/Jhila River, with a much smaller area connecting with the Matla. The Saptamukhi estuary catchment has almost no aquaculture development.

**Figure A5.18. Areas of Aquaculture Ponds (Shaded) Mapped from Satellite Imagery (2004)**



Calculation of the contribution made to the tidal prism of each estuary is difficult, as management of the ponds is largely unregulated so that no records exist. Enquiry of several managers in the field suggests that ponds are emptied and recharged only during the highest spring tides. The process often takes up to four tides to complete and the pond water depth involved is approximately 0.5 m. Applying these figures to the total area in each catchment allows an approximate calculation of the tidal volumes involved in their recharge per tide, and these are shown in Table A5.1.

**Table A5.1: Contribution of Aquaculture Ponds to Tidal Prism in the Bhanga (Raimangal), Bidya, and Matla Estuaries**

	Matla	Bidya	Bhanga
Aquaculture area (ha)	5,428	3,759	30,443
Aquaculture volume per tide ( $10^3 \times \text{m}^3$ )	5,496	4,505	38,054
Tidal prism of estuary ( $10^3 \times \text{m}^3$ )	1,922,531	225,888	196,622
Aquaculture/tidal prism (%)	0.28	1.99	19.35

It can be seen from Table A5.1 that aquaculture has the potential to increase tidal prism in the Bhanga by 19 percent, in the Bidya by 2 percent, but in the Matla by only 0.3 percent. These increases in tidal prism over the past few decades would explain why the Bhanga and Bidya are significantly narrower than their predicted widths: they have not had sufficient time to adjust to the newly imposed tidal conditions.

The impact of aquaculture on tidal channel morphology is proposed here only as a tentative hypothesis requiring further testing. In particular, detailed measurement of tidal flows during aquaculture pond recharge would be needed in view of the lack of any formal record of recharge events. It does appear from the limited circumstantial evidence offered here that aquaculture does have an impact on tidal morphology and that it may account for the instability of embankments in these upper reaches of the eastern Sundarbans estuaries – particularly during surge events. The widening channels erode intertidal areas and undercut embankments so that, during surge events when embankment sediments become saturated, mass failure occurs, causing widespread flooding through the resultant breaches.

#### 5.7.4 Managed Realignment

The conclusion to be drawn from this study is that in many, but not all, of the estuaries within the Sundarbans, a future 1 m sea level rise will necessitate realignment of the existing embankments in order to allow a wider tidal channel to develop. Failure to do so will result in erosion of intertidal areas and undercutting of embankments, causing their failure and widespread flooding. Such realignment incurs, of course, loss of agricultural land and, in some cases, settlements, and consequently, in order to justify such a management decision, a detailed benefit–cost analysis is required, based on the amount of increase in estuary width and loss of land needed to accommodate future sea level rise. The prediction of the amount of change in an estuary width, however, cannot assume that the existing estuary has reached equilibrium with its existing environment. In many cases, as discussed above, the existing estuary channel is still catching up with environmental impacts that occurred some time ago and these too must be accommodated in a realignment program.

As shown by this analysis, the distance over which embankments must be moved back depends entirely on their location. In most cases, this distance will be less than 100 m, that is 50 m on each bank, in order to accommodate a sea level rise of 1 m. In other cases, such as the Banstala, no realignment will be needed as the channels are already oversized due to management practices. But in estuaries such as the Pathanakhali and Bhanga Khal, unless major changes in aquacultural practices are initiated, realignment must be over distances in excess of 300 m (150 m on each bank) in order to accommodate the combined impacts of future sea level rise and aquacultural discharges. In addition to the realignment distance to accommodate sea level rise, in many cases, it would also be judicious to incorporate a further setback distance of between 30 m and 50 m to allow development of fringing mangrove to reduce wind velocities during cyclones.

Embankment realignment will, therefore, be necessary and widespread, but it should be carefully tailored to fit each location using the type of predictive methods outlined here.

It may also be tentatively concluded that the practice of closure of headwater creeks with flap sluices to produce freshwater reservoirs could be a potential management tool. Such creek closure reduces tidal prism in the main channels and, thus, provides accommodation space for future sea level rise. It may be that limited use of this small-scale technique could be beneficial, but experience in other estuarine systems indicates that closure of larger channels can have a significant impact on the tidal processes of the outer estuaries and lead to irreversible changes in their morphology.

#### 5.7.5 Unembanked Areas

Although this study has focused attention on the embanked estuary channels, an important outcome of the work has been a recognition that the natural, unembanked, mangrove channels will, paradoxically, demand far greater accommodation space to respond to sea level rise than the embanked channels. This arises from the fact that natural channels exhibit extensive intertidal areas, mostly colonized by mangrove, so that increased tidal prism will occur as sea level rises.

Calibration of such changes has not been undertaken in this study, but it is clear that significant loss of mangrove habitat will occur unless sedimentation manages to keep pace with sea level rise. The loss of wildlife habitat, including that of the threatened Bengal tiger, may be an inevitable consequence. Management intervention will not be possible, unless in the form of far-field attempts to increase the supply of suspended sediment into these areas.

### 5.8. Conclusions

A detailed study of the morphology and tidal environment of the Sundarbans estuaries suggests that there exists a wide range of adjustment to prevailing and predicted future sea levels. Three classes of adjustment are identified in this study:

- Oversized estuaries in which removal of head water creeks from tidal flow using flap sluices has reduced tidal prisms and increased accommodation space for future sea level rise;
- Equilibrium estuaries in which existing channel widths have kept pace with past sea level rise but in which accommodation space is now at a minimum so that future sea level rise will result in major embankment collapse; and
- Undersized estuaries that result from a combination of past sea level rise together with a recent increase in the tidal flow to and from aquaculture ponds. Accommodation space in these estuaries is already negative so that a response to future sea level rise is predicted to be severe.

Future management of the Sundarbans estuaries must, therefore, recognize these inherent differences and adjust the response to future sea level rise accordingly. In the oversized estuaries, no response will be required. In the equilibrium estuaries, a managed realignment of embankment will be necessary but the scale of this retreat can be predicted using the regime model approach outlined here. In the undersized estuaries, it is recommended that, before any embankment realignment occurs, urgent attention is given to the aquaculture practices that make a major contribution to tidal flows and thus erosion of these channels. In the natural unembanked estuaries connecting the wildlife reserves of the Sundarbans, sea level rise will result in widening and erosion of the channels with loss of mangrove habitat as an inevitable consequence unless sediment input to these areas can be maintained at a high level.

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# Annex 6.

## Policies and Programs in the Sundarbans<sup>1</sup>



### Abstract

The development strategy currently being pursued in the Sundarbans is suboptimal because it is likely to place even greater populations at risk and result in additional unsustainable demands on the forest. An evaluation of current programs and policies in place in the Sundarbans suggests that they might hamper long-term socioeconomic and human development, as well as long-term vulnerability reduction. Current programs do not seem effective in lifting people out of poverty in the long term and giving residents the opportunity to integrate themselves into areas that offer greater job opportunities, higher wages, improved safety, and greater access to healthcare, education, and other social services. This annex assesses the goals and strengths of key programs and policies that have been implemented in the Sundarbans and analyzes their effectiveness in vulnerability reduction, socioeconomic development, and biodiversity conservation. It finds that the current development strategy encourages in-migration into the area and hampers long-term vulnerability reduction and socioeconomic development in the Sundarbans.

### 6.1. Introduction

The Sundarbans region of West Bengal is a resource-rich and

biodiverse mangrove ecosystem that provides livelihood support to over 1.3 million people directly and indirectly. The inhabited portions of the Sundarbans contain over 4.4 million people, who constitute some of the most impoverished and vulnerable communities in India. About one half of this population lives below the poverty line, with poverty incidence highest in the blocks close to the vast mangrove forest. Nearly 80 percent of the households pursue livelihood options that involve inefficient production methods in agriculture, fishing, and aquaculture. Sea level rise and extreme weather events compound the development challenges of the Sundarbans. The limited education and job skills, and lack of access to urban markets force many residents to rely on de facto open access to forest and fishery resources for livelihood purposes, and overexploitation of natural resources has contributed to severe biodiversity loss in the region.

Policies, programs, and subsidies that aim to promote economic development and biodiversity conservation (herein known as “incentives”<sup>2</sup>) can have unintended and undesired impacts that can hamper long-term development goals (Box A6.1). In the context of the Sundarbans, undesirable consequences might take the form of: (a) increased migration into the area as a result of programs provided to residents; and (b) decreased integration of residents into areas of lower environmental risk and better job opportunities. Some programs, such as the expansion of aquaculture development,

<sup>1</sup>This annex is prepared by Ghazal Dezfali and Sanjay Gupta based on background reports prepared by S.C. Rajshekar, Lidvard Gronnevet, Santiago Enriquez, Subimal Roy, World Wildlife Fund, Juan Luna-Kelser and Christine Heyniger, West Bengal Green Energy Department Corporation, and Chandreyee Das.

<sup>2</sup>Defined broadly, an incentive is a factor (financial or nonfinancial) that motivates a particular course of action. It is a factor that attempts to encourage people to behave in a certain way. In terms of biodiversity conservation in the Sundarbans, incentive measures can be implemented in order to conserve or restore valuable biological ecosystems and increase the cost to programs that have adverse environmental impacts. For example, landowners who are given financial compensation if they adopt sound management practices that protect the environment will be more willing to use sustainable farming practices than they otherwise would.

- **Positive incentives.** Monetary or nonmonetary inducements that lead to positive behavioral change (for example, reduction of overexploitation of forest resources) and contribution to long-term vulnerability reduction, socioeconomic development, and biodiversity conservation;
- **Disincentives.** Policies, programs, and mechanisms that penalize people when they engage in certain activities that have negative consequences (for example, harming biodiversity by overexploiting forest resources and aquatic species), and thus discourage them from engaging in such activities; and
- **Indirect incentives.** Programs, policies, and mechanisms that change the costs or benefits of engaging in activities indirectly, encouraging positive behavior by setting in place general enabling conditions that will cause people to change their economic behavior.



are damaging to biodiversity but are encouraged because the activities are deemed profitable as their full costs, including biodiversity degradation, are not taken into account. To cite another example, subsidies that provide free electricity or water supply discourage residents from leaving the Sundarbans and may encourage those from outside to migrate into the area, thus increasing human vulnerability to environmental risks.

This annex<sup>3</sup> is based on an examination of a select number of key policies and programs implemented in the Sundarbans (as shown in Table A6.1) and their impacts on improving long-term socioeconomic development, vulnerability reduction, and

biodiversity conservation. Section 2 analyzes the extent of assistance from government programs in the Sundarbans, with particular reference to MGNREGA. Section 3 analyzes the potential impacts of key local, state, national, and private programs and policies on development outcomes in the following categories: DRM, livelihoods (including agriculture, aquaculture, and tourism), education, health, water supply and sanitation, transportation, energy, and biodiversity conservation. Sections 4 and 5 provide recommendations and conclusions, including a summary of the likely implications if the BAU approach prevails in the region.

#### **Box A6.1: Factors Inducing Negative Behavior and Threatening Biodiversity Conservation**

According to the International Union for Conservation of Nature (IUCN) (2000), certain factors or systemic failures might act as incentives that induce negative behavior and thus threaten biodiversity conservation (for example, increases in unregulated shrimp harvesting expansion) or hamper long-term socioeconomic development and vulnerability reduction.

**Institutional and policy failures.** These include laws, programs, and policies that are implemented to stimulate a certain activity or to meet national or sectoral goals, such as agricultural expansion or employment promotion, but can also reduce biodiversity conservation because they represent only the interests of a particular group or sector (such as corporate businesses and shrimp export companies). Laws and policy instruments, including subsidies, can reduce long-term biodiversity conservation and socioeconomic development. For example, policies and programs can directly stimulate activities that lead to biodiversity loss or fail to check biodiversity degradation (for example, poor forest border patrol regulation or lack of regulation of aquaculture expansion). Also, rural development policies can encourage development and settlement in ecologically sensitive areas such as the Sundarbans, thereby increasing population pressures, human vulnerability to environmental risks, and the rate of biodiversity loss. Agricultural policies offering subsidies for various inputs can encourage residents to maintain livelihoods in a sector that has poor potential for development in the region. Institutions can also have weak capabilities in protecting biodiversity; it is not uncommon for those very institutions that have sustainability mandates (for example, the Department of Fisheries and Aquaculture) to be ineffective in implementing on-the-ground conservation activities or to disregard biodiversity conservation in activities.

**Market failures.** Market failure exists when the production or use of services and goods by the market is not efficient. In the context of the Sundarbans, market failures are often associated with negative externalities stemming from the use of public goods. When individuals or private economic agents exploit scarce resources (fish species or timber products) for their own economic pursuit and self-interest, this leads to overexploitation of resources and, consequently, their long-term depletion. In other words, individuals only consider their own marginal private benefits and marginal private costs, without giving consideration to external costs. The underlying essence of this problem stems from poorly protected or no property rights; as individuals do not own these common goods (for example, the forest), they have little incentive to extract resources in a sustainable manner. Positive incentives, such as financial compensation schemes for preserving biodiversity (for example, Payment for Ecosystem Services (PES) programs or strict forest regulation based on a system of permits) can help prevent resources from being permanently destroyed or at least being extracted at a sustainable rate.

**Livelihood failures.** Demographic conditions, biophysical conditions, local economic conditions, and nature and effectiveness of policies and programs are all factors for determining people's employment activities, needs, constraints, and opportunities. When economic opportunities are scarce or limited, people often have little choice or alternative but to overexploit forest resources and thereby contribute to biodiversity loss in order to make a living. In the Sundarbans, limited economic opportunities and high poverty levels force many residents to be dependent on the forest and natural resources, leading to degradation of the resource base upon which much of the population depends.

*Source:* IUCN 2000.

<sup>3</sup>While this annex examines the nature of programs and subsidies in the Sundarbans, it does not measure the effect of these programs and their economic costs.



**Table A6.1: Selected Programs and Policies in the Sundarbans**

Sector	Selected Programs and Policies
Disaster risk management and erosion control	<p>Embankment rehabilitation and realignment undertaken by the Department of Irrigation and Waterways</p> <p>National, state, and NGO programs for development of cyclone shelters</p> <p>Forest Department/NGO schemes for planting mangroves; small-scale bilateral donor schemes for mangrove plantation</p>
Livelihoods: agriculture, aquaculture, forestry, tourism	<p>National job employment schemes, for example, MGNREGA</p> <p>Development of marine fisheries by the Department of Fisheries and Aquaculture through measures such as construction of deep fishing harbors</p> <p>Expansion of mass tourism programs by the Department of Tourism, for example, development of tourism infrastructure, including lodges</p> <p>Input subsidies for BPL families for sunflower, moong, and cotton provided by SDB</p> <p>Small-scale irrigation work undertaken by SDB Landshaping and integrated farming programs provided by SDB, NGOs, and private landowners</p> <p>Distribution of seeds, training and demonstrations, lessons on plant protection, and pest management programs provided by the Department of Agriculture National and state programs aimed at increasing agricultural growth (for example, Rashtriya Krishi Vikas Yojana scheme to incentivize states to make higher expenditure on agriculture and allied sectors)</p> <p>National Food Security Mission to increase production of rice, wheat, and pulses, create employment opportunities, and increase farmers' profits</p> <p>Integrated Scheme of Oilseeds, Pulses, Oilpalm, and Maize to promote crop diversification</p> <p>Technology Mission on Cotton to increase cotton productivity via training</p>
Education	<p>National-level education policies, such as Sarva Shiksha Abhiyan for free elementary education, Mid-Day Meals Program aimed at improving nutritional status of children in schools, and provision of hostels and boarding facilities for secondary and higher secondary students</p> <p>Creation of higher education institutions provided by DSA</p> <p>Vocational training provided by NGOs at the local level, for example, NGO-run vocational training in the form of short courses in modern methods of fishing, bamboo work, and other such small indigenous sectors. Examples of NGOs active in the region include the All India Council for Mass Education, Rambati Nistarini, and Ambedkar Social Welfare Mission</p>
Health	<p>Public health services under national health and state programs for improving nutrition and reproductive and child health, reducing disease, decreasing maternal and infant mortality rates, increasing institutional deliveries in BPL families, developing and upgrading public health facilities, and increasing the number of health personnel (examples of programs include National Anti-Malaria Program, Revised National Tuberculosis Program, Integrated Child Development Services Program)</p> <p>NGO programs providing health and hygiene education, medical camps, and preventive medicine, and running hospitals and diagnostic centers. Examples of NGOs working in close collaboration with the Directorate of Health Services and SDB include Southern Health Improvement Samity, Bhargar; Sri Ramkrishna Ashram; and Tagore Society for Rural Development</p>
Water supply and sanitation	<p>Subsidies for water supply services in the Sundarbans (including piped water supply) provided by PHED</p> <p>District-level schemes for improving sanitation facilities (for example, implementation of the Total Sanitation Campaign, which is now termed the Nirmal Bharat Abhiyan)</p> <p>Digging of tubewells and groundwater extraction provided by PHED</p> <p>Rainwater harvesting schemes provided by PHED</p> <p>National and state programs for providing safe drinking water to all villages (for example, Rajiv Gandhi National Drinking Water Mission)</p>
Transportation	<p>Construction of roads (brick paved, bituminous, concrete), bridges, culverts, drainage structures, and jetties provided by SDB, PHED, and Public Works Department</p>

**Table A6.1 (continued): Selected Programs and Policies in the Sundarbans**

Sector	Selected Programs and Policies
Energy	<p>Extension of grid electricity and provision of free electricity connections to rural BPL households provided by the Ministry of Power's Rajiv Gandhi Grameen Vidyutikaran Yojana national program</p> <p>Renewable energy power plants and solar home systems (available at a subsidized rate to households in unelectrified remote villages) implemented by the West Bengal Renewable Energy Development Agency</p> <p>Diesel generator schemes operated by private operators</p>
Biodiversity	<p>Forest Department/NGO schemes for planting mangroves</p> <p>Small-scale bilateral donor schemes for mangrove plantation (usually below 20 ha)</p> <p>State programs aimed at protecting habitats of the Bengal tiger and binational programs for promoting overall biodiversity conservation</p>

*Note:* Table A6.1 includes key programs and policies that have been implemented in the recent past or are currently being implemented in the Sundarbans, and does not cover all programs and policies implemented in the Sundarbans. Source: Building Resilience for Sustainable Development of the Sundarbans through Estuary Management, Poverty Reduction, and Biodiversity Conservation: A Non-Lending Technical Assistance, Final Report (2014).

## 6.2. Background on Public Service Delivery: Local Institutions

In West Bengal, decentralization of expenditures for basic services has taken place on a large scale. The West Bengal experience with local development programs has spanned more than three decades (Bardhan and Mookherjee 2006). In 1950, the Indian Constitutions laid the foundation for decentralization in the country. The state of West Bengal developed a three-tier system of self-government under the 1957 Panchayat Act and the 1963 Parishad Act. The Left Front government successfully implemented the three-tier local government system in the late 1970s, with the GP as the lowest level of the three-tier system. The other two levels are the Panchayat Samitis and the Zila Parishads. The former are councils at the block level, while the latter are councils at the district level. A GP is elected every five years, and includes roughly eight to 15 villages.<sup>4</sup>

To promote government accountability and transparency in decision-making processes, the 73<sup>rd</sup> Constitutional Amendment of 1992 required that the GPs consult their constituents regarding the financial allocations during the yearly GP-level meetings. In West Bengal, these meetings, which have been held since 1998, allow voters to participate in local governmental processes.

Bardhan and Mookherjee (2006) argue that, unlike other Indian states (with the exception of Karnataka and Kerala), considerable responsibilities have been devolved to the GPs of West Bengal, including selection of beneficiaries for welfare programs, implementation of land schemes, investment in infrastructure programs, distribution of agricultural kits, among others.

The extent of reforms implemented by the GPs was arguably unprecedented in scale and scope. As an example, agrarian reforms, most notably the promotion of high-yielding rice varieties, by the

GPs increased agricultural growth rates from one of the lowest in the 1970s to the highest during the 1980s (Saha and Swaminathan 1994). Appu (1996) finds that over 6 percent of land had been redistributed to households in the early 1990s, compared to less than 1 percent in most Indian states.<sup>5</sup> Bardhan and colleagues further argue that the devolution of power from the state to the lowest tier of government (GPs) shifted the balance of political and economic power away from the large landholders to the poorer segments of society.

Given the significant responsibilities of the GPs and the numerous funds allocated by the central government to the local levels, the next section shall assess how well the development programs actually are targeting the poor in the Sundarbans region.

## Extent of Assistance from Government Programs in Sundarbans: Results from 2011 Household Survey

### 6.2.1 Overview of Survey Results

Results from the 2011 household survey reveal mixed findings pertaining to the strength of several government assistance programs aimed at reducing poverty (including enhancing health and education) in the Sundarbans. For example, only 7 percent of the 2,188 households surveyed reported that they had received prenatal and postnatal healthcare assistance under the Janani Suraksha Yojana program during the previous year. Under the Mid-Day Meals Program for children studying through class 8, less than half of households (48.5 percent) reported that their children had received assistance from the program during the previous year. Moreover, only 2.4 percent of the 2,188 households reported that they had received assistance during the previous year from the Swarna Jayanti

<sup>4</sup>Bardhan, et al., 2010.

<sup>5</sup>Ibid.

Gramin Swarojgar Yojana program, a self-employment program that aims to bring poor families above the poverty line by organizing them into self-help groups through the process of social mobilization, training, and capacity building, and provision of income-generating assets through government subsidies and bank credits. With regard to subsidies, 95 percent of the sampled households reported that they received kerosene through their ration card within the previous 12 months, and 55 percent of the respondents stated that they received rations through their APL card.

### 6.2.2 Case Study: National Rural Employment Guarantee Act

MGNREGA aims to enhance the livelihood security of people in rural areas by guaranteeing 100 days of wage employment in a financial year to rural households whose adult members *demand* work.<sup>6</sup> The employment work under the Act gives priority to the following activities: water harvesting, groundwater recharge, and drought proofing. An indicator of the success of this demand-driven program is its coverage of those asking for work. An indicator of effectiveness is the number of days provided to those who obtain work. The national average of workdays under MGNREGA was 46.1 days in 2012–13. Just over 10 percent of worker households completed 100 days of work. The findings from the 2011 household survey reveal that the average days of work provided per households that got work under this scheme was only 30 days. The average days of work provided per household that got work in West Bengal was 26 days, based on statewide MGNREGA performance figures from 2008–09 (Planning Commission 2011).

These findings prompt the question: does the low provision of work reflect a lack of demand or ineffectiveness in being able to meet the demand? Indeed, one would expect that demand for work would be higher in regions where poverty was high, such as the Sundarbans and West Bengal. Possible explanations could be lack of attention by states to energize MGNREGA; lack of awareness among potential workers regarding the program or entitlements under the program; and lack of awareness of the demand-driven nature of the program (in many areas in India, people are unaware that they must demand work in order to be covered under MGNREGA). Without awareness generation at the GP level on the demand-driven nature of MGNREGA, performance of the program in the Sundarbans will continue to remain poor. On the other hand, if evidence had shown that the employment program under MGNREGA was effective in the Sundarbans (that is, a majority of households were provided with 100 days of work), this may have served as an incentive to keep people trapped in an inhospitable environment and possibly attract in-migration to the Sundarbans.

## 6.3. Analysis of Key Current Programs in the Sundarbans

The following subsections present an analysis of key current

programs in the Sundarbans. Subsection 6.3.1 considers an aspect of vulnerability reduction, namely DRM; the remaining subsections consider various aspects of poverty reduction, namely agriculture; aquaculture; tourism; education; health; water supply and sanitation; transportation; energy; and biodiversity conservation. Poverty reduction measures implemented in the Sundarbans aim to: (a) increase livelihood opportunities in key sectors such as agriculture and aquaculture, including through increasing their productivity and profitability; and (b) enhance human development outcomes, including health and education.

### 6.3.1 Disaster Risk Management

Current DRM programs in the Sundarbans focus on the following: national and state programs for embankment rehabilitation and realignment; national, state, and private programs for the development of cyclone shelters; and state and private schemes for mangrove plantations (Table A6.2). The current embankment reconstruction strategy employed by the Irrigation Department following Cyclone Aila reflects the recommendations of this NLTA that substantial embankment realignment will, at times, be necessary, and that mangrove restoration is an important element of providing a protective bioshield. Managed realignment will be essential to prevent channel bank erosion from undercutting embankments. A key impact of cyclone shelter construction, embankment realignment, and mangrove restoration is that all three elements contribute to vulnerability reduction; cyclone shelters and mangrove plantations protect people and assets from cyclones, and embankment realignments address sea level rise and erosion problems.

However, these measures together, by protecting residents, may encourage them to stay in the area in the short and medium terms until these measures can no longer effectively combat the environmental risks that the Sundarbans will experience in the long run. Estuary management commitments through embankment realignment, mangrove restoration, and salinity management provide long-term threat reduction, whereas DRM interventions being implemented (including the construction of cyclone shelters) provide near-term DRM strategies. These strategies do not provide a permanent solution for safety in the region; they will, however, provide a significant and essential additional measure of safety to the residents of the Sundarbans over the next 50-plus years, during which time human capacity can be built through targeted programs of poverty reduction and livelihood enhancement to allow residents to integrate themselves into urban areas. Appropriate DRM and estuary management measures must address the fact that a significant proportion of the inhabited delta has become unstable and inhospitable to life because of past and current maladaptive management practices. A significant long-term multigenerational element of the recommended adaptation strategy involves measures such as risk communication to make existing residents and potential migrants into the region aware of the likelihood that sea level will continue to rise and that climate change is expected to increase the intensity of future cyclonic storms.

<sup>6</sup>See <http://nrega.nic.in/netnrega/home.aspx> for more information.

**Table A6.2: Impact of Disaster Risk Management Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
National and state programs for embankment realignment and retreat	Contribute to vulnerability reduction as people and assets are protected from sea level rise; but may encourage people to stay in the area	Protect agricultural lands from salinity; however, depth of the rivers may increase and the area of tidal prism may decrease as a result of embankments, thus increasing salinity	Disincentive to out-migrate as they make people feel safer and provide employment opportunities in mangrove restoration schemes	Limited human capital development in embankment restoration techniques
National and state programs for the construction of cyclone shelters	Contribute to vulnerability reduction as people and assets are protected from sea level rise; but may encourage people to stay in the area	Not applicable	Disincentive to out-migrate as they make people feel safer and provide employment opportunities in mangrove restoration schemes	Enhancement of human capital if cyclone shelters used as schools during times of nonemergency
Forest Department, NGO, and private programs for mangrove restoration	Contribute to vulnerability reduction as people and assets are protected from sea level rise and storms; but may encourage people to stay in the area in the long term	Enhance biodiversity conservation by increasing reproductive and nursery grounds of aquatic species that rely on mangroves	Disincentive to out-migrate as they make people feel safer; may encourage in-migration as a result of employment opportunities in mangrove restoration schemes	Limited human capital development in mangrove planting/restoration techniques

### 6.3.2 Agriculture

The centrally sponsored schemes in India are the main instruments for promoting agricultural growth, and include focus on seed production, extension, soil health, crop production, and postproduction issues. The two major programs being implemented by the Department of Agriculture in the Sundarbans are the Rashtriya Krishi Vikas Yojana, and the National Food Security Mission.<sup>7</sup> The objective of the Rashtriya Krishi Vikas Yojana is to incentivize states to make higher expenditure on agriculture and allied sectors. The National Food Security Mission is a relatively new centrally sponsored scheme initiated in 2007-08 (Planning Commission 2011). The scheme centers on: (a) increasing the production of rice, wheat, and pulses by expanding the area of production and enhancing productivity in a sustainable manner; (b) restoring soil fertility and productivity at the farm level; and (c) creating employment opportunities. Major interventions under the scheme include distribution of high-yielding seed varieties, integrated pest management, integrated water management, and training. Components of the program are being implemented in South 24 Parganas, and include the following interventions: providing hybrid

varieties of paddy; providing incentives for use of micronutrients; and farmer training

The Integrated Scheme of Oilseeds, Pulses, Oilpalm, and Maize aims to promote the cultivation of oilseed crops in the region. Under this scheme, assistance is provided to farmers for the purchase of seeds (including breeder and foundation seeds). Certified seeds, seed minikits, plant protection chemicals and equipment, and weedicides are among the items distributed to farmers to encourage them to grow oilseeds. In the Sundarbans, sunflower cultivation is promoted under this scheme.<sup>8</sup> However, lack of a local market and difficulties in accessing distant markets have meant that the crop has not been an economically attractive investment.

Apart from the major schemes, the SDB provides input subsidies for selected BPL families for sunflower, cotton, and moong. In recent years, SDB has been providing infrastructural development support and subsidized quality seeds for cotton to select farmers through the Ramkrishna Ashram Krishi Vigyan Kendra Program, Nimpith. However, the scale of activity in this program is small and has not been shown to have any major impact on agricultural productivity in the region.

<sup>7</sup>The National Food Security Mission and the Rashtriya Krishi Vikas Yojana were both introduced in 2007–08 to provide states with additional resources on a 100 percent grant basis. States were afforded the flexibility to address priorities in agriculture, choose interventions, and set targets through these two programs. In West Bengal, however, the goal of the Rashtriya Krishi Vikas Yojana was not met; the state made an average allocation of less than 4 percent to agriculture and allied sectors (3.2 percent) during the period 2007–10. Other states, such as Himachal Pradesh (11.1 percent) and Nagaland (9.7 percent), allocated relatively higher expenditures to agriculture during the same period (Planning Commission 2011).

<sup>8</sup>See website of the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India: [http://agricoop.nic.in/dacdivision/tmop/Tmop\\_isopom.htm](http://agricoop.nic.in/dacdivision/tmop/Tmop_isopom.htm).



**Growth centers.** The Agriculture Division provides extension services to Sundarbans farmers through 27 growth centers located in the 19 development blocks of the Sundarbans under the supervision of three branch offices located in Canning, Nezat, and Kakdwip. The main activities of the growth centers are canal renovation; pond desilting; distribution of minikits for crops, including cotton; and overseeing the implementation of land shaping and rainwater harvesting technology in their blocks. Except for land shaping and rainwater harvesting, all activities are implemented through the GP, which identifies beneficiaries and distributes agricultural materials, including seed kits. However, information gathered as part of this NLTA has revealed that the growth centers are staffed with personnel that lack knowledge of crop sciences and capacity to promote better cropping practices or provide information on improved practices, such as integrated pest management, integrated nutrient management, or market information. Growth centers do not prepare any local plans to increase production or productivity. Overall, farmers view the SDB as ineffective in promoting agricultural development. If indeed these centers are to promote growth, certain changes are required, for example, re-staffing, retraining and reorientation of staff, and revamping institutional delivery.

Currently, there is a lack of emphasis on promoting saline-resistant rice varieties in the Sundarbans. This is a cause of concern, as there is a high degree of risk associated with agriculture in the Sundarbans as a result of high salinity<sup>9</sup> levels and lack of freshwater availability, which together limit the long-term viability of agriculture in the region. Traditional crop varieties provide much lower yields on land that has high salinity levels.

None of the above schemes being implemented is in specific response to conditions pertinent in the Sundarbans, resulting in an inefficient allocation of financial resources. While the schemes, in general, do provide some short-term livelihood enhancement, subsidies in agriculture and free provision of agricultural materials are likely to encourage residents to stay in this environmentally risky area, and may also attract in-migrants from outside the area. In the long run, this could increase population pressures in the transition zone, and the number of people at risk from storms and sea level rise.

### 6.3.3 Aquaculture

National, state, and private aquaculture development programs in the Sundarbans: (a) contribute to erosion and instability of many protective embankments; (b) threaten the livelihoods of agricultural farmers; and (c) encourage further ecosystem degradation as a result of unsustainable prawn seedling collection practices.

The Sundarbans region of West Bengal is characterized by small-scale farmers and traditional rice paddy/prawn cultivators (Philcox et al. 2010). The Department of Fisheries and Aquaculture is focused

on increasing export earnings from coastal commercial fishing. For example, a deep-sea fishing harbor is being constructed at Mayagoalinirghat, Sagar Island, South 24 Parganas, as part of an attempt to strengthen marine fishing. West Bengal's Sundarbans mangroves are considered to be the largest potential area available for shrimp aquaculture in the country, due to the role played by mangroves as breeding grounds and nursery habitats for shrimp hatchlings. To take advantage of the rising demand for shrimps in domestic and international markets, a substantial growth in shrimp farming has taken place in the Sundarbans in the last two decades. However, shrimp aquaculture has been relatively neglected in the development of sustainable practices (Philcox et al. 2010).

Current aquaculture schemes have had serious adverse impacts on biodiversity: a major aquaculture-related problem in the Sundarbans concerns the “by-catch”, the enormous numbers of unwanted aquatic species that are discarded during prawn seedling collection using fishing nets. Coastal fishing has resulted in a decline in catch-per-unit effort from 150–200 kg per haul to 58–65 kg per haul during the past 15 years as a result of over exploitation of aquatic species. The loss in terms of juvenile species is substantial, and the catch and earnings of fishers have declined over time. There has been no serious effort to develop hatcheries. Moreover, high levels of waste occur in inland fishing because of lack of infrastructure such as storage facilities, ice plants, roads and transportation, and cold chains. The introduction of mechanized boats and motorized country boats, supported by the Department of Fisheries and Aquaculture, as well as open access use and excessive use of bottom trawling, are further aggravating the problem.

The use of hatcheries to obtain prawn seedlings and development of appropriate codes of conduct can help minimize the adverse effects and help realize gains from a modernized aquaculture sector. Implementing international standards for responsible fishing practices, such as the Code of Conduct for Responsible Fisheries, can help promote long-term sustainability in the aquaculture sector. Indeed, the 11th Five Year Plan (Planning Commission 2011) promoted responsible fishing practices by highlighting the importance of the implementation of the Code of Conduct for Responsible Fisheries and regulations in coastal fisheries; hatchery accreditation guidelines; adoption of fish seed certification; guidelines for illegal, unregulated, and unrecorded fishing in compliance with European Union requirements; strengthening domestic markets for fish and fish products; enhancing the use of databases and geographic information systems in both marine and inland fisheries; and assessment of income, health, and literacy levels of fishers.

### 6.3.4 Tourism

The current tourism policy in the Sundarbans, implemented by the Department of Tourism, centers on promoting mass tourism rather than environmentally sustainable ecotourism. Indeed, the environmental impacts of mass tourism in a fragile system such as

<sup>9</sup>Soil salinity in the Sundarbans occurs primarily due to two factors: (a) inundation by tidal waters due to breach of embankments; and (b) capillary action of water in the soil bringing up salt from the layers below during the rabi season. For further details, see Annex 9.

**Table A6.3: Impacts of Livelihood Development Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
State, NGO, and private landowner schemes for land shaping and rainwater harvesting	Encourage people to stay in and migrate to the region, thereby increasing human vulnerability to natural hazards	Potentially negative effect on biodiversity as they may alter the natural landscape	Potential reduction in outward migration, potential increase in inward migration	Limited human capital development in agricultural techniques
National and state programs aimed at increasing agricultural growth (for example, Rashtriya Krishi Vikas Yojana and National Food Security Mission)	Encourage people to stay in and migrate to the region, thereby increasing human vulnerability to natural hazards	Potentially negative effect on biodiversity as they may alter the natural landscape	Potential reduction in outward migration, potential increase in inward migration	Limited human capital development in agricultural techniques
National job employment schemes (for example, MGNREGA)	Encourage people to stay in and migrate to the region, thereby increasing human vulnerability to natural hazards	Potentially negative effect on biodiversity as they may alter the natural landscape	Potential reduction in outward migration, potential increase in inward migration	Potential human capital development in a variety of jobs
National, state, and local shrimp and aquaculture expansion schemes	Encourage people to stay in and migrate to the region, thereby increasing human vulnerability to natural hazards; conversion of agricultural land into shrimp ponds threatens the livelihoods of agricultural farmers	Reduction in aquatic species and negative effect on environmental landscape, with increases in salinity in agricultural fields	Potential reduction in outward migration, potential increase in inward migration	Limited human capital development in agricultural techniques
Mass tourism development	Encourage in-migration into the area as a result of increases in tourism-related jobs	Noise, air, and land pollution; habitat fragmentation; disturbance of wildlife	Potential reduction in outward migration, potential increase in inward migration to the area as a result of increases in tourism-related jobs	Limited human capital development as a result of training for jobs in tourism

the Sundarbans has already contributed to environmental degradation in the form of habitat fragmentation and reduction in biodiversity through the ill-planned construction of roads, resorts and jetties, and high noise and air pollution levels as a result of large tour buses, autos, and motorized boats. The tourism policy aims to improve and diversify tourism products by opening new tourist destinations, developing new products, and extending existing ones. The policy can be modified to include provisions for environmentally sustainable ecotourism at levels strictly limited by the ecosystem's carrying capacity. Mass tourism in the transition zone should be phased out as it will degrade the natural resources of the Sundarbans Reserve Forest and the local environment to a point at which the

area would have little value for high-end, environmentally sensitive ecotourists.

Table A6.3 summarizes the impacts of livelihood development schemes for agriculture, aquaculture, and tourism.

### 6.3.5 Education

The policies currently active in the region are the national policies framed in accordance with the Right of Children to Free and Compulsory Education Act, 2009. No education policies specifically designed for the Sundarbans region exist. Among the major national education policies, only the Sarva Shiksha Abhiyan,

**Table A6.4: Impacts of Education Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
National/state education policies (for example, Sarva Shiksha Abhiyan for free elementary education, Mid-Day Meals Program aimed at improving the nutritional status of children in schools)	May increase vulnerability by encouraging families to stay in the high-risk area	Not applicable	Potential outward migration in the long run	Contingent on strength of programs; short-, medium-, and long-term human capital development possible (improvements in health and education)
State schemes for constructing a limited number of higher education institutions	May increase vulnerability by encouraging families to stay in the high-risk area	Not applicable	Potential outward migration in the long run	Long-term human capital development
State and private schemes offering vocational training (for example, fishing, bamboo work, and other small indigenous sectors)	May increase vulnerability by encouraging residents to engage in fishing and forestry work in the Sundarbans; may also decrease vulnerability if people take their new skill sets to urban areas	May lead to biodiversity loss (reduction in fish species and exploitation of forest resources); may also decrease biodiversity loss if people take their skill sets to urban areas	Potential inward migration and outward migration	Human capital development in select natural resources fields

which aims to provide universal elementary education in West Bengal, has widespread implementation in the Sundarbans region (Table A6.4). The authorities at the block and Panchayat levels interviewed for this NLTA were unaware of such programs as the National Program for Education of Girls at Elementary Level<sup>10</sup> or the Kasturba Gandhi Balika Vidyalaya.<sup>11</sup> Among the major incentives promoted by the government to enroll children in school are the Mid-Day Meals Program,<sup>12</sup> the provision of free books and uniforms to students of elementary schools, and some monetary benefits to members of scheduled castes and tribes. However, there are gaps in

the implementation of the present policies. The distribution of benefits has been substandard: not all required books are distributed, no stationery or writing materials are provided to students, and distribution of uniforms by schools has remained lagging.

The Mid-Day Meals Program has been implemented across the country, providing a hot lunch to students till class 8. However, West Bengal has been one of the last states in India to implement the scheme and not all schools have implemented the program. Roughly 16 percent of primary schools and over 50 percent of upper

<sup>10</sup>As the Sarva Shiksha Abhiyan has limited financial provisions for girls' education in the form of free textbooks and innovations at the district level, the National Program for Education of Girls at Elementary Level has been formulated for providing additional support for the education of underprivileged and disadvantaged girls at the elementary level. The program is a part of the Sarva Shiksha Abhiyan and will be implemented under its umbrella, though as a distinct and separate gender component. For more information see <http://www.education.nic.in/npegl.asp>.

<sup>11</sup>The Kasturba Gandhi Balika Vidyalaya scheme introduced by GoI aims to provide educational facilities for girls belonging to Scheduled Castes, Scheduled Tribes, and other underprivileged classes.

<sup>12</sup>The Mid-Day Meals Program began in 1995 to support the universalization of primary education by enhancing enrollment, retention, and attendance, and simultaneously improving the nutritional status of primary school children. By 2004, the program was providing hot cooked meals to all children in primary classes. It was extended to include upper primary (classes 6–8) children in 3,479 educationally disadvantaged blocks in October 2007 and then universalized at the elementary level in 2008–09. Implementation of the Mid-Day Meals Program rests with the states, while the central government provides food grains free of cost, transport assistance, and financial assistance for the construction of kitchen sheds and stoves (Planning Commission 2011).

primary schools still do not have a separate kitchen for cooking food. Discussions with parents conducted as part of this NLTA revealed that there were concerns about the quantity and quality of food served under the program. In some schools, meals are not being provided on a daily basis. The quality of food, according to the beneficiaries, varies from average to very poor. Given the poverty of many families in the region, the Mid-Day Meals Program has managed to induce many families to send their children to school. However, the aim of the scheme, along with increasing enrollment in school, is to provide proper nutrition to children who otherwise would not be able to receive it. Steps should, therefore, be taken to expand and strengthen the program to enhance the quality and supply of food offered to children in schools.

### 6.3.6 Health

Public health services under the national health and state programs for improving nutrition and reproductive and child health, reducing disease, decreasing maternal and infant mortality rates, and increasing institutional deliveries in BPL families exist in the Sundarbans (Table A6.5).<sup>13</sup> Examples include the National Anti-Malaria Program, Revised National Tuberculosis Program, and Integrated Child Development Services program.<sup>14</sup> However, their results on the ground have been quite mixed, and the strength of any health program in the Sundarbans will greatly influence long-term human capital development in the region. A major obstacle to improved health under the current BAU model is the inefficiency of the current

**Table A6.5: Impacts of Livelihood Health Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
National and state programs for increasing access to healthcare, increasing institutional deliveries, developing and upgrading public health facilities, and increasing quality and quantity of health personnel (for example, Integrated Child Development Services, National Rural Health Mission)	May increase vulnerability by keeping people in the region; but may reduce vulnerability as improved health increases mobility and allows people to seek better livelihood opportunities in urban areas	Not applicable	Potential inward migration depending on strength of programs; long-term outward migration	Depending on strength of program, increase in human capital (improved health) in the long run
NGO programs providing health and hygiene education, medical camps, and preventive medicine, and running hospitals and diagnostic centers	May increase vulnerability by keeping people in the region; but may reduce vulnerability as improved health increases mobility and allows people to seek better livelihood opportunities in urban areas	Not applicable	Potential inward migration depending on strength of programs; long-term outward migration	Depending on strength of program, increase in human capital (improved health) in the long run

<sup>13</sup>In the Sundarbans, the government is the primary service provider for institutional delivery. Privately operated facilities remain scarce in the region. Block primary health centers and subdivisional hospitals are being developed as first referral units with the human resources to handle caesarian deliveries. In the Sundarbans, six facilities have been upgraded to first referral units, four in the south and two in the north. However, none of the rural hospitals has been allocated a gynecology and obstetrics specialist, an anesthetist, or a pediatrician. In general, institutional deliveries increased between 2007 and 2009 but none of the rural hospitals upgraded to first referral units is capable of performing caesarian sections.

<sup>14</sup>The Integrated Child Development Services Program is committed to improving the welfare of pregnant and lactating women, and children below six years of age in India. The primary objective of the program is to improve the nutritional status of children less than three years of age. The major focus is on children suffering from Grade I and Grade II category malnutrition, who constitute more than 50 percent of children enrolled under this scheme.



referral system for health services, which ignores the reality that the “nearest” medical care center may be impossible for many households to access because of the difficult geographic terrain or lack of transport.<sup>15</sup> Many of the better facilities and their staff are located outside the transition zone, but the health referral system has been constrained to send people to services that often lack capacity and are – in any event – not accessible because of transportation issues. The referral chain design in the Sundarbans should incorporate spatial and nonspatial factors related to geographic terrain, seasonality, and disease-specific facility availability.

Most primary health centers suffer from a shortage of medical staff, including doctors and nurses, as well as inadequate infrastructure. Upgrading human resources is currently being undertaken under the National Rural Health Mission<sup>16</sup> program but the problem of lack of support staff remains, including shortages of auxiliary nurse midwives and accredited social health activists. Several national and state programs, such as the Janani Suraksha Yojana,<sup>17</sup> have been compromised due to lack of adequate facilities, including water supply, toilet and examination facilities, and facilities for institutional deliveries. Overall, institutional delivery has not increased significantly despite the relevant programs. The National Anti-Malaria Program, which aims to eradicate malaria, has suffered from staff shortages, and collection and smear examinations have been declining. In addition, shortage of laboratory technicians has led to a reduction in the number of examinations.

The primary objective of the Integrated Child Development Services program is to improve the nutritional status of children less than three years of age. However, while the focus of this program is on children suffering with Grade I and Grade II malnutrition (who constitute more than 50 percent of children enrolled under this scheme), those with Grade III and Grade IV malnutrition have been neglected, which is a cause of concern as malnourishment is high in these categories. Moreover, the scheme has suffered from a shortage of workers, lack of expertise, and infrastructural inadequacies, as well as poor quality of food supply and service delivery.

There is a need to improve the targeting of health services, especially in hard-to-reach places in the Sundarbans, and improve the quality of care and facilities. In the health sector, investments are needed to strengthen and expand existing health initiatives implemented by the Department of Health with the aim of: (a) improving and expanding programs in hard-to-reach places, most of which are located in the high-risk area of the Sundarbans; and (b) placing additional emphasis on illnesses pertinent in the region. Wild animal attacks, as well as high diarrhea incidence linked to salinity intrusion,<sup>18</sup> are two examples of situations that are specific to the Sundarbans and require appropriate preventive and response interventions to reduce incidence and impacts.

### 6.3.7 Water Supply and Sanitation

Key schemes for improving the quantity and quality of water supply and sanitation in the Sundarbans include subsidies for piped water supply and implementation of the Total Sanitation Campaign (now called Nirmal Bharat Abhiyan) (Table A6.6). The scheme is intended to enhance human health in the region, thereby contributing to human development. However, perverse incentives may exist when water supply and sanitation sources are provided by the government at little to no cost to residents which encourage them to stay in an inhospitable environment that will not be suitable for habitation in coming years. This hampers the long-term goal of integrating people into areas of lower environmental risk and greater economic opportunities, as well as allowing them to take advantage of more advanced health facilities and services located in urban areas.

### 6.3.8 Transportation

DSA, since its establishment in 1994, has built about 50 km of black-topped roads (of bituminous concrete), 100 km of cement concrete roads, and 3,000 km of brick-paved roads (Table A6.7). Bituminous roads are constructed mostly in the mainland area, connecting the national and state highways and district roads in order to establish a road network linking villages. The SDB<sup>19</sup> constructs bituminous roads in special cases where the traffic volume

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<sup>15</sup>In the Sundarbans, the referral of patients from basic to more sophisticated levels of care is considered an integral part of the allopathic health system, which follows a hierarchical pattern of healthcare delivery. Health cases beyond the scope of treatment provided in a lower-tier (primary) health facility are referred to a higher-tier (tertiary) facility. The block-level facilities serve as the referral hubs, or the gateways to higher levels of care.

<sup>16</sup>The National Rural Health Mission is a major flagship program of the government in the health sector, and aims to improve access to quality healthcare for those residing in rural areas, particularly women, children, and the poor, by promoting integration and decentralization and encouraging community participation in health programs (Planning Commission 2011).

<sup>17</sup>GoI launched Janani Suraksha Yojana in 2005. It is a conditional cash transfer program to incentivize women to give birth in health facilities.

<sup>18</sup>Sea level rise could increase the incidence of diarrhea by decreasing the amount of available “sweet” groundwater, thereby reducing the supply of potentially potable water.

<sup>19</sup>The engineering wing of SDB comprises five divisions and nine subdivisions. The chief engineer heads the engineering wing. Of the five divisions, four are working divisions that directly implement the civil works scheme of the Board. The fifth division – the Survey, Investigation, and Design Division – was created in 2003 to prepare drawings, designs, and estimates for different schemes and projects undertaken by the Board. Although most of the technical staff members are deputed from other agencies, they usually remain there for a long time (having the opportunity to live in Kolkata with family and commute to the work site daily). The chief engineer and his or her staff are responsible for the survey, design, and implementation of all communication infrastructure projects, and the budget allocation to the area is increasing.

**Table A6.6: Impacts of Water Supply and Sanitation Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
State subsidies for water supply services, including piped water supply	Increase vulnerability by encouraging people to stay in an environmentally risky area	Not applicable	Potential inward migration and potential outward migration in the long run	Improvements in health
District-level schemes for improving sanitation facilities and hygiene; (Total Sanitation Campaign)	Increase vulnerability by encouraging people to stay in an environmentally risky area, but may increase mobility in the long term through improvements in health	Not applicable	Potential inward migration and potential outward migration in the long run	Improvements in health
Rainwater harvesting schemes provided by PHED	Increase vulnerability by encouraging people to stay in an environmentally risky area	Not applicable	Potential inward migration	Improvements in health

**Table A6.7: Impacts of Transportation Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
Construction of roads (brick paved, bituminous, concrete), bridges, culverts, drainage structures, and jetties by SDB	Can reduce vulnerability by connecting people to areas of lower environmental risk; but can increase vulnerability by facilitating in-migration into the area	Increase in noise, air, and land pollution; possibly loss of natural landscape; in-migration can increase pressure on forest and aquatic resources	Both inward and outward migration	Improved educational attainment and health through increased access to urban areas

is heavy. Small buses and auto rickshaws ply these roads. DSA has so far built about 30 bridges of various sizes to improve the connectivity of the islands with the mainland.

Contingent on location of the construction, transport infrastructure can help connect residents to urban markets, where there are greater economic opportunities, access to public services (health and education), higher wages, and lower vulnerability to environmental risk. However, at the same time, transport infrastructure, including roads, can increase in-migration to the area, which can increase vulnerability if it results in more human settlements in the area. Programs for road transport can also potentially increase pollution and noise levels as a result of a greater number of vehicles on the road. Road building can also lead to a loss of natural landscape. Unplanned transport infrastructure can fragment wild life habitats, leading to potentially significant impacts on biodiversity conservation. Demand-based analysis and environmental and social impact assessments should play a role in planning and designing transportation interventions. The following key interventions are

being planned: (a) a proposed port at Sagar Island, which is expected to increase connectivity and boost the local economy, leading to greater population density in the area; (b) proposed bridges (for example, over the Muriganga River), enabling more efficient transport systems and connecting urban centers with clusters of livelihoods in the stable zone; and (c) expansion of the railway network in the Sundarbans toward the south, with further studies approved. In addition to being aligned with the long-term development strategy of the NLTA, these and other new transport system developments should be based on careful analyses of travel demand and they should be subject to in-depth environmental and social direct, indirect, induced, and cumulative impact assessments.

### 6.3.9 Energy

Current schemes for improving energy access in the Sundarbans include provision of free electricity connections to rural BPL households provided by the Ministry of Power's Rajiv Gandhi Grameen Vidyutikaran Yojana national program; renewable energy

**Table A6.8: Impacts of Energy Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
National schemes providing free electricity to the islands (for example, Rajiv Gandhi Grameen Vidyutikaran Yojana)	Encourage people to stay in the area, and hence increase vulnerability to environmental risk	Not applicable	Potential reduction in outward migration; possible inward migration	Human capital development (improvement in health, education, job productivity)
State programs providing renewable energy and solar home systems (available at a subsidized rate to households in unelectrified remote villages)	Encourage people to stay in the area, and hence increase vulnerability to environmental risk	Electricity from renewable resources generally does not contribute to local air pollution, as no fuels are combusted in these processes	Potential reduction in outward migration; possible inward migration	Human capital development (improvement in health, education, job productivity)

power plants and solar home systems (available at a subsidized rate to households in unelectrified remote villages) implemented by the West Bengal Renewable Energy Development Agency; and diesel generator schemes operated by private operators (Table A6.8). GoWB is extending the state grid to all villages in the Sundarbans. Providing adequate, affordable energy is essential to enhance living standards and promote human development. Greater use of renewable energy sources, such as solar energy, can reduce the levels of air and water pollution in the Sundarbans. Energy sources are provided by the government at no cost to residents; this may be a factor in encouraging residents to stay in an inhospitable environment that will not be suitable for habitation in the coming years.

### 6.3.10 Biodiversity Conservation

Programs for protection of biodiversity in the Sundarbans include Forest Department and NGO schemes for planting mangroves; issuance of forest permits by the Forest Department to reduce exploitation of forest resources; state programs aimed at protecting the habitat of the Bengal tiger; and binational biodiversity protection programs with Bangladesh (for example, the Ecosystem Forum on the Sundarbans) (Table A6.9). Mangrove plantation schemes reduce vulnerability as they protect humans and assets from the impacts of cyclones. Allowing for the natural regeneration of mangroves also has positive benefits for biodiversity in the area, as mangroves serve as reproductive and nursing grounds for a variety of aquatic species. To reduce population pressures on the forest, the Forest Department is implementing a permit allocation system to control entry into the forest. An important goal for the core area is the elimination of illegal poaching of tigers, clearing of mangroves, and settlement in protected areas. However, illegal felling of timber is still prevalent

in the forest. Regulatory instruments that must be enforced are already in place, but new market-based incentive mechanisms could improve regulatory efficiency and help realize positive biodiversity conservation outcomes. The use of economic incentives funded by revenues from climate change mitigation programs can play an important role in enhancing the effectiveness of regulatory enforcement in the near term. As a short-term measure, the present Sundarbans Reserve Forest should be given a higher level of protection by declaring it a combination of areas legally protected for conservation (wildlife sanctuaries and national parks). In that context, all economic activity in the existing forest reserve should be gradually reduced.

## 6.4. Moving Away from Business As Usual: Institutional Strengthening

Existing governmental organizations in the Sundarbans are frequently hobbled by a lack of resources. Lack of availability of adequately trained staff remains a constraint in many organizations: doctors, teachers, and other technical professionals have no incentives to work in an environment with risks as high as they are in the Sundarbans. Outdated technical approaches continue to be used: examples include prevalence of monospecific forestry, overreliance on excessively restrictive and unenforceable conservation regulations, and lack of modernized systems to handle isolated communities in need of basic social services. There are few incentives to cooperate or coordinate programs, and this is apparent from the number of contradictory and maladapted initiatives that have been adopted over past decades. Numerous examples exist: (a) aquaculture development undermines embankment stability;

**Table A6.9: Impacts of Biodiversity Conservation Schemes**

Schemes/ Instruments	Pillar 1: Vulnerability Reduction	Pillar 2: Biodiversity Conservation	Pillar 3: Socioeconomic Development	
			(a) Migration	(b) Human Capital Strengthening
Forest Department and NGO schemes for planting mangroves	Contribute to vulnerability reduction as people and assets are protected from sea level rise and storms; but may encourage people to stay in the area	Enhance biodiversity conservation by increasing the reproductive and nursery grounds of aquatic species that rely on mangroves	Disincentive to out-migration as they make people feel safer	Limited human capital development in mangrove restoration techniques
State and binational programs for promoting overall biodiversity conservation (for example, Ecosystem Forum on the Sundarbans with Bangladesh)	Contribute to vulnerability reduction by encouraging residents to seek livelihood opportunities in urban areas	Reduce population pressures in core zone, thereby decreasing exploitation of forest and aquatic resources	Potential decrease in inward migration; potential increase in outward migration	Not applicable

(b) complete bans on mangrove cutting reduce incentives for communities to manage them well and have, in fact, turned pursuit of some potentially sustainable uses into a crime; (c) ration cards intended to improve livelihood security keep people trapped in poverty by discouraging them from integrating themselves into areas of lower risk and greater economic opportunities; (d) referral systems for health services ignore the reality that the “nearest” medical care center may, in fact, be impossible to reach because of difficult geographic terrain or lack of appropriate transport. These examples point to the need for changing the BAU way of doing things (see Annex 13 for further details).

## 6.5. Conclusion and Recommendations

This annex finds that incentives with unintended and negative consequences exist in key categories, including agriculture, health, energy, transport, and water supply and sanitation. These incentives might keep residents trapped in the region, and increase human vulnerability to sea level rise and other hazardous environmental forces. In addition to programs and subsidies, there is an array of implicit subsidies, especially where environmental externalities with consequences for society reveal that the true costs of production or construction have not been met. For example, road construction schemes that are not based on sound environmental designs and

assessments may increase pollution in the area, with negative effects on societal health. Uncontrolled aquaculture schemes affect agricultural lands and threaten the livelihoods of farmers. Such initiatives currently being implemented in the Sundarbans are socially inequitable and environmentally harmful. Even programs that aim to enhance the human development of Sundarbans residents (for example, education and health) often have severe shortcomings, as they fail to reach all intended targets or are deficient in quality.

Any incentive measures must be consistent with, and supportive of, wider goals for long-term socioeconomic development. Alternative policies identified in this report target the same objectives as subsidies and programs, but promote long-term socioeconomic development, biodiversity conservation, and vulnerability reduction. Positive incentive measures in biodiversity conservation (see Annex 12) should not be viewed as alternatives to conservation interventions or other traditional regulatory techniques in place, but rather as a means to support and complement them (OECD 1996). Education campaigns have a complementary role to play, along with regulatory and incentive-based measures. Evidence strongly suggests that people are willing to take proper action when they are more aware of what is under threat and why it may be important.



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# Annex 7.

## Environmental Risks and Measures to Reduce their Costs<sup>1</sup>



### Abstract

The main environmental health risks in the Sundarbans are inadequate water supply, sanitation, and hygiene; and household air pollution from use of solid cooking fuels. The estimated cost of environmental damage associated with ecosystem degradation and biodiversity loss is about INR 6.7 billion<sup>2</sup> annually, equivalent to 4.8 percent of the Sundarbans GDP in 2009.<sup>3</sup> The losses stem from a combination of factors associated with unsustainable and inefficient economic activities, including mangrove destruction, reduced agricultural yields, unsustainable fisheries, and loss of protection against cyclones and other ecosystem services. The annual cost of health effects is estimated at INR 6.2 billion, equivalent to about 5 percent of Sundarbans' GDP in 2007-08. A range of interventions could be implemented in the Sundarbans to mitigate the severe health consequences of environmental risks. The benefits of several interventions significantly outweigh their costs, particularly for the following interventions: installing improved cooking stoves to reduce household air pollution, conducting handwashing campaigns to protect young children, disinfecting household drinking water to protect young children, and supplying households with improved toilet facilities. Interventions including embankment realignment, mangrove restoration, and modernization of aquaculture practices are recommended to reduce biodiversity loss.

### 7.1. Introduction

Residents of the Sundarbans suffer from poor health outcomes and increased vulnerability as a result of environmental degradation in the form of adverse natural events, such as cyclones and storms and increases in soil salinity. The main environmental health risks in the Sundarbans are inadequate water supply,

sanitation, and hygiene (WSH), and household air pollution from use of solid cooking fuels. These risk factors contribute considerably to mortality and morbidity, particularly among women and children. In addition, degradation of natural resources and natural disasters impose high costs on the Sundarbans residents in the form of lost income, and increased poverty and vulnerability. The estimated annual cost of environmental damage is about INR 6.7 billion, equivalent to 4.8 percent of the Sundarbans GDP in 2009.

This annex first provides an overview of the effects of household WSH, and household air pollution from solid cooking fuels, on health indicators; then discusses the degradation of natural resources, and natural disasters and their high costs to the Sundarbans; and finally considers the benefit–cost assessment of development and conservation alternatives. An analysis of the cost of environmental degradation in the Sundarbans, complemented by the cost of interventions to mitigate those costs, allows interventions to be ranked and prioritized.

### 7.2. Cost of Health Effects of Inadequate Water Supply, Sanitation and Hygiene, and Household Air Pollution

The main environmental health risks in the Sundarbans are inadequate WSH, and household air pollution from use of solid cooking fuels. These risk factors caused an estimated 3,800 deaths (90,000 years of life lost) and 1.9 million cases of illness (4,900 disability-adjusted life years (DALY)) in the Sundarbans in 2008 (Figure A7.1).<sup>4</sup> The estimated mortality in children from these risk factors represents over 30 percent of total under-five child

<sup>1</sup>This Annex is a summary of the reports prepared by B. Larsen and E. Strukova.

<sup>2</sup>Reflects average exchange rate in 2009: US\$1 = INR 45.

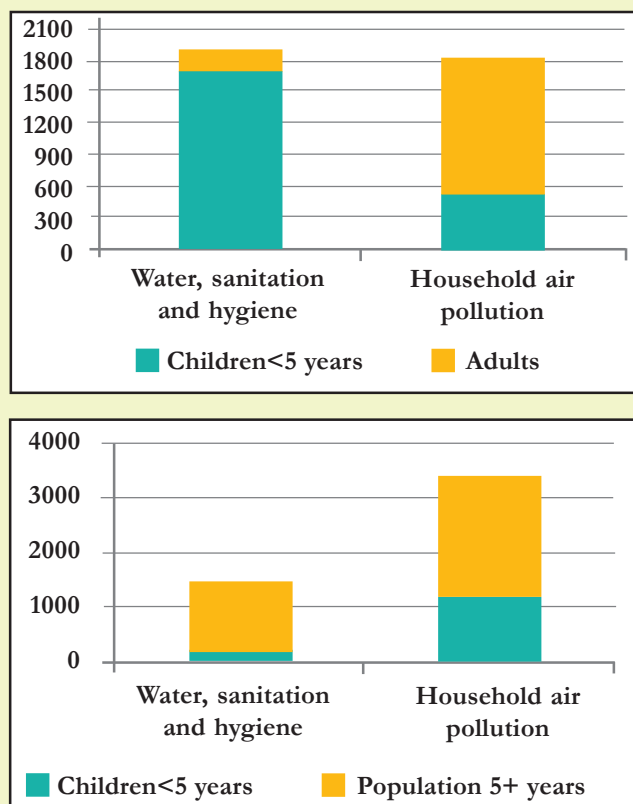
<sup>3</sup>This total damage estimate only partly captures losses from mangrove degradation and overfishing.

<sup>4</sup>Years of life lost from mortality and DALY lost from illness are estimated according to WHO calculations using age weighting and a discount rate of 3 percent.

mortality. The estimated mortality in adult women (30+ years) from the use of wood and other biomass (wood/biomass) fuels for cooking represents 11 percent of total mortality in this age group of women (Larsen 2011a).

The annual cost of these health effects is estimated at INR 6.2 billion, equivalent to 5 percent of Sundarbans' GDP in 2007-08 (Figure A7.2). About 57 percent of this cost results from inadequate WSH, and 43 percent from household air pollution caused by the use of solid fuels. About 80 percent of the total cost is associated with mortality and 20 percent with morbidity.<sup>5</sup>

**Figure A7.1: Annual Cases of Mortality and Years of Life Lost from Illness Due to Major Environmental Health Risks in the Sundarbans, 2008**

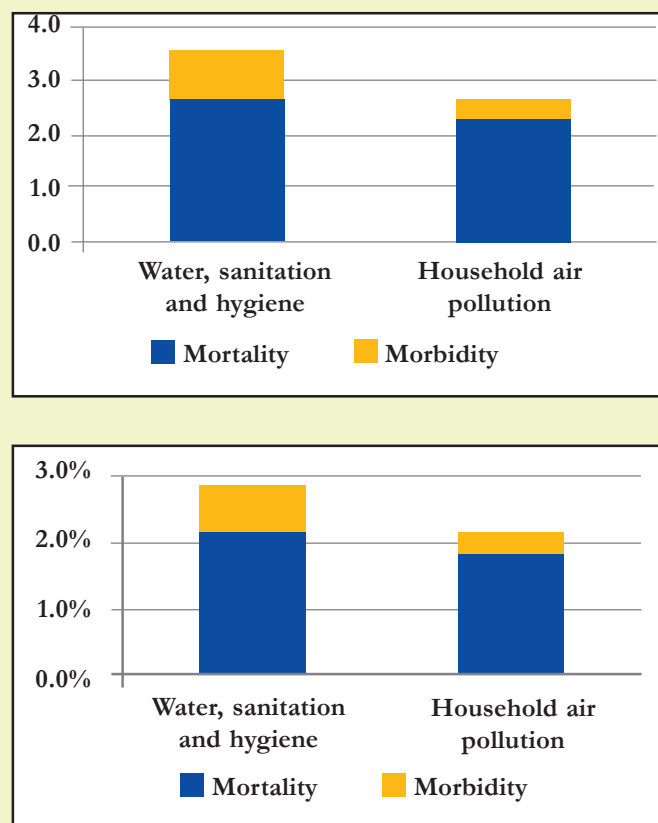


Source: Larsen 2011a. Left: Annual deaths. Right: DALY lost from illness.

### 7.2.1 Household water supply, sanitation, and hygiene

Household WSH is a challenge in the low-lying areas of the Sundarbans. Available information indicates that 26 percent of

**Figure A7.2: Annual Cost of Health Effects (Billions of INR and Percentage of GDP, 2007-08)**



Source: Larsen 2011a. Note: Midpoint estimate of annual cost. Left: Billions of rupees. Right: Percentage of GDP.

habitations in the Sundarbans have piped water supply distributed to standpipes from central deep tubewells, 68 percent have tubewells with handpumps (spot sources), and 6 percent are without any of these water sources (Mohan 2011). A recent survey of 1,130 households in all blocks of the Sundarbans reported that more than 75 percent have tubewells with handpumps (IIHMR 2010).

Only 66 percent of the population has access to a toilet facility in rural South 24 Parganas compared to 90 percent in rural North 24 Parganas (IIPS 2009). This indicates that about 70 percent of the population in the Sundarbans has a toilet facility. The Total Sanitation Campaign (now called Nirmal Bharat Abhiyan) has been implemented in the Sundarbans for several years. Toilets have been provided to over 280,000 BPL households and 26,000 APL households of South 24 Parganas district, and to over 155,000 BPL households in the Sundarbans of North 24 Parganas district (Mohan 2011).<sup>6</sup>

<sup>5</sup>The estimated health effects and associated costs do not include impacts from arsenic contamination in the groundwater. These health impacts are of undetermined magnitude as data are not readily available to estimate the impacts. Also not included in the estimates are parasite infestations, typhoid, and other diseases related to inadequate water supply, sanitation and hygiene, cardiovascular morbidity from household air pollution, and health effects among adult males from household air pollution. In this respect, the estimates of health effects and their social cost should be considered conservative.

<sup>6</sup>There are an estimated 819,000 households in the Sundarbans, based on a population of 4.4 million and average household size of 5.3.



Less than 10 percent of households recently surveyed in eight blocks and subdivisions in the Sundarbans used appropriate drinking water treatment methods, such as boiling or filtering. Nearly 20 percent strained water through a cloth and 70 percent did not treat water prior to drinking.<sup>7</sup> The low rates of appropriate treatment are a potential concern for public health, as appropriate household treatment of drinking water is found globally to reduce diarrheal illness by 30–50 percent (Clasen et al. 2007; Arnold and Colford 2007; Fewtrell et al. 2005). While use of appropriate drinking water treatment among the sample of households in the Sundarbans is much higher than in rural West Bengal, according to NFHS 2005–06, it is substantially lower than in East Asian countries (for example, Cambodia, Lao People’s Democratic Republic, Vietnam) where, often, more than 70 percent of households boil or filter their drinking water.

Limited information is available on household and community hygiene practices and conditions in the Sundarbans. The Total Sanitation Campaign (now Nirmal Bharat Abhiyan) has been implemented and some villages have achieved open defecation-free status. NFHS 2005–06 contains information on household practices of children’s stool disposal. Data for rural West Bengal may provide an indication of practices in the Sundarbans. The vast majority of households practice unhygienic or unsafe disposal of children’s stools. Only about 10 percent of children’s stools are disposed of in a toilet. Even among households with a toilet, only 21 percent dispose of the stools in a toilet.

An estimated 1,700 children under five years of age died from inadequate household WSH in the Sundarbans in 2008. This represents 29 percent of total under-five child mortality.<sup>8</sup> About 40 percent of deaths resulted from diarrheal mortality and 60 percent

was mortality caused by the effect of diarrhea on child nutritional status and consequent increase in mortality from infectious diseases.<sup>9</sup> Diarrheal deaths among the population five years and older are estimated at 225 per year, bringing estimated deaths from inadequate WSH to about 1,925 in year 2008.<sup>10</sup> These deaths represent a loss of about 60,000 years of life, of which 58,000 are among children under five years.<sup>11</sup> In terms of annual morbidity, there were an estimated 580,000 cases of diarrhea among children under five years and 955,000 cases among the population five years and above, or a total of over 1.5 million cases.<sup>12</sup>

The annual cost of these health effects is estimated at INR 3.1–4.0 billion, with a midpoint estimate of INR 3.6 billion.<sup>13</sup> This cost is equivalent to 2.5–3.2 percent of the Sundarbans GDP in 2007–08.<sup>14</sup> About 75 percent of the cost is associated with mortality and 25 percent with morbidity. Nearly 80 percent of the cost is from health effects among children under five years, versus somewhat over 20 percent among the population over five years of age.

## 7.2.2 Household Air Pollution from Solid Cooking Fuels

Over 90 percent of households in the Sundarbans use wood and other biomass (wood/biomass) fuels for cooking. DLHS 2007–08 reported that 5.6 percent of rural households in North 24 Parganas and 3.7 percent of rural households in South 24 Parganas used liquid petroleum gas (LPG) (IIPS 2009). LPG is predominantly used by the richest households; wood by middle-income households; and other biomass fuels (agricultural residues, animal dung, and straw, shrubs, and grass) by poorer households.<sup>15</sup> These fuels are often the most polluting household fuels.

<sup>7</sup>Survey administered in the Sundarbans by Dr. Banerjee in 2009–10 for the World Bank.

<sup>8</sup>Annual mortality among children under five is estimated based on a mortality rate of 60 per 1,000 live births, a crude birth rate of 23 per 1,000 population, and a total population of 4.4 million in the Sundarbans. The crude birth rate in the Sundarbans is assumed to be the same as reported for rural West Bengal in NFHS 2005–06, adjusted to the year 2008. The cause-specific structure of child mortality is for all of India, as estimated by WHO (2010) for the year 2008.

<sup>9</sup>Mortality caused by the effect of diarrhea on child nutritional status (child underweight) is estimated based on methodologies in World Bank 2008 and Fishman et al. 2004. Prevalence of severe, moderate, and mild underweight among children under five years of age in the Sundarbans is estimated at 11 percent, 37 percent, and 32 percent, respectively, based on data in IIPS/Macro 2008, IIPS/MoHFW 2006, and IIMR 2010.

<sup>10</sup>Diarrheal mortality among the population five years and older is estimated by applying the diarrheal mortality rates in India reported in WHO 2009 to the population in the Sundarbans.

<sup>11</sup>Years of life lost are estimated according to WHO’s calculation of DALY using age weighting and a discount rate of 3 percent.

<sup>12</sup>Annual cases of diarrhea among children under five years of age are estimated from IIMR 2010 and IIPS/Macro 2008 (NFHS 2005–06, rural West Bengal). These two sources provide almost identical estimates of cases of diarrhea. Annual cases among the population five years and above are estimated from international surveys, indicating that incidence of diarrhea among this population group is one-fifth of the incidence among children under five.

<sup>13</sup>The lower bound reflects valuation of health effects using the human capital value (HCV) for mortality and cost-of-illness (COI) approach for morbidity. The upper bound reflects using HCV for child mortality, VSL for adult mortality, and willingness-to-pay (WTP) for morbidity. HCV is estimated at INR 1.4 million for children under five and INR 0.39 million for adults. VSL for adults is estimated at INR 1.9 million. COI includes cost of medical treatment, medicines, and time losses due to diarrhea. Cost of medical treatment and medicines is from IIMR 2010. Cost of time losses is estimated at a rate of 50 percent of average hourly wage rate. Hourly wage rate is estimated at INR 19.8 (calculated based on an estimated annual income of INR 41,000 per working person, 260 work days per year, and an eight-hour working day). WTP to avoid a case of diarrhea is assumed to be twice the estimated COI.

<sup>14</sup>GDP per capita in South 24 Parganas is estimated at INR 29,000 (US\$725) in the year 2007–08, or approximately 85 percent of GDP per capita in West Bengal (see <http://www.indiastat.com>). It is assumed here that GDP per capita in the Sundarbans is the same as in South 24 Parganas. GDP of the Sundarbans in the year 2007–08 is, therefore, estimated at INR 125 billion, assuming a then population of 4.3 million.

<sup>15</sup>From analysis of NFHS 2005–06 data for rural West Bengal.

A majority of households in the Sundarbans cooks indoors, but a substantial share does cook outdoors.<sup>16</sup> Cooking outdoors reduces but does not eliminate exposure to air pollution from use of solid fuels. Cooking outdoors often implies the use of a simple shelter from rain and wind which captures and retains a portion of the emissions. Outdoor cooking may also entail community effects and entering of smoke into dwellings. A study in southern India found that 24-hour exposure to atmospheric particulate matter from outdoor cooking was 35 percent lower than from indoor cooking for the cook and 60 percent lower for other household members (Balakrishnan et al. 2002). A study in Andhra Pradesh found a 50 percent lower exposure to particulate matter from outdoor cooking for the cook and 35 percent lower exposure for other household members (Balakrishnan et al. 2004).

An estimated 1,850 children and women died prematurely from acute lower respiratory infections (children), chronic obstructive pulmonary disease, cardiovascular disease, and lung cancer (women) due to use of wood/biomass fuels for cooking in the Sundarbans in 2008.<sup>17</sup> About 28 percent of those deaths were among children under five years and 72 percent among adult women. The deaths represent over 30,000 years of life lost per year, of which about 58 percent are among children below five years.<sup>18</sup> In addition, solid fuel use caused an estimated 365,000 cases of acute respiratory infections in children and nearly 1,000 cases of chronic obstructive pulmonary disease in women.<sup>19</sup>

### 7.3. Environmental Health: Benefit–Cost Assessment of Select Interventions

The cost of health effects of inadequate WSH, and household air pollution from use of solid fuels in the Sundarbans of India was estimated at 5 percent of the region's GDP in 2007–08. These environmental health risk factors caused an estimated 3,800 deaths and 1.9 million cases of illness in 2008. Estimated mortality in children from these risk factors represents over 30 percent of total under-five child mortality. Estimated mortality in adult women (30+ years) from the use of wood/biomass fuels for cooking represents 11 percent of total mortality in this age group of women (Larsen 2011a).

The potential benefits of interventions to reduce these health effects are substantial, but should be compared to the cost of such interventions. Such benefit–cost analysis is increasingly used in many countries for assessing the merits of potential interventions. The analysis can serve as an instrument to establish priorities and guide allocation of scarce public and private resources. The results of a

benefit–cost analysis can be expressed as a benefit–cost ratio. A benefit–cost ratio is the present value of benefits divided by the present value of costs of an intervention evaluated over the useful life of the intervention, that is, over the time period or number of years that the intervention is expected to provide benefits.

In the Sundarbans, it is estimated, from a set of environmental health interventions evaluated, that household adoption of improved wood/biomass stoves, whether cooking takes place in the indoor or outdoor environment, have the highest benefits relative to costs (Figure A7.3). These stoves emit far less unhealthy smoke, save fuel, and reduce cooking time compared to unimproved open stoves or open fires. The benefits of improved wood/biomass stoves are estimated to be in the order of 12–15 times higher than the combined cost of promotion programs and stoves.

Household treatment of drinking water (especially boiling of water) for young children and proper handwashing with soap among mothers and caretakers of young children have the second highest benefits relative to costs (Figure A7.4). These practices have been found internationally to substantially reduce the incidence of diarrheal illness in children and thus reduce child mortality as well as contribute to improved nutritional status. Benefits of these interventions are estimated to be in the order of four to six times higher than the combined cost of promotion programs and household costs associated with these interventions (soap and water, energy for boiling water, and time needed for these practices).

Benefits relative to costs of improved household toilet facilities are also high (Figure A7.4). Improved toilet facilities reduce the risk of pathogen transmission compared to unimproved facilities and prevent open defecation for households without any facility. Benefits of this intervention are estimated at nearly four times higher than the cost of infrastructure and maintenance.

Benefits relative to costs of piped water supply greatly depend on capital costs (Figure A7.4). Capital costs vary markedly with distance from water source to served communities. Benefits are estimated to exceed costs even for capital costs of INR 3,600 per person served when nonhealth benefits of increased water quantity for nondrinking purposes are included and valued at INR 20 per square meter (m<sup>2</sup>).

Interventions with the lowest benefits relative to costs, and for which benefits are mostly estimated to be lower than the costs of the interventions, are adoption of LPG stoves and household treatment of drinking water (by boiling) for adults, and improved handwashing practices with soap among adults other than mothers and caretakers of young children (Figures A7.3 and A7.4).

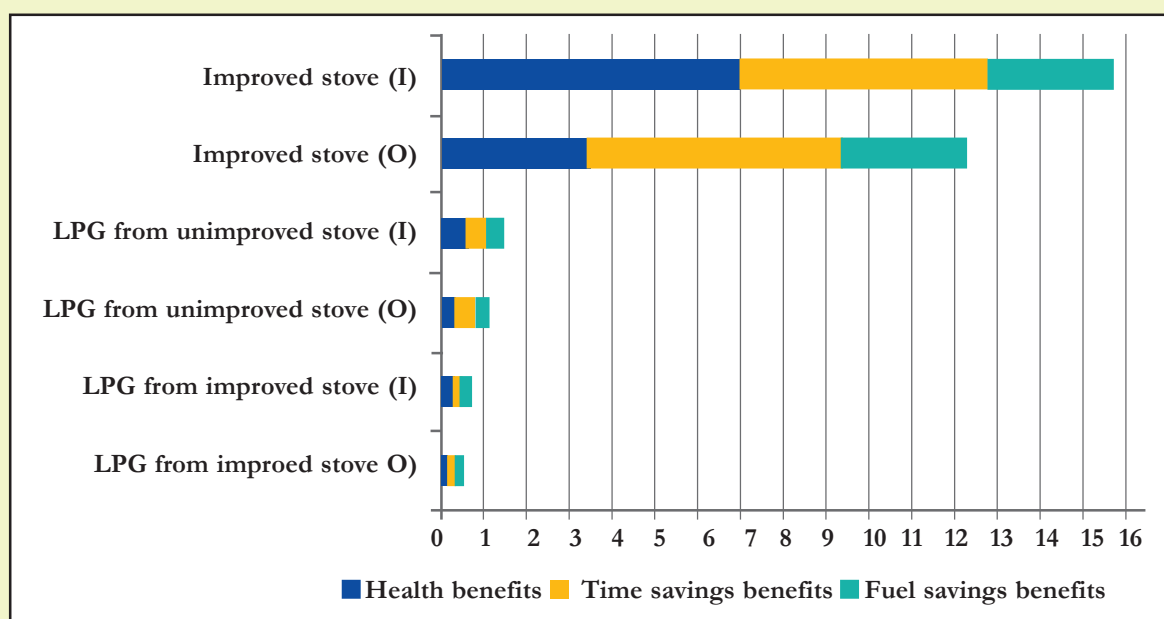
<sup>16</sup>According to NFHS 2005–06, about 70 percent of the rural population in West Bengal cooking with wood/biomass fuels primarily cooks indoors and 30 percent primarily cooks outdoors. The situation may be similar in the Sundarbans.

<sup>17</sup>Estimated based on relative risks of illness and mortality from use of solid fuels for cooking reported by Desai et al. (2004), Dherani et al. (2008), McCracken et al. (2007), and Lawes et al. (2004).

<sup>18</sup>Years of life lost are estimated according to WHO's calculation of DALY using age weighting and a discount rate of 3 percent.

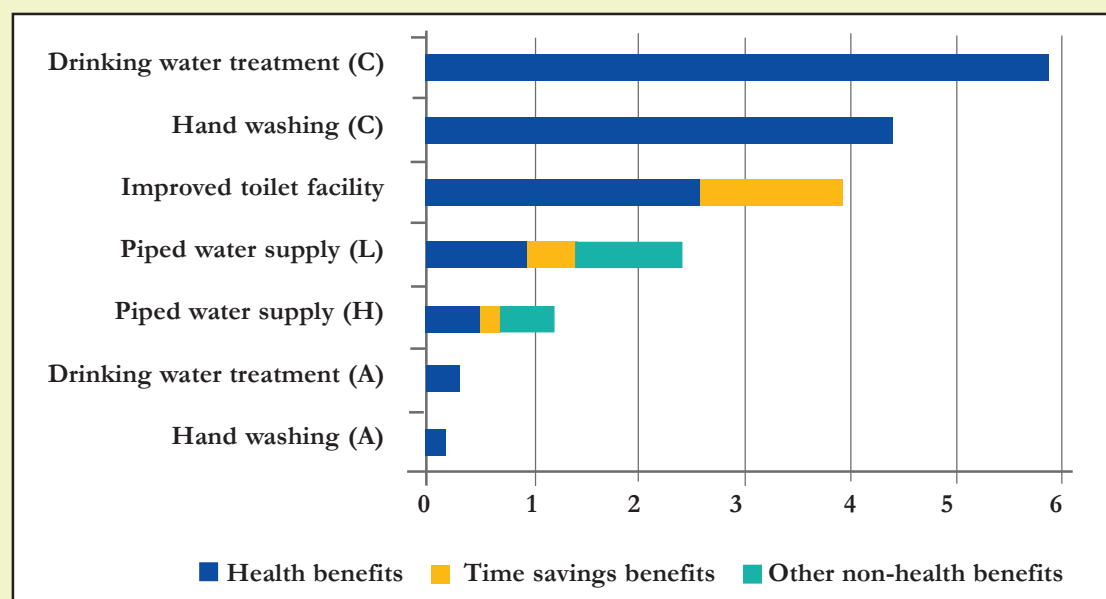
<sup>19</sup>Data used for estimating mortality and cases of morbidity from use of solid cooking fuels are from NFHS 2005–06, and WHO (2009; 2010).

**Figure A7.3: Benefit–Cost Ratios of Household Air Pollution Control Interventions**



Source: Larsen 2011b. I=indoor cooking; O=outdoor cooking.

**Figure A7.4. Benefit–Cost Ratios of Household Water Supply, Sanitation, and Hygiene Interventions**



Source: Larsen 2011b. C=child health protection; A=adult health protection; L=low capital cost (INR 1,650 per person); and H=high capital cost (INR 3,600 per person).

### 7.3.1 Household Cooking Fuels

There were an estimated 1,850 deaths and nearly 370,000 cases of acute lower respiratory infections, acute upper respiratory infections, and chronic obstructive pulmonary disease in the Sundarbans from

household air pollution due to use of wood/biomass fuels for cooking in 2008. Around 520 of the deaths were from acute lower respiratory infections among children under five years of age, and 1,330 deaths were from chronic obstructive pulmonary disease, cardiovascular disease, and lung cancer among adult women. The

annual cost of these health effects is estimated in the range of INR 1.5–3.8 billion (Larsen 2011a).<sup>20</sup>

Benefits relative to costs of adoption of improved wood/biomass stoves and LPG stoves to control household air pollution from use of solid cooking fuels are presented in Table A7.1.<sup>21</sup> Benefits include health improvements, wood/biomass fuel savings, and time savings from reduced cooking time requirements.<sup>22</sup> Benefit–cost ratios are presented for outdoor and indoor cooking.

Benefits relative to costs of replacing unimproved wood/biomass stoves with improved wood/biomass stoves are greater than 1 (that is, benefits are greater than costs) for households cooking outdoors or indoors. This is the case even when only health improvements are included as benefits.

Benefits relative to costs of switching to LPG stoves are consistently

greater than 1 only for households switching from an unimproved wood/biomass stove when all benefits are included (health, fuel, and time benefits). This suggests that households will make a transition to LPG as their income and valuation of time saving increases.

### 7.3.2 Household Water Supply, Sanitation, and Hygiene

There were an estimated 1,925 deaths and over 1.5 million cases of diarrhea in the Sundarbans from inadequate household WSH in 2008. Around 1,700 of these deaths were among children under five years of age. The annual cost of the health effects is estimated in the range of INR 3.1–4.0 billion, of which INR 2.7–2.9 billion are from health effects among children under five years of age and INR 0.4–1.1 are from health effects among the population five years of age and over (Larsen 2011a).<sup>23</sup>

**Table A7.1. Benefit–Cost Ratios of Interventions to Control Household Air Pollution from Solid Cooking Fuels**

		Households Cooking Outdoors		Households Cooking Indoors	
		Low	High	Low	High
1	Improved wood/biomass stove (health only)	2.0	5.0	3.9	9.9
	Improved wood/biomass stove (health & fuel savings)	4.9	7.9	6.8	12.8
	Improved wood/biomass stove (health, fuel, and time savings)	10.7	13.7	12.7	18.7
2	LPG from unimproved stove (health only)	0.20	0.50	0.39	1.0
	LPG from unimproved stove (health & fuel savings)	0.56	0.86	0.76	1.4
	LPG from unimproved stove (health, fuel & time savings)	1.0	1.3	1.2	1.8
3	LPG from improved stove (health only)	0.10	0.25	0.20	0.50
	LPG from improved stove (health & fuel savings)	0.32	0.47	0.41	0.71
	LPG from improved stove (health, fuel & time savings)	0.46	0.61	0.56	0.86

*Source:* Larsen 2011b. “Low” reflects valuation of health effects using HCV for mortality and COI for morbidity. “High” reflects using HCV for child mortality, VSL for adult mortality, and WTP for morbidity.

<sup>20</sup>The low end of the estimate is based on using HCV for valuation of child and adult mortality and the COI approach for morbidity. The high end of the estimate is based on using HCV for child mortality, VSL for adult mortality, and the WTP approach for morbidity. HCV for children under five year of age is INR 1.4 million. HCV for adults is INR 0.4 million. VSL for adults is INR 1.9 million. WTP = 2\* COI. COI is estimated based on treatment cost and time losses from illness. Time losses are valued at 50 percent of the average wage rate.

<sup>21</sup>Key parameter values applied for estimating benefits and costs are: health effects from the use of an improved wood/biomass stove are 50 percent of the effects from the use of an unimproved stove. Use of LPG eliminates the health effects from the use of unimproved wood/biomass stoves. Biomass consumption when using an improved wood/biomass stove is 40 percent lower than when using an unimproved stove, resulting in an annual saving of INR 900 per household per year. Use of an improved wood/biomass stove or LPG stove saves 30 or 45 minutes per household per day, respectively, in cooking time compared to the use of an unimproved stove, resulting in annual time savings per household per year worth INR 1,810 for an improved wood/biomass stove and INR 2,710 for an LPG stove (time savings valued at 50 percent of average wage rates). It is assumed that a program to promote improved wood/biomass stoves (or LPG stoves) costs INR 200 per household adopting improved wood/biomass stoves or LPG stoves. The cost of an improved wood/biomass stove is INR 300 (three years useful life; 10 percent discount rate). The cost of an LPG stove is INR 2,400 (10 years useful life; 10 percent discount rate). Estimated LPG consumption for cooking is 108 kg per household per year at an economic price of US\$1.3 per kg.

<sup>22</sup>“Low” reflects valuation of health effects using HCV for child and adult mortality and the COI approach for morbidity. “High” reflects valuation using HCV for child mortality, VSL for adult mortality, and WTP for morbidity.

<sup>23</sup>The low end of the estimate is based on using HCV for valuation of child and adult mortality and the COI approach for morbidity. The high end of the estimate is based on using HCV for child mortality, VSL for adult mortality, and the WTP approach for morbidity. HCV for children under five year of age is INR 1.4 million. HCV for adults is INR 0.4 million. VSL for adults is INR 1.9 million. WTP = 2\* COI. COI is estimated based on treatment cost and time losses from illness. Time losses are valued at 50 percent of the average wage rate.



Good-quality household water supply remains a challenge in the Sundarbans. Surface water sources have, in the past, not been viable options, and shallow groundwater is most often affected by salinity. Two predominant kinds of water supply systems are currently available. One system provides piped water from a central deep tubewell that is distributed to standpipes. The second system is small tubewells with handpumps (spot sources), generally with a much lower water production capacity per capita.

The Nirmal Gram Puraskar<sup>24</sup> has been awarded to 24 of 50 GPs of the Sundarbans in North 24 Parganas and to 28 of 140 GPs in the Sundarbans of South 24 Parganas for open defecation-free status (Mohan 2011). Challenges related to toilets, especially on remote islands, include difficulty in transport of materials, space constraint for construction of toilets, inundation from floods, and submergence of toilet blocks. After flooding some toilets have to be changed, which requires considerable expenditure by the household. The low rate of appropriate treatment of drinking water in the Sundarbans is a potential concern for public health, as appropriate household treatment of drinking water is found globally to reduce diarrheal illness, often by 30–50 percent (Arnold and Colford 2007; Clasen et al. 2007; Fewtrell et al. 2005).

Handwashing with soap has been found internationally to be highly effective in reducing the incidence of diarrhea in both children and adults. Reviews of these studies by Curtis and Cairncross (2003) and Fewtrell et al. (2005) suggest that diarrheal incidence, on average, is reduced by about 45 percent. Handwashing by mothers and caretakers of young children involves handwashing with soap at critical times such as after going to the toilet, after cleaning a child, and before preparing meals and feeding a child.

Benefits relative to costs of piped water supply, improved toilet facility, household treatment of drinking water (by boiling), and handwashing with soap are presented in Table A7.2.<sup>25</sup> Benefits

include health improvements and time savings for piped water supply and improved toilet facility, and other nonhealth benefits of increased water quantity for piped water supply.<sup>26</sup> Benefits relative to costs are highest for household treatment of drinking water (boiling of water) for young children and proper handwashing with soap among mothers and caretakers of young children. Benefits relative to costs of improved household toilet facilities are also high. Benefits relative to costs of piped water supply greatly depend on capital costs. Capital costs vary markedly with distance from water source to served communities. Benefits are estimated to exceed costs even for capital costs of INR 3,600 per person served when nonhealth benefits of increased water quantity for nondrinking purposes are included and valued at INR 20 per m<sup>2</sup>. Benefits are estimated to be lower than the costs of household treatment of drinking water (by boiling) for adults and improved handwashing practices with soap among adults other than mothers and caretakers of young children.

## 7.4. Cost of Environmental Degradation

Degradation of natural resources and natural disasters impose high costs on the Sundarbans residents in the form of lost income, and increased poverty and vulnerability. Estimated annual cost of environmental damage was about INR 6.7 billion, equivalent to 4.8 percent of Sundarbans' GDP in 2009. The estimated costs are from six damage categories (Figures A7.5 and A7.6). Damage costs from cyclones are the highest at INR 2.9 billion (2.1 percent of GDP) and include damages to houses and agriculture, and human injuries and fatalities.<sup>27</sup> The cost of shrimp postlarvae by-catch losses (crabs and fin fish) associated with fry collection and lack of hatcheries is estimated at INR 2 billion (1.5 percent of GDP). The cost of carbon sequestration losses associated with degradation and suboptimal density of mangrove forest is estimated at INR 0.8 billion.<sup>28</sup> The cost of soil salinity in terms of impacts on yields of paddy rice is estimated at INR 0.6 billion. The cost of biodiversity

<sup>24</sup>GoI's award-based incentive scheme for fully sanitized and open defecation free GPs, blocks, districts and states.

<sup>25</sup>Key parameter values applied for estimating benefits and costs are: reduction in incidence of diarrhea is 32 percent from the use of an improved toilet facility, 25 percent from provision of piped and treated water supply for drinking, 30 percent from household treatment of drinking water (by boiling), and 45 percent from handwashing with soap at critical junctures. The cost of piped water supply ranges from INR 1,650 (low capital cost) to INR 3,600 (high capital cost) per person depending primarily on distance from the water source to served communities (20 years useful life; 10 percent discount rate). The operations and maintenance cost is about INR 75 per person per year. The benefit of reduced water collection time is about INR 115 per person per year (10 minutes per household per day, valued at 50 percent of average wage rate). Nonhealth benefits of increased water quantity for nondrinking purposes from piped water supply compared to spot sources is valued at INR 20 per m<sup>2</sup>, or INR 255 per person per year. The cost of an improved pit toilet with slab is about INR 2,500 per household (five years useful life; 10 percent discount rate). The operations and maintenance cost is about INR 25 per person per year. The benefit of reduced access time to place of defecation (relative to open defecation) is about INR 200 per person per year (five minutes per person per day, valued at 50 percent of average wage rate for the household members 15 years of age and over). The annualized program cost for promotion of handwashing with soap and household treatment of drinking water is nearly INR 200 per household adopting these practices, assuming that these practices are sustained for two years. For handwashing, the cost of soap, incremental water consumption, and time used for handwashing (five minutes per person per day, valued at 50 percent of average wage rate) is about INR 180, INR 40, and INR 300 per person per year, respectively. For household treatment of drinking water, the cost of boiling water is about INR 60 for children under five years of age (0.5 liters per day), nearly INR 120 for the population five years and over (1 liter per day), and cost of time used for boiling of water (10 minutes per household per day, valued at 50 percent of average wage rate) is INR 115 per person per year.

<sup>26</sup>"Low" reflects valuation of health effects using the HCV for child and adult mortality and the COI approach for morbidity. "High" reflects valuation using HCV for child mortality, VSL for adult mortality, and WTP for morbidity.

<sup>27</sup>The estimate is based on probabilistic distribution of cyclone occurrence, and not on a single year occurrence of cyclones.

<sup>28</sup>Based on a carbon price of US\$20 per ton of carbon dioxide (CO<sub>2</sub>).

**Table A7.2: Benefit–Cost Ratios of Household Water Supply, Sanitation, and Hygiene Interventions**

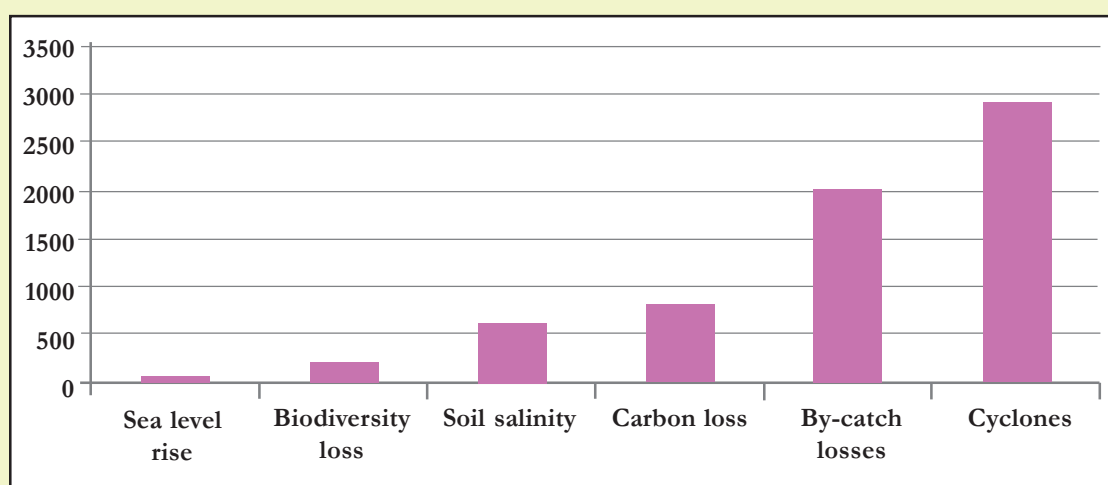
Interventions	Primary Beneficiaries	By Valuation Method of Health Benefits	
<b>Improved water supply and sanitation</b>		Low	High
Piped water supply (low capital cost)	Children & adults	2.3	2.5
Piped water supply (high capital cost)	Children & adults	1.1	1.3
Improved household toilet facility	Children & adults	3.6	4.3
<b>Household drinking water treatment</b>			
For health protection of young children	Children < 5 years	5.6	6.1
For health protection of older children and adults	Population 5+ years	0.2	0.4
<b>Handwashing with soap</b>			
For health protection of young children	Children < 5 years	4.2	4.6
For health protection of older children and adults	Population 5+ years	0.1	0.3

Source: Larsen 2011b. “Low” reflects valuation of health effects using HCV for mortality and COI for morbidity. “High” reflects using HCV for child mortality, VSL for adult mortality, and WTP for morbidity.

losses is estimated at INR 0.2 billion, and of preventable sea level rise at INR 0.045 billion.<sup>29</sup> These costs do not, however, account for losses due to mangrove degradation and overfishing, because of lack of data.

“Low” and “high” damage cost estimates are presented in Table A7.3. The range for cost of cyclones is, in large part, associated with uncertainties and variations in frequency and severity of extreme weather events. Carbon loss uncertainties are related to the scenario approach to enforcement of the conservation policy in mangroves

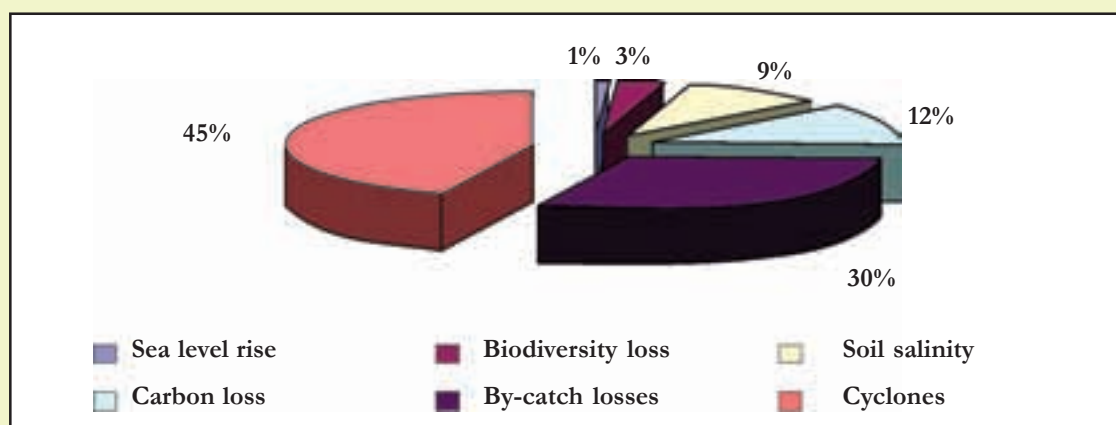
and unclear results of international negotiations on full carbon accounting. The range for postlarvae by-catch losses is mainly from the uncertainty related to additional revenue from mixed aquaculture practices. The range for agricultural soil salinity losses is associated with uncertainty of yield losses from salinity. The range for biodiversity losses reflects two different valuation techniques for estimating the social value of biodiversity. The range for losses from sea level rise is associated with different forecasts of real prices of agricultural output and uncertainty about cropping intensity.

**Figure A7.5: Annual Cost of Environmental Degradation (Million INR per Year)**

Source: Strukova 2010.

<sup>29</sup>The cost of preventable sea level rise is associated with loss of agricultural land. As sea level rise is gradual, the cost is calculated as the annualized discounted cost of land losses over the next 100 years.

**Figure A7.6: Share of Damage Cost by Environmental Category**



Source: Strukova 2010.

**Table A7.3: Annual Cost of Environmental Damage: Low and High Estimates, Million INR per Year**

	Low	Mean Estimate	High
Sea level rise	23	45	72
Biodiversity loss	135	225	315
Soil salinity	225	630	1,080
Carbon loss, 80% confidence interval	360	810	1,305
By-catch losses	1,800	2,025	2,250
Cyclones, 80% confidence interval	900	2,925	5,625
<b>Total annual costs</b>	<b>3,443</b>	<b>6,660</b>	<b>10,647</b>
<b>Total annual cost, % of Sundarbans' GDP in 2009</b>	<b>2.5%</b>	<b>4.8%</b>	<b>7.6%</b>

Source: Strukova 2010.

## 7.5. Natural Resources: Benefit–Cost Assessment of Development and Conservation Alternatives

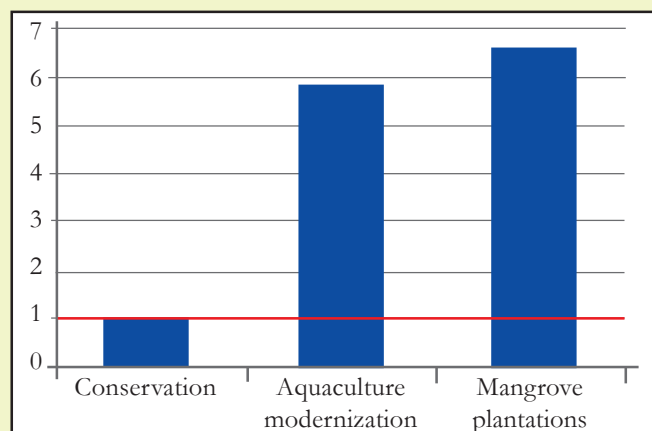
An analysis of the damage costs of environmental degradation in the Sundarbans presented above, complemented by the cost of interventions to mitigate those damages, helps to rank and prioritize interventions. The analysis of damage costs revealed substantial uncertainties associated with extreme weather events aggravated by climate change. This influences cost estimates and priorities. For instance, if sea level rise is high, then embankment projects are essential not only to protect the economy of the Sundarbans, but for its survival. Only through accumulation of knowledge over a long time can the true benefits of embankment projects be assessed. In the meantime, other interventions can be implemented. These interventions may prevent up to 55 percent of damage costs, which is comparable with uncertain damage that may be prevented by embankment projects.

Estimates of benefits and costs (benefit–cost ratios) of three interventions to mitigate damage costs of environmental degradation are presented in Figure A7.7. Mangrove plantation and aquaculture modernization (shrimp hatcheries) appear to be the most efficient interventions to protect the Sundarbans and ensure

increased productivity of the local economy. Benefits of mangrove plantations are contingent upon monetization of carbon benefits, and benefits of shrimp hatcheries may trigger collateral damage to agriculture and ecosystems of the Sundarbans. Land conservation has an estimated benefit–cost ratio close to 1, suggesting that conservation is favorable on low-yield agricultural land. Improved education and reduced illiteracy are key conditions for conservation, intensification of agriculture and aquaculture, and mangrove plantations. The cost of improved education is, therefore, included as part of the cost of interventions and reflected in the benefit–cost ratios in Figure A7.7. A preliminary analysis of embankment projects indicates that costs of embankments outweigh their benefits (see below).

### 7.5.1 Mangrove Plantations

Mangroves are a foundation of ecosystems in the Sundarbans. They provide food and shelter for animals, as well as numerous ecosystem services for the local population. Banerjee (2010) suggests a comprehensive approach to valuation of mangrove forest in the Sundarbans, applying both market prices for direct use values and benefit transfer for nonuse values (Figure A7.8). The value of direct use of mangroves in four study areas on the populous Sagar Island in the Sundarbans is estimated at about US\$560 per ha in the protected areas and US\$770 per ha in the areas where timber logging is allowed.

**Figure A7.7: Benefit–Cost Ratios of Interventions**

Source: Strukova 2010.

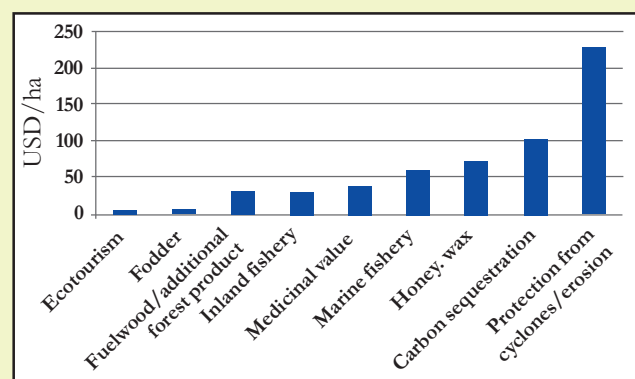
No carbon benefit is included in these estimates. In the absence of an active conservation policy on other than forest lands, mangrove plantation could take place only in degraded mangrove areas. Incremental carbon benefits from plantations in degraded areas may be about US\$80 per ha per year when valuing carbon at US\$20 per ton of carbon dioxide (CO<sub>2</sub>). Banerjee (2010) provides estimates of the cost of a mangrove plantation. The cost of plantation in degraded mangrove areas could approximate the cost of gap filling and maintenance. Annualized, this cost is estimated at about US\$12 per ha. Thus the benefit–cost ratio of mangrove plantation in degraded areas is about 6.6 if only carbon benefits are considered. This is likely a conservative estimate in light of the benefits of mangrove forest reported by Banerjee (2010).

The high value of the protective function of mangroves demonstrates the importance of their preservation, and justifies reforestation and afforestation efforts in the Sundarbans, which would have not only local but regional and global implications. Mangroves, vital for local communities in the Sundarbans, also serve as a natural shield that protects the vulnerable Ganges Delta, which faces multiple challenges of natural and anthropogenic origin.

### 7.5.2 Aquaculture Modernization

GoWB promotes sustainable aquaculture in the Sundarbans. Intensive seed collection from the wild for stocking of ponds has been banned. Only certified hatcheries producing seed should be used for stocking, and overstocking of ponds must be avoided. Tiger shrimp postlarvae from hatcheries should be of good quality, tested and certified. Investment in hatcheries that could form a network of seed banks can help reduce the cost of environmental degradation.

Small-scale hatcheries are usually operated by a family group on a small plot of land. Their advantages include relatively low construction and operating costs and flexibility to open and close, depending on the season and market factors. They utilize small tanks (less than 10 tons) and concentrate on just one phase of

**Figure A7.8. Estimated Annual Benefits per Hectare of Mangroves**

Source: Banerjee 2010, author's estimate.

production – postlarvae production. They often use low densities and untreated water, and thus are susceptible to diseases. Survival of the developing larvae in small-scale hatcheries ranges from zero to over 90 percent, depending on a wide range of variables, such as stocking densities, temperature, and the experience of the hatchery operator.

Angell (1994) estimates that one small-scale hatchery with three cycles of production per year can produce about 2 million postlarvae, with fixed costs of about US\$23,000 and operational costs of about US\$9,000. The annualized net present value of such a hatchery is estimated at about US\$7,100, assuming 10 percent interest rate and a 10-year life cycle of equipment. Based on the estimate of Biswas (2010), that the annual use of wild postlarvae is about 1.2 billion, the cost for a small-scale hatcheries program of equivalent output is about US\$4.7 million annually. However, this is a lower estimate of cost associated with the current level of wild postlarvae collection. With the expected increase in aquaculture, demand for postlarvae would grow, and the required investment in hatcheries would increase in parallel.

### 7.5.3 Land Conservation

Conservation of land, by converting the most saline, flood-prone, and erosion-prone agricultural land back to mangrove forest and mud flats, can provide many benefits to the Sundarbans. Most of the problematic agricultural lands are reclaimed from mangrove forest and, more recently, from mud flats. One can assume that converted agricultural land will transform into mud flats. As Nanda, Mukhargee, and Chauhan (2001) report, mud flats are made up of soft-grain mud and act as a sustainable habitat for a variety of fauna and flora, including mangrove and marsh vegetation. Laffoley and Grimsditch (2009) suggest that tidal salt marshes could accumulate up to 2.1 tons of carbon per ha per year. Even if mud flats were to be 50 percent less carbon productive, carbon accumulation would still be about 1 ton of carbon per ha per year. Assuming a price of carbon of US\$20 per ton of CO<sub>2</sub>, the carbon value of the mudflats would be about US\$73 per ha per year. To this value can be added nonuse values at US\$15 per ha of wetlands, as reported in Barbier, Acreman,



and Knowler 1997.<sup>30</sup> Thus benefits are estimated at about US\$88 per ha or at about US\$2.8 million annually for conservation of about 32,000 ha.

The cost of land conservation is the annual net revenue of crop cultivation that will be lost from lands converted from agriculture to conservation. The most saline and waterlogged lands in the Sundarbans – which are the first candidate for conversion to conservation land – have much lower rice yields than nonsaline land (about 800 kg per ha lower). Cropping intensity tends also to be lower on these saline lands (about 1 on nonproductive saline lands). Lastly, these lands may gradually be abandoned anyway, as they may become increasingly saline. Assuming gradual agricultural land loss over the next 50 years, lost net revenues per ha of saline lands allocated for conservation is estimated at about US\$85 per ha per year. Total conservation costs are then about US\$2.7 million annually. This is close to the estimated benefit of conservation at a carbon price of US\$20 per ton of CO<sub>2</sub>. Conservation may be coupled with mangrove plantations. More research is needed to estimate annual capacity for mangrove plantations in the area, taking into account embankment projects and mangrove plantations in other areas.

#### 7.5.4 Embankments

A preliminary analysis of the embankment project suggests that benefits may be lower than costs. Ruitenbeek (2010) estimates a total capital cost of embankment projects to protect the Sundarbans at about US\$4–5 billion in the next 20 years, concentrating on realignment of existing embankment, and US\$8–10 billion in the next 20–100 years to retreat and build new embankments. The estimated annualized cost of project implementation is thus about US\$300 million, assuming 5–6 percent opportunity cost of capital and 40 years total project implementation time. However, the mean annual estimate of damage attributed to cyclones is about US\$65 million, with a “high” estimate of US\$125 million (see section 4). Thus, the benefits of embankments, in terms of protection and reduced cost from cyclones, appear to be lower than the cost of embankments. Nevertheless, there may be areas of the Sundarbans where benefits are likely to exceed the costs, and an options value analysis indicates that further research on embankments is warranted. Such research can create an option for the implementation of adaptation strategies stage by stage, concentrating first on the highest-risk zones.

### 7.6. Conclusion and Recommendations

From a set of environmental health interventions evaluated here for the Sundarbans, the benefit–cost analyses indicate that the promotion of household adoption of improved wood/biomass stoves should receive high priority, even among households that cook outdoors. This is especially important as over 90 percent of households use wood/biomass fuels for cooking in the Sundarbans.

Various improved stoves can be piloted to test for household preferences and likelihood of adoption. Promotion programs can educate households on the benefits, and emphasize the potential social status that cleanliness and use of more sophisticated technology can bring.

While it may be a formidable challenge to provide every household in the Sundarbans with piped water supply or spot sources of satisfactory drinking water, household treatment of drinking water (boiling or other appropriate methods) can be promoted with substantial health benefits relative to costs. The promotion of household treatment of drinking water is especially important as so few households seem to apply this practice in the Sundarbans. Households with young children would be the main beneficiaries.

As an increasing number of communities in the Sundarbans are achieving open defecation-free status through adoption of household toilets and improved sanitary practices, handwashing with soap by mothers and caretakers of young children should receive increased emphasis in light of the results of the benefit–cost analysis presented here. Global handwashing campaigns and promotion programs in India can provide substantial experience and guidance for giving this issue increased emphasis in the Sundarbans.

Extreme weather events put additional pressure on the struggling population. According to a preliminary analysis, an expected value of losses due to productivity shocks could be about US\$65 million annually. With a probability of 5 percent, expected value of losses could be three times more. Expensive long-term investments in embankment improvements may not cover mitigated risk. The proposed embankment project has a significant potential value that justifies further research, including more detailed analysis of extreme weather events, exposure to hazards, and the cost of embankments in different areas of the Sundarbans.

Benefit–cost analysis can assist in ranking and prioritizing interventions, though there are significant uncertainties associated with extreme weather events triggered by climate change. The high risk of catastrophic damage may lead to revision of cost estimates and consequent adjustment of priorities. For instance, if sea level rise is at the high end of estimates, then the embankment project is critical, not only to protect the economy of the Sundarbans but for its very survival. An assessment of the true benefits of the embankment project will take considerable research. In the meantime, other interventions could be implemented, with more certainty of positive outcomes. Mangrove plantation and modernization of aquaculture and shrimp hatcheries appear to be the most efficient interventions for protecting the Sundarbans and ensuring productivity growth of the local economy. However, the benefits of mangrove plantations are contingent upon monetization of carbon benefits, and avoidance of ecosystem damage due to activities such as shrimp farming. Ecotourism also has the potential to boost the local economy.

<sup>30</sup>Other indirect use values could be included too, but this issue requires special consideration, as only indirect services of mangrove forests were studied, not values of mud flats.

There are significant possibilities to improve productivity and reduce the cost of environmental degradation through adoption of new technologies. Some moderate increase of productivity in agriculture could be obtained, but rice production is vulnerable to extreme weather events triggered by climate change. In the future, agricultural land use could make way for aquaculture, which is a significantly more efficient and productive land use option. Aquaculture has the potential to become a major source of growth in the area if environmental and hydrological concerns are addressed. Substitution of postlarvae collection by hatcheries will reduce damage to fragile mangrove biodiversity and fisheries. Increasing the density of mangroves in the buffer zone, with a simultaneous increase in nontimber products and sustainable fuel wood collection, could generate greater forest revenues. Monetization of carbon sinks in fast-growing mangroves and soil depositions of carbon could be significant sources of additional revenue.

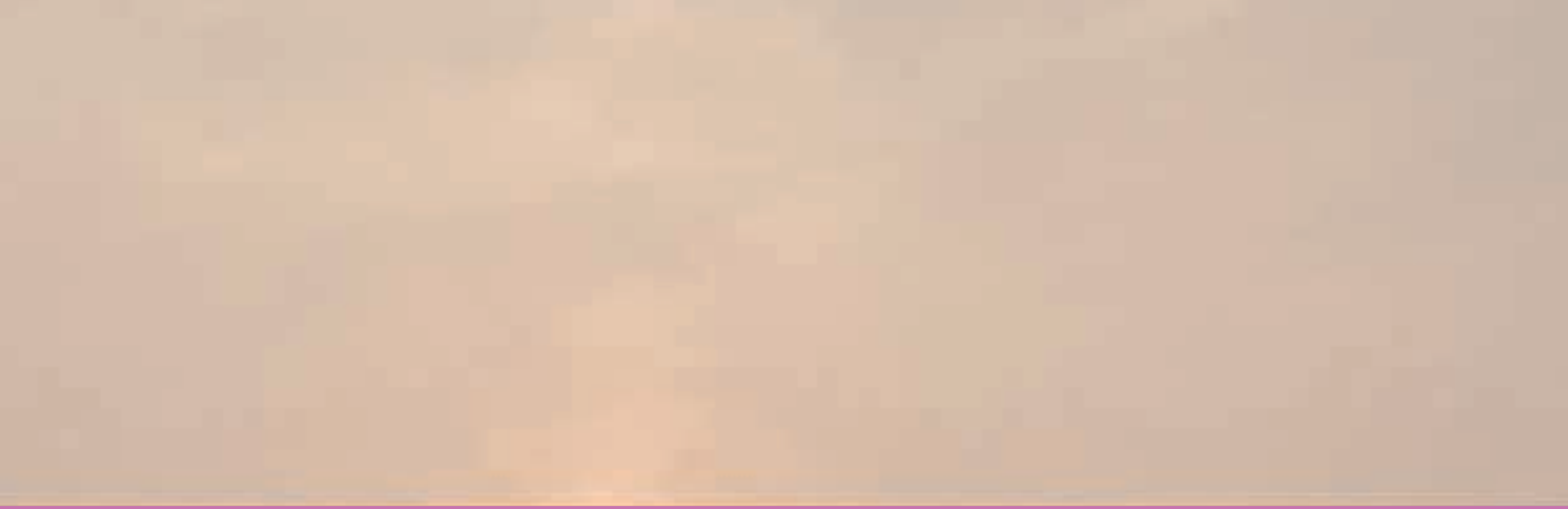
Education is a key for successful implementation of a new concept of economic growth that recognizes the value of reducing the excessive labor supply, protecting biodiversity, and increasing the productivity of forest through both traditional and new activities. Conservation measures could have direct economic benefits and the additional benefit of reducing the costs of environmental degradation. Coupled with ecotourism, these measures could provide additional opportunities for rural communities to diversify into more market-oriented business activities and contribute to improvement of the well-being of the local population.

Protection from extreme weather events and sea level rise could be improved to alleviate productivity shocks. The benefit–cost ratio of the proposed embankment project is uncertain, but incorporating research and development into the adaptation strategy may reveal an option whereby a stage-by-stage approach, concentrating on the highest risk zones first, yields positive results.

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# Annex 8.

## Spatially Blind Policies to Promote Human Development<sup>1</sup>



### Abstract

A response to the risks and opportunities faced by the residents of the Sundarbans can be provided through a spatial transformation that will serve to build their health and skills, to enhance their mobility and link them with growing opportunities in less risky environments. Current profiles of households in the Sundarbans exhibit links between poverty, and poor education and health outcomes. Interventions focused on building human capital, irrespective of location within the Sundarbans, will be critical for promoting socioeconomic development in the region. This will serve to reduce the effects of poverty and build social resilience, and to better link local populations and communities with growing opportunities outside the Sundarbans. Without efforts to improve their health, education, and skills, residents of the Sundarbans will continue to face limited opportunities outside the high-risk areas. And when subsistence in the Sundarbans is no longer a viable option, poverty and limited opportunities will drive out residents.

### 8.1. Introduction: Human Development

In order to address the interlinked issues of poverty reduction, biodiversity conservation, and resilience to natural disasters in the Sundarbans, the World Bank initiated a NLTA to GoWB to better understand the key issues in the Sundarbans and the priority actions that needed to be taken. Under this NLTA, 21 studies were conducted, including a study on education (IMRB 2011), studies on health and environmental health (Das 2010; Larsen 2011), and a comprehensive survey of the 19 Sundarbans blocks in West Bengal's North and South 24 Parganas districts. The outcomes of these studies form the basis for recommended strategies in the health and education sectors that would serve to build the human capital essential for a fundamental spatial transformation of the Sundarbans.

The following sections provide an overview of the findings of the various studies conducted in health and education, as well as demographic information found in the comprehensive survey of 2,188 households in the Sundarbans blocks. A section on recommendations draws from the evidence presented to lay the foundations for a strategy of spatial transformation.

### 8.2. Education

West Bengal boasts some of the highest literacy rates in India, and literacy rates in the Sundarbans, while below the state average, remain above the national average. While this is impressive, upon closer examination, several issues stand out with respect to educational attainment in the Sundarbans. Specifically, the research conducted under this NLTA indicated a transition dropout rate that shows a marked decline in the 90 percent enrollment at the primary level as students transition to higher levels of education. Households cited the hidden costs of education as a primary factor when withdrawing children from school, and the potential income that especially boys could earn through labor. Vocational training is virtually nonexistent in the Sundarbans, and skills training and job placement is in high demand. Studies show that the quality of education is also a critical issue in the Sundarbans.

#### 8.2.1 Educational Profile of Sundarbans Residents

There are numerous challenges to educating children in the Sundarbans, including accessibility and transportation, but also issues such as poverty and hidden costs of education. Issues of accessibility and transportation to schools are critical for attracting students to primary school, but issues of poverty, hidden costs of education, and quality of education are extremely important to retain students.

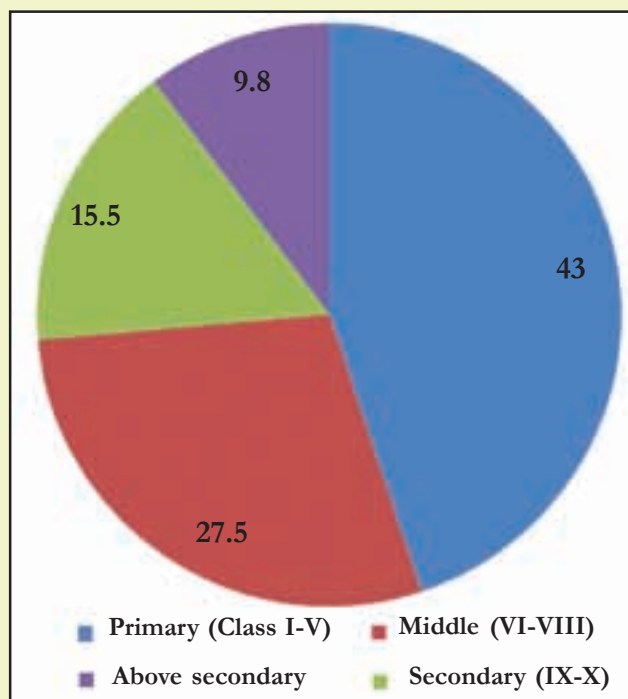
<sup>1</sup>This annex was prepared by Anna O'Donnell, Nalin Jena, and Ruma Tavorath based on reports prepared by IMRB Consultants (education), Bjorn Larsen (environmental health), and Chandrayee Das (health), and drew data from a 2011 household survey commissioned as part of the Non-Lending Technical Assistance.

District-level data for North 24 Parganas and South 24 Parganas show that more than 90 percent of children within the appropriate age group at the primary level are in school, and similar figures are seen through the region. However, a household survey of the 19 Sundarbans blocks indicated that around 24 percent of the population aged five or more had never attended school, a much higher rate than elsewhere in the district or state.

Literacy in West Bengal is also quite high. Preliminary results from the 2011 Census showed that the literacy rate had grown from 68.64 percent in 2001 to 77.08 percent in 2011, versus a national average of 74 percent. North 24 Parganas had the highest literacy rate at 87.66 percent, followed by South 24 Parganas with 87.14 percent. However, a household survey of the 19 Sundarbans blocks indicated that nearly a quarter of the population was illiterate (23.9 percent), also significantly higher than the district and state averages.

Of the population aged 22 years or older who attended school, 43 percent completed primary school and 27.5 percent completed middle school. A little less than 10 percent completed any level above secondary (Figure A8.1).

**Figure A8.1: Highest Level of Education (Sundarbans Blocks) Completed by Those Aged 22 or Older Who Attended School**



Source: Household survey, 2011.

<sup>2</sup>Although, in theory, the statewide Sarva Shiksha Abhiyan scheme embraces the concept of free elementary education, it does not eliminate the hidden costs that families have to bear when sending their children to schools. Such expenses become even more critical for an area such as the Sundarbans, where most people have low levels of income.

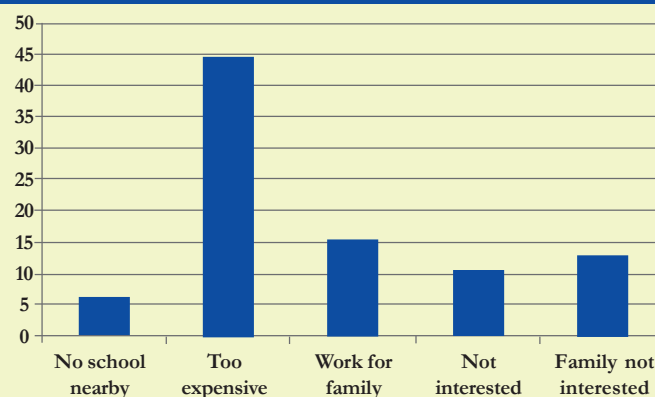
<sup>3</sup>In the Sundarbans, transport by waterway is often so challenging that students miss school regularly because of the poor reliability of the transport system.

This finding on the high rate of transition drop out was confirmed in a further study by the Indian Market Research Bureau (IMRB) (2011), a consultant firm contracted under this NLTA, which noted that the percentage of children leaving school drastically increases with additional years of schooling, especially in South 24 Parganas district. Most dropouts take place at transition points – from primary to upper primary, from upper primary to secondary, and from secondary to higher secondary. The issue of transition dropout was validated by community-level stakeholders, parents, and students interviewed during the study, who reported that, following primary education, it became difficult to sustain children's education due to the cost involved in schooling, and the fact that boys of this age are seen as potential wage earners for the family. While the main reason for girls dropping out of school was marriage, for boys the reasons were related to the hidden cost of schooling<sup>2</sup> and the need for boys to start working early in order to supplement family income.

The 2011 household survey in the Sundarbans blocks found that nearly half of the respondents, who had either not ever attended school or not attended in the 2010–11 school year, cited the cost of education as the primary reason for not attending school. Poverty-stricken households had difficulties obtaining the funds needed for school fees, books, uniforms, and transport (Figure A8.2).<sup>3</sup>

IMRB (2011) also found that financial difficulties pertained to payments made to the school as admission fees (often disguised as other costs) and cost of uniform and textbooks (which in most parts of the region are not distributed free of cost). In the Sundarbans, the riverine terrain was also found to be a contributing factor in raising transportation costs; anecdotal evidence collected by IMRB suggested that the average travelling costs for many

**Figure A8.2: Reasons for Never Attending School or Not Attending in Academic Year (2010–11)**



Source: Household survey, 2011.

students required to take a boat to school could be INR 4 to INR 10 per day, adding up to an average of more than INR 200 per month. Parents reported that, in addition to the costs of travel, on average, a family needed to spend between INR 500 and INR 2,000 per month to keep its children in primary school. Costs were found to increase as students progressed in school.

## 8.2.2 Institutional Constraints to Education

Institutional constraints to education also exist in the Sundarbans, with limited availability of school facilities, particularly at the secondary, postsecondary, and vocational levels. In a study on the state of education in the Sundarbans, IMRB (2011) found that, particularly at the secondary level, access becomes a serious issue because of the lack of adequate school facilities, or poor infrastructure of available schools. In interviews with parents, Panchayat members, and community members, IMRB found high levels of dissatisfaction over the quality of education.

The household survey of the Sundarbans blocks found that a large majority of households (84.5 percent) would be willing to send their children outside the Sundarbans for educational purposes (Table A8.1). This finding was true across religious groupings and poverty levels, and reflected a high level of dissatisfaction among households with the availability and quality of educational facilities in the Sundarbans.

Vocational training institutions currently offering any kind of vocational training in the Sundarbans are few in number, and those that do exist either do not function properly or impart poor quality training that lacks relevance to the employment needs of young people. Information received from the Department of Technical Education and Vocational Training shows that, at present, only five industrial training institutions and one industrial training center exist in the Sundarbans.<sup>4</sup> The trades being taught are those of fitters, welders, plumbers, sewers, and carpenters, among other basic vocations.

The almost complete absence of any kind of formal vocational training provision in the Sundarbans severely constricts the opportunities for local young people to gain employable skills. For those who do not want to or are unable to pursue higher education, these vocational training institutions could offer a means of ensuring skills development and increasing opportunities for employment. In the absence of such provisions, young people are forced either to migrate to nearby cities or other states in search of (mostly unskilled) labor or to settle in the region and join the unemployed or seasonally employed workforce involved in agriculture and fisheries.

Almost all vocational training in the region is imparted in the form of informal apprenticeships whereby young children apprentice with adults in a particular vocation and train under them until they can find employment on their own or begin their own petty business. These apprenticeships typically involve manufacture of puffed rice, jaggery, mats, fishing nets, and boats, all which are extremely low paying. A few NGOs have begun short training courses in modern methods of fishing, bamboo work, and other such small indigenous sectors that allow the trainees to earn a little money with the skills learned.

IHMR 2010 study found that there was high demand for technical and vocational education and training in the region. Young people and their parents aspire to employable technical and vocational education and training that will allow them access to better jobs and higher wages. This finding was confirmed in the household survey of the Sundarbans blocks, in which nearly 80 percent of respondents indicated that they would be willing to participate in vocational training outside the Sundarbans (Table A8.2).

While there are about 65 colleges in the two districts of North and South 24 Parganas, including three polytechnics and three management colleges, almost without exception they are located in Barasat, Basirhat, Barrackpore, Diamond Harbour, and other centers in the vicinity of Kolkata, and therefore are not easily accessible to the aspiring students of the Sundarbans region.

**Table A8.1: Willingness to Send School-age Children outside the Sundarbans for Education**

	All	Hindu	Muslim	Poor	Nonpoor
Yes, for all children	84.5	85.8	80.19	85.61	83.47
Yes, but only for male children	9.7	9.0	11.87	9.09	10.19
Yes, but only for female children	0.1	0.05	0.16	0.14	0.02
No	5.8	5.15	7.78	5.17	6.32
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: Household survey, 2011.

<sup>4</sup>Industrial training institutions are public establishments and industrial training centers are private establishments. They function under the Ministry of Labor and Employment, GoI, and provide trade skills training of different durations under national trade certification.

**Table A8.2: Willingness to Participate in Technical Institute or Vocational Training outside Sundarbans**

	All	Hindu	Muslim	Poor	Nonpoor
Yes, for all	77.8	79.54	72.11	77.77	77.84
Yes, but only for men	9.9	8.66	14.1	10.1	9.78
Yes, but only for women	0	0.05	0	0	0.07
Yes, for all, but only if employment is assured after the training program	9.1	8.76	10.43	8.99	9.29
No	3.1	2.99	3.35	3.14	3.02
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: Household survey, 2011.

### 8.3. Health

Residents of the Sundarbans face numerous health challenges, and the state of health of the population is poorer than in other districts of West Bengal. In the rural areas of the Sundarbans (which constitute the blocks close to the forest), residents reported issues with airborne diseases, especially acute respiratory infections, which are common in many parts of rural India where households rely on traditional biomass-based cooking stoves. In addition, residents of the Sundarbans face illnesses or injuries that are particular to living in wet and marshy conditions, most notably vector-borne diseases, pneumonia, and bites from crocodiles, snakes, or tigers. Institutional constraints to healthcare also exist in the Sundarbans, with residents citing costs of provision or lack of access as key constraints to seeking medical care and attention.

#### 8.3.1 Health Profile of Sundarbans Residents

Residents of the Sundarbans face numerous health challenges. Many of these challenges can be attributed to poverty, lack of adequate water supply and sanitation facilities, or airborne diseases common to rural lifestyles in India. However, residents of the Sundarbans blocks also face challenges specific to the environmental terrain, such as vector-borne diseases, pneumonia, or animal bites.

In the household survey of the Sundarbans blocks conducted in 2011, most household members reported that they were not suffering from a disability (96.8 percent); 10 percent of the population reported facing a chronic illness; and 2 percent reported suffering from acute respiratory infection. However, acute respiratory infection showed high relative prevalence in certain blocks, including Sandeshkhali I, Canning I, Canning II, and Kakdwip, with several blocks registering a rising trend. Malaria is endemic in the Sundarbans, and the annual parasite incidence<sup>5</sup> showed a rising

trend, particularly in the post-Aila period. In a number of blocks, there was a high prevalence of *Plasmodium falciparum*, the most dangerous type of malarial infection. Leishmaniasis (kala-azar) is another vector-borne disease prevalent in some blocks of the Sundarbans, with contributory factors including low socioeconomic status, inadequate sanitation, unsafe water supply, and poor housing facilities.

At the block and district levels, tuberculosis continues to be a major health problem and is the main cause of death from infectious disease among adults, both in the Sundarbans and in India as a whole. Pulmonary tuberculosis comprises about 85 percent of all new tuberculosis cases. Canning I and Canning II have the highest endemicity of tuberculosis, linked strongly to the poverty and sociocultural context. A number of chronic noncommunicable diseases are prevalent in the Sundarbans, including arthritic pains, cardiovascular disease, asthma, diabetes, skin-related problems, and vision problems. The mortality and morbidity rates for these diseases in the Sundarbans are higher than the state average (IHMR 2010).

Inadequate water supply and sanitation in the Sundarbans blocks also contributes to the health problems of residents, particularly women and children. It is estimated that 1,700 children under five years of age died due to inadequate household WSH in the Sundarbans in 2008 (Table A8.3), representing 29 percent of total under-five child mortality.<sup>6</sup> Of those deaths, about 40 percent was directly attributable to diarrhea and 60 percent was mortality caused by the effects of diarrhea on child nutritional status and consequent increase in mortality from infectious diseases. Diarrheal deaths among the population aged five years and older are estimated at 225 per year, and estimated deaths due to deficient WHS totaled 1,927 in 2008.<sup>7</sup>

<sup>5</sup>Annual parasite incidence is the number of blood smear tests found positive for the malaria parasite in a year per 1,000 population.

<sup>6</sup>Annual mortality among children under five is estimated based on a mortality rate of 60 per 1,000 live births, a crude birth rate of 23 per 1,000 population, and a total population of 4.4 million in the Sundarbans. The crude birth rate in the Sundarbans is assumed to be the same as reported for rural West Bengal in NFHS 2005–06, adjusted to the year 2008. The cause-specific structure of child mortality is for all of India as estimated by WHO for the year 2008.

<sup>7</sup>Diarrheal mortality among the population five years and older is estimated by applying the diarrheal mortality rates in India reported by WHO to the population in the Sundarbans.



**Table A8.3: Estimated Annual Child Mortality from Inadequate WSH in Sundarbans, in 2008**

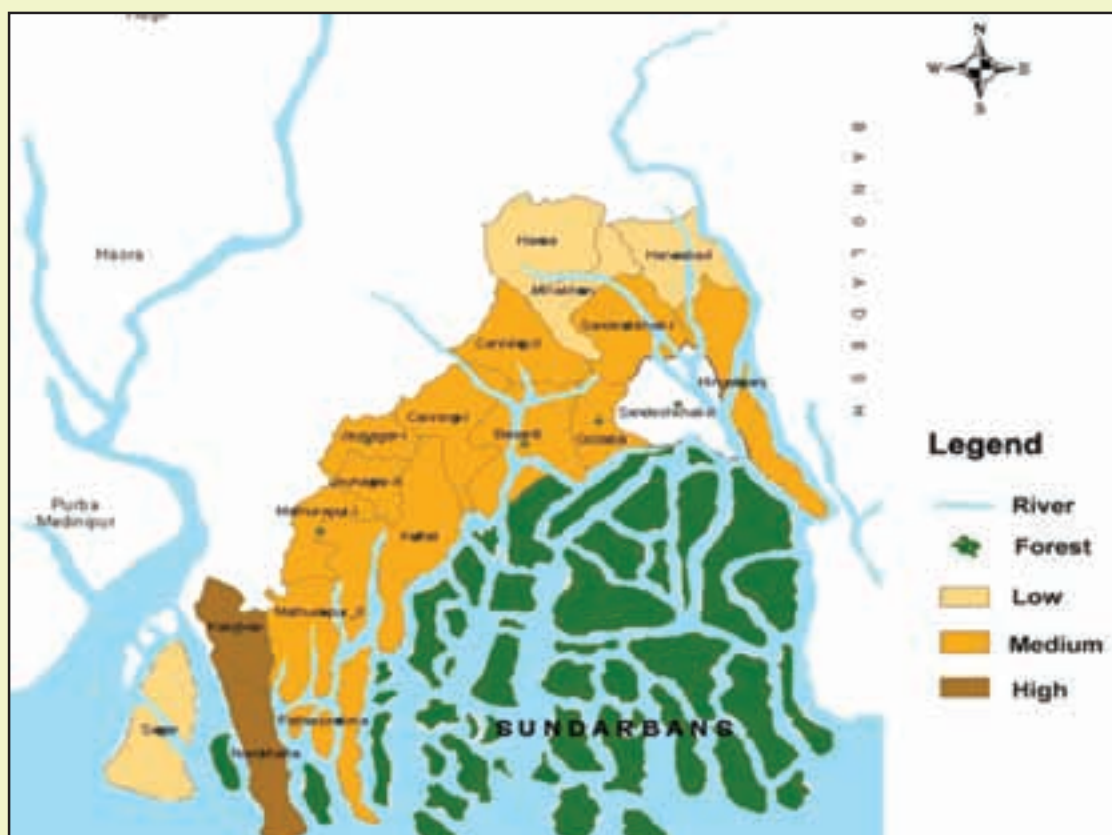
	Annual Mortality among Children under 5 Years	Attributable Fraction from WSH	Annual Mortality from WSH	Years of Life Lost from WSH
Diarrheal diseases	771	88%	679	23,081
Acute lower respiratory infections	1,205	42%	502	17,052
Measles	261	34%	89	3,024
Other infectious and parasitic diseases	1,009	43%	433	14,711
Other causes	2,688	0%	0	0
<b>Total</b>	<b>5,934</b>	<b>29%</b>	<b>1,702</b>	<b>57,868</b>

Source: Larsen 2011.

The marshy and wet environmental conditions of the Sundarbans contribute to the persistence of gastrointestinal disorders (diarrhea) and respiratory problems, as well as water- and vector-borne diseases. The prevalence of diarrheal disease in the Sundarbans is shown in Figure A8.3. The prevalence rates, particularly in South 24 Parganas, have shown a rising trend over 2008 and 2009. Cases of diarrhea peak substantially during the rainy season from June to October.

The threat of animal bite (from tigers, crocodiles, dogs) is grave, especially among those who frequent the swamps and waterways of the Sundarbans for fishing and collecting forest products.

Incidences of snakebites are historically high in South 24 Parganas due to various factors, including its low-lying nature and suitable habitat for a variety of venomous snakes. According to official estimates, about 30 persons fall prey to animal attacks every year as they are engaged in fishing or collecting honey or wood from the forest. Fortunately, the Department of Health has sufficient availability of antivenom and antirabies vaccine to manage the situation. Enteric fever is also quite prevalent in the riverine blocks of North 24 Parganas (Sandeshkhali I, Minakhan, and Hasnabad), the main causes of the endemicity being contaminated food and water.

**Figure A8.3: Diarrheal Disease Prevalence in Sundarbans**

### 8.3.2 Institutional Constraints to Healthcare Provision

Primary health centers are the backbone of the rural public healthcare system, but their service has been suboptimal in the Sundarbans due to a range of factors, including absenteeism of doctors and support staff. While this is a challenge across many regions in West Bengal and in India, the Sundarbans is additionally constrained due to the remoteness and inaccessibility of much of the population and lack of infrastructure, including accommodation facilities. The health infrastructure in Sundarbans is extremely limited by systemic human resource challenges such as absenteeism and vacancies, due to which many basic services cannot be offered to the population. There is a high level of dependence on the public health system, due to the stark absence of private service providers. Outreach services play a significant role in the Sundarbans to provide basic healthcare services to a large and widely dispersed population.

In the household survey of the Sundarbans blocks, around one quarter of the population reported having suffered from an accident or illness in the previous six months (24.6 percent). The most prevalent illness cited was fever or cold (16.1 percent). Of those citing an illness or accident over the previous six months, most sought medical care from informal healthcare providers (“quacks”) (42.5 percent) followed by a private doctor (23.3 percent). Less than 10 percent of all household members who were ill and had sought medical attention in the previous six months went to a primary health center (7.5 percent) (Figure A8.4).

Infant and maternal mortality rates reported for the Sundarbans are unexpectedly low, most likely due to under reporting resulting from inadequate numbers of health workers, lack of efficiency, and irregular field visits due to difficult terrain and poor accessibility. High maternal mortality in the Sundarbans results from malnutrition, prevalence of anemia among pregnant mothers, and young age at marriage (Das 2010). About 21 percent of pregnant women in the Sundarbans zone of South 24 Parganas suffered

from anemia, according to 2006–07 records. Infant death among BPL families was 53 percent in the non Sundarbans zone of South 24 Parganas and 60 percent in the Sundarbans zone.

The immunization rate for the Sundarbans has been reported as 43 percent, compared to 88 percent in North 24 Parganas and 73 percent in South 24 Parganas as a whole (Chakrabarty 2009). The low rates are due to low female literacy and lack of awareness, insufficient numbers of health personnel, inadequate cold chain, and irregular availability of vaccines. However, there are discrepancies, as some land blocks have low success rates while some inaccessible areas have high performance rates. Such discrepancies reflect lack of systematic planning and optimized scheduling, misreporting, and inadequate monitoring.

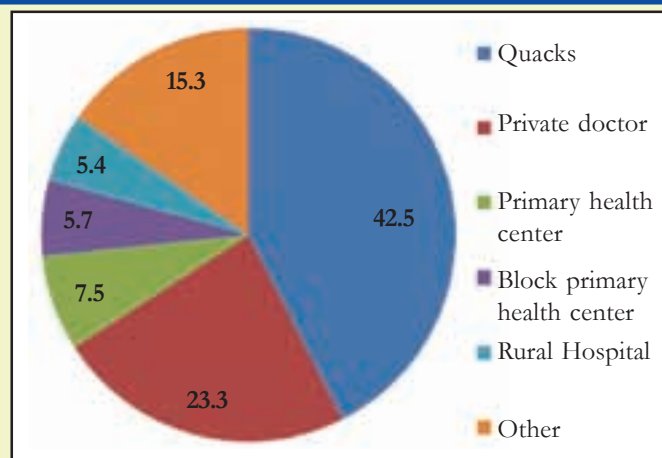
Institutional delivery still lags behind at 22 percent, though in 2008–10 all districts and blocks registered an increase. The dropout rate from the complete antenatal care cycle is high, despite monetary incentives provided through national programs. Chronic malnutrition has been observed among children in the Sundarbans in the age group zero to five years. As expected, for the Sundarbans of North 24 Parganas, Grade I and Grade II categories malnutrition surpasses that of non Sundarbans areas, while in South 24 Parganas the levels are equivalent. Malnutrition in the Sundarbans is the result of marginal dietary intake compounded by infection, household food insecurity, lack of alternative sources of income, and lack of clean water.

Health-seeking behavior is, therefore, impacted by poor road and transport infrastructure, low literacy and awareness levels, no availability of or difficulty in accessing health services, and the general lack of socioeconomic development of the area. Provision of healthcare services is also poor due to insufficient healthcare staff on the ground, inadequate infrastructure, and limited number of alternative services provided by trained private sector professionals. The referral system is also constrained due to various reasons, including poor information and communication facilities, and inappropriate counseling and follow-up. All in all, the challenges related to public health and disease indicators in the Sundarbans are complex, due to the multifaceted interface of social, economic, institutional, and geographic factors.

### 8.4. Recommendations on Improving Human Development

The population in the Sundarbans has been historically isolated and underserved by public services and infrastructure, and faces high levels of poverty, malnutrition, poor health, limited access to education, and high risks from natural disasters. This places residents of the Sundarbans in a situation where human capital is consistently eroded, further undermining resilience and perpetuating poverty. The concept of “building resilience” requires that the natural threats be addressed concurrently with attempts to improve the socioeconomic status of residents, with the long-term intention of improving the welfare of present and future generations. In the short and medium terms, interventions should focus on a set of

**Figure A8.4: Sources of Medical Care for Sundarbans Residents**



Source: Household survey, 2011.

*spatially blind* investments (that is, investments made regardless of location within the Sundarbans) to meet the basic needs of residents with the underlying objective of building human capital.

Labor and vocational training programs are needed as a way to improve the employment prospects of Sundarbans residents in both the transition and stable zones, especially for those seeking employment opportunities in urban areas. Reductions of indoor air pollution and improved water and sanitation programs will improve human health, which is essential for building human capital: healthy students are better learners and healthy workers are more productive (Bloom and Canning 2005). Improvements in human capital will, in the long term, provide local populations with the skills and means necessary to pursue livelihood opportunities in lower-risk areas that provide available employment opportunities.

Investments in health (with particular emphasis on preventive healthcare), education, and job training are the central ingredients in building human capital. Postnatal care, and nutrition and immunization programs for young children are among the steps that can be taken to improve early childhood development, which is well established as a basis of future learning and success in the labor market (World Bank 2010).

Spatially blind interventions concern basic entitlements and needs regardless of where people reside in the Sundarbans. Providing residents with educational and health services is essential to building a healthy and educated work force to better equip local residents with the skills and human capital necessary to take advantage of opportunities that pose lower risk to their livelihoods. It is anticipated that many of these opportunities will probably be in the growing urban areas of India, including in nearby Kolkata, but will almost surely be far from the growing dangers in the Sundarbans. The following sections outline key interventions that could serve to build human capital in the Sundarbans.

#### 8.4.1 Spatially Blind Policies in Education

Education is a critical component for building human capital. Studies of global education demonstrate the link between education and poverty reduction; statistics have demonstrated that completing secondary school (12 years of education) protects 80 percent of young people against poverty (ECLAC 1997; CPRC 2009). Thus, while basic education remains a priority, investment beyond the primary level is also vital.

The delivery of education to local residents in the Sundarbans must be reconsidered, given the current challenges in accessing schools and maintaining quality of service. Studies of the 19 Sundarbans blocks indicate that education is a critical priority for many households in the Sundarbans, and households are willing to search outside the Sundarbans to locate adequate educational facilities for improved skills training. Thus, the primary recommendation for the education sector in the Sundarbans is to move beyond targets for provision of educational infrastructure towards better linkage of demand with

supplies of educational facilities.

In order to do this, the key constraints to accessing educational facilities must be addressed. Studies conducted on education in the Sundarbans indicate that households are willing to send children to educational facilities that provide hostels or other types of living facilities, which would address key geographic constraints in accessing schools. Second, in terms of education, intensifying current financial assistance programs that provide scholarships could reduce financial constraints that cause some families to remove students from school<sup>8</sup>. Cash or vouchers could be offered to residents of the Sundarbans, but only on the condition that their children attend school in the stable zone or more urban areas. Cash or vouchers could be offered to existing (not new) families in the transition and stable zones, but only on condition that their children stay in school. In addition, cash or vouchers for post-secondary school training could cover a student's tuition and living expenses as well as provide money to families to help cover the income that would otherwise be earned if children did not extend their education beyond high school. The amount of cash could increase as the student progressed from one education level to the next, thus reducing dropout rates during transitions.

Moreover, parents can be further incentivized to send their children to school by expanding and intensifying national and state programs for improving the nutritional status of children in schools (such as the Mid-Day Meals Program); enhancing the quality of education in schools; and improving school water supply systems and latrines (especially for girls).

Demand-based technical and vocational training programs should be created (outside the Sundarbans) to provide better employment opportunities, particularly for young men and women. The World Bank experience with a conceptual framework known as "Stepping up skills – for more jobs and higher productivity" can provide a basis for thinking through alternative education program designs. The framework was developed to assist those designing education policies and programs to prepare individuals for employment. It includes five interlinked steps: (a) getting children off to the right start in early childhood which, in the case of the Sundarbans, would involve both the home environment and primary school; (b) ensuring that all students learn by having well-trained teachers and adequate resources for schools; (c) building job-relevant skills that employers demand which, in the case of the Sundarbans, would relate to jobs created in the new livelihood clusters as well as skill development to prepare individuals for work in tourism, agriculture, aquaculture, and fisheries; (d) encouraging entrepreneurship and innovation by developing appropriate incentives for both pre-employment and on-the-job training programs; and (e) matching the supply of skills with the demand, which would mean providing information and intermediation services for both residents of the transition zone seeking employment and firms in the various sectors looking for employees. In addition, intensifying national and state programs aimed at increasing the literacy and numerical skills of

<sup>8</sup>Students from weaker sections are eligible to get financial assistance in the form of scholarships from the government in order to pursue their education. Source: Shri S. Ghosh, Chief Secretary, West Bengal (June 14, 2012).



Sundarbans residents (aged 15 years and older) can help equip adult residents with basic skills needed for employment.

#### 8.4.2 Spatially Blind Policies in Health

In his 2001 address to the World Health Assembly, United Nations Secretary-General Kofi Annan said: “The biggest enemy of health in the developing world is poverty” (United Nations 2001). Poverty creates ill health because it forces people to live in environments that lack decent shelter, clean water, or adequate sanitation. Poverty creates hunger, which in turn leaves people vulnerable to disease. Poverty denies people access to reliable health services and affordable medicines, and causes children to miss out on routine vaccinations. Poverty creates illiteracy, leaving people poorly informed about health risks and forced into dangerous jobs that harm their health.

Efforts at socioeconomic development of the Sundarbans cannot be made without significant investments in health and human development. Studies conducted on the health sector indicate that access to health services is well below district and state averages, driven in part by the difficult terrain of the Sundarbans, but also linked to the high poverty of its residents. However, at present, the residents of the Sundarbans face severe health risks that undermine health and well-being, and this makes it difficult to pursue socioeconomic development possibilities. Key public health issues will need to be addressed to build the human capital of the local population.

In the short term, it is critical to place emphasis on preventive healthcare to reduce the incidence of diseases. Examples of preventive healthcare services include provision of health and hygiene education, physical examinations and screenings, immunizations, and vaccinations. Moreover, existing health initiatives<sup>9</sup> implemented by the Department of Health need to be strengthened with the aim of: (a) improving and expanding these programs in hard-to-reach places, most of which are located in the high-risk area of the Sundarbans; and (b) placing additional emphasis on illnesses specific to the region. Wild animal attacks as well as high diarrhea incidence linked to salinity intrusion<sup>10</sup> are two examples of situations that are specific to the Sundarbans and require appropriate preventative and response interventions to reduce incidence and impacts.

Campaigns for hygiene education should be conducted to encourage hand washing, to improve household sanitation in food handling and preparation, and to promote treatment of domestic drinking water. Because people’s motivation to improve hygienic practices hinges on their ability to comprehend linkages between disease and hygiene, instruction on these linkages should be a part of any

campaign. Interventions to improve domestic hygiene could help to significantly reduce childhood morbidity and mortality. One study showed that not even 10 percent of households surveyed in eight blocks in the Sundarbans used appropriate drinking water treatment methods, such as boiling or filtering. Nearly 20 percent strained water through a cloth and 70 percent did not treat water at all prior to drinking. Several studies have demonstrated that appropriate hand washing can reduce gastrointestinal diseases and upper respiratory illness, especially among children. Promoting use of footwear can decrease morbidity among children by drastically reducing worm infestation.

Interventions should be undertaken to help educate women, who are typically in charge of domestic water supply, food preparation, and hygiene issues, on the positive health impacts of boiling water and value of employing safe cooking methods and effective household hygiene practices in reducing disease, especially among young children. To address the many systemic aspects of malnutrition, initiatives are being recommended for improving water supply and sanitation facilities, and enhancing awareness of hygiene and hand washing through educational curricula and community groups. In parallel, the health sector needs to support the immediate malnutrition concerns through the proposed interventions, such as promoting the nutrition support program for high school girls through a targeted voucher scheme and involving women and self-help community groups in the national programs for child nutrition.<sup>11</sup>

Other health-related recommendations concern ways of decreasing morbidity and mortality by reducing indoor air pollution. Cooking stoves that burn biomass (straw, shrubs, and grass, agricultural crop residues, and animal dung) should be replaced by alternative cooking devices. A 2008 World Bank study emphasized the impact of indoor air pollution on morbidity and mortality, especially in women and children, and recommended alternative options for cooking (World Bank 2008). These could include such devices as biogas cooking stoves and smokeless *chulas*. Replacement of biomass-based cooking stoves would yield significant decreases in household air pollution, with consequent reductions in morbidity and mortality. Combustion of biomass tends to generate the most smoke, followed by wood, then coal or charcoal. The main strategy for cooking should focus on improved cooking stoves (for example, biogas cooking stoves and smokeless *chulas*), which decrease indoor air pollution and provide energy services at higher efficiencies than traditional biomass-based cooking stoves. Expanded use of gas as cooking fuel might be promoted using resources from the current scheme that subsidizes biogas plants.

<sup>9</sup>These programs include the Reproductive and Child Health Program, Revised National Tuberculosis Program, National Anti-Malaria Program, and HIV/AIDS Control Program.

<sup>10</sup>Sea level rise could increase the incidence of diarrhea by decreasing the amount of available “sweet” groundwater, thereby reducing the supply of potentially potable water.

<sup>11</sup>A complementary or supportive nutrition program was implemented in Canning II block through the Integrated Child Development Services program under the Backward Region Grants Fund. Packed Nutrimix was provided to all malnourished children to be consumed according to the degree of malnutrition, and the program achieved remarkable results. A similar social business proposal was funded by the World Bank in 2009 to support livelihood generation for rural women through promoting their active participation in the production, packaging, and distribution of Nutrimix.



Improving primary healthcare services, especially in hard-to-reach areas, will be critical to improved healthcare for Sundarbans residents. The National Health Policy, in principle, recognizes the participation of alternative service providers, and partnerships with NGOs and private service providers have had positive results in the Sundarbans. There is a need to orient health service delivery towards private partnerships coupled with replication of government financial incentive schemes in the form of vouchers through a pro-poor approach. Special emphasis should be accorded to strengthening health infrastructure outside the vulnerable zones, and special logistic arrangements in terms of referral transport should be provided to the people from the vulnerable zones to safe zones to avail of health services. To address the high incidences of animal attacks, it is recommended that trauma care facilities be strengthened in relevant primary health centers, with strengthened transportation logistics.

## 8.5. Summary and Conclusion

Despite rapid economic growth in India, the Sundarbans blocks in North and South 24 Parganas districts remain some of the poorest and most isolated areas. An effective antipoverty strategy should incorporate the enhancement of education and skills among poor households. This will enhance their productivity in the informal urban and rural economy, and it will also increase their eligibility for paid employment in the formal sector and for advancement once they are employed.<sup>12</sup> Financial assistance in education and health can be offered to residents to link them with existing facilities outside the Sundarbans. Currently, Canning, Namkhana, and other peri-urban areas are relatively well connected to Kolkata and other major population centers by road, rail, and sometimes by waterways, and they contain institutions to meet some of the health and educational needs of the hinterland. Provision of educational and health services is needed to enhance human capital and will be critical to access growing opportunities in India's urban areas.

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<sup>12</sup>There is much literature pointing to the strong positive association between education and income. See, for example, Sianesi and Van Reenen 2000 and Psacharopoulos 1985. There is a consensus in the existing literature that education is an important determinant of individual earnings in the long run as well as long-term economic growth.





# Annex 9.

## Enhancing Livelihood Opportunities<sup>1</sup>



### Abstract

Poverty reduction in the Sundarbans requires a program across multiple socioeconomic dimensions that addresses human capital development as well as an improvement in livelihood opportunities, and remediation of the deep poverty and insecurity in which the majority of the inhabitants of the Sundarbans live. The promotion of livelihood opportunities that takes advantage of local resources is the only sustainable way of improving both income and food security for these individuals. The greatest opportunities lie in sustainable agriculture, modernized aquaculture, sustainable community-based forestry in an expanded forest estate, and well-planned, high-value-added tourism that expands on the region's current abundant biodiversity assets. Spatial development of these opportunities will concentrate the higher-impact activities in the stable zone, whereas in the transition zone livelihood activities avoid higher-risk options that are not sustainable, given the natural pressures on the ecosystems and delta. Opportunities exist to develop livelihood clusters in the stable zone. The overriding strategy of this NLTA is to enable residents to enhance their skills and become equipped to take advantage of more lucrative livelihood options in less physically hazardous settings in peri-urban areas.

### 9.1. Introduction

There are multiple sources of livelihood in the Sundarbans, predominantly in the agriculture, fishing and aquaculture, forestry, and tourism sectors. Nearly 60 percent of the total working population of the Sundarbans depends on agriculture as a primary occupation and all households have at least one member of the household engaged in agriculture (Rajshekar 2011).<sup>2</sup> The estimated total number of inland fishing families in

North 24 Parganas and South 24 Parganas is 52,917 and 50,897, respectively (Chatterjee 2011). Over 32,000 households in the Sundarbans have at least one member who visits the forest regularly for sustenance purposes, cash income (from the sale of honey), and fuelwood (Gupta 2010). Tourism in the area is seasonal, not well organized, and limited by lack of accessibility, but it has the potential to generate employment for Sundarbans residents. Industry, except for limited cottage industry, is virtually absent.

Livelihoods in the Sundarbans are threatened by the high levels of risks from cyclonic storms, tidal creek erosion, embankment failures, salinity intrusion, and other natural processes. The question that arises is what can be done to improve the livelihood opportunities of the local people in a changing climate, as any socioeconomic strategy for the region should consider livelihoods patterns, constraints, and opportunities. This annex examines the predominant livelihood activities in the Sundarbans and makes recommendation for this sector. The chapter commences with three sections dealing with agriculture, fisheries and aquaculture, and forestry activities. This is followed by an examination of tourism activities associated with the Sundarbans Reserve Forest, and a section discussing the implications of fostering growth in pockets of concentration in the stable zone of the study area.

### 9.2. Agriculture

Agriculture<sup>3</sup> is an important source of livelihood in the Sundarbans economy. Nearly 60 percent of the total working population depends on agriculture as a primary occupation, either as cultivators (23.6 percent) or as agricultural laborers (36.1 percent). More than 80 percent of total farmers in the region farm in marginal areas. The average landholding among farmers is just 0.36 ha.<sup>4</sup> More than 75 percent of the inhabited portions<sup>5</sup> of the Sundarbans are used

<sup>1</sup>This annex was prepared by Ghazal Dezfali, Priti Kumar, and R. R. Mohan, and it is based on background reports prepared by S.C. Rajshekar, Lidvard Gronnevet, Subimal Roy, World Wildlife Fund, Soumya Kapoor, Juan Luna-Kelser, and Christine Heyniger.

<sup>2</sup>Household survey, 2011.

<sup>3</sup>Information in this section, including facts and figures, is based on Rajshekar 2011, unless otherwise noted.

<sup>4</sup>Calculated as net cropped area in ha per number of cultivators.

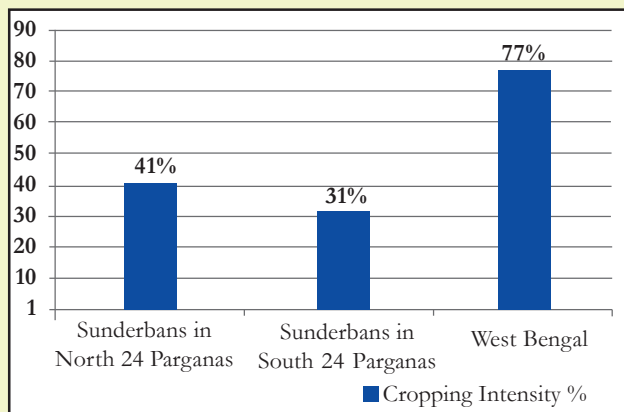
<sup>5</sup>The inhabited portions of the Sundarbans equal roughly 4,444 km<sup>2</sup>.

for agriculture. The cropping pattern is largely a single crop of rain-fed paddy (*aman*) cultivated during the kharif season (rainy season). During the rabi season (dry season), cropping is made difficult due to the lack of irrigation facilities in the Sundarbans. Soil salinity limits crop productivity in the region. An analysis<sup>6</sup> of more than 10,000 soil samples taken from eight blocks of the Sundarbans found that 32.4 percent of the samples had high salinity levels.<sup>7</sup>

The cropping intensity<sup>8</sup> is 41.1 percent in North 24 Parganas and 31.3 percent in South 24 Parganas – low compared to the state of West Bengal as a whole (77 percent) (Figure A9.1). The irrigation intensity<sup>9</sup> is 30.2 percent in North 24 Parganas and 12.3 percent in South 24 Parganas, again lagging significantly behind the state of West Bengal as a whole (68 percent) (Figure A9.2). Roughly 16 percent of the net cropped area is irrigated in the Sundarbans, compared to 41 percent in North and South 24 Parganas districts (Figure A9.3). Sources of irrigation in the Sundarbans are primarily tanks (71 percent) and shallow tubewells (13 percent), with the former method being the preferred choice. However, these tanks, which are small ponds, only irrigate, on average, 0.3 ha of land.<sup>10</sup> The resultant poverty is reflected in the poor scores on the livelihood index and the standard of living index calculated for North 24 Parganas and South 24 Parganas (GoWB 2009). Five blocks out of six in North 24 Parganas have a livelihood index score that is less than the average for the district, and a similar situation is found in South 24 Parganas.

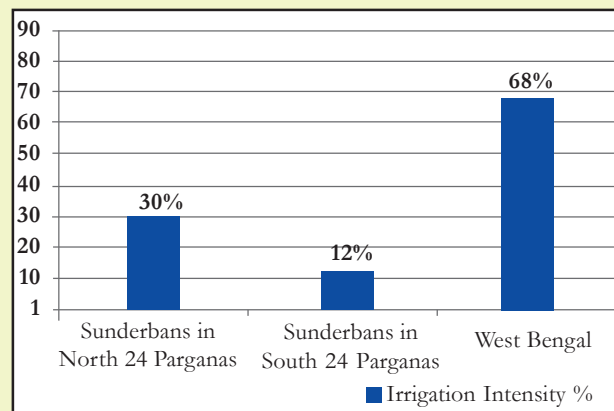
Interestingly, the paddy yield in the Sundarbans is higher than that of the country as a whole, and comparable to the yields in the 24 Parganas districts and the state of West Bengal. The average yield

**Figure A9.1: Cropping Intensity in the Sundarbans**



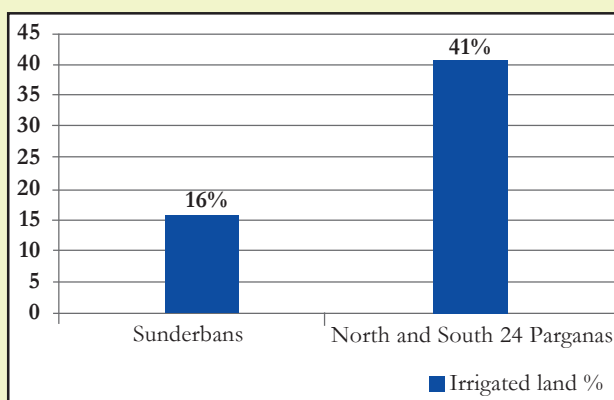
Source: S.C.Rajshekar (2011).

**Figure A9.2: Irrigation Intensity in the Sundarbans**



Source: S.C.Rajshekar (2011).

**Figure A9.3: Percentage of Irrigated Land in the Sundarbans Compared to the 24 Parganas Districts**



Source: S.C.Rajshekar (2011).

of paddy in the Sundarbans is 2,177 kilogram (kg) per ha, higher than the average yield in India (2,011 kg per ha) (Diwakar 2009). Yields in the Sundarbans are also comparable to average yields in West Bengal (2,528 kg per ha), North 24 Parganas district (2,605 kg per ha), and South 24 Parganas district (2,191 kg per ha) (Figure A9.4).

## 9.2.1 Priority Issues in Agriculture

Many of the Sundarban's problems in agriculture stem from its inhospitable topography and water salinity. Most of the Sundarbans is formed from land reclaimed before the delta

<sup>6</sup>Analysis conducted by the agriculture cell at the Tagore Society for Rural Development, Rangabelia.

<sup>7</sup>Electrical conductivity of >3 millimhos/cm.

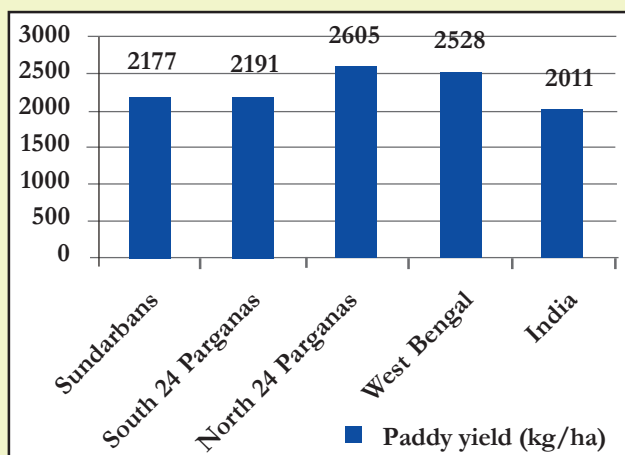
<sup>8</sup>Cropping intensity represents the number of crops that are harvested in a year from a given piece of land and is calculated as the ratio of gross cropped area to net cropped area, expressed as a percentage. The higher the cropping intensity, the higher the gross returns to the farmer.

<sup>9</sup>Irrigation intensity is calculated as the ratio of net irrigated area to net sown area, expressed as a percentage. The higher the irrigation intensity, the higher the cropping intensity, yield, and thereby the gross returns.

<sup>10</sup>In the Sundarbans, there are 72,408 tanks irrigating 21,284 ha (Rajshekar 2011).



**Figure A9.4: Paddy Yield in Sundarbans, 24 Parganas Districts, West Bengal, and India**



formation process was complete. Therefore, the land is often low lying and typically below the high tide mark. Further, construction of embankments to keep out the tidal flow has led to a complete cessation of sediment deposition in protected areas of the delta, and there is no opportunity for the land level to rise naturally. The result is low-lying lands that get flooded with heavy rains and face long periods of water stagnation during the kharif season, severely affecting choice of crops, varieties sown, and yield obtained. This is one of the major reasons for the predominance of aman paddy (kharif) in the Sundarbans. Indeed, there is effectively no choice for the farmer.

Nearly 40 percent of the gross cropped area of the Sundarbans blocks of North 24 Parganas is affected by salinity. Soil salinity in the Sundarbans has two causes: inundation by tidal waters from embankment breaches, and the capillary action of water in the soil bringing up salts from the underlying layers during the rabi or winter season. Fresh water is needed to leach these salts down to enable crop production. With little or no fresh groundwater in addition to rivers carrying saline water from tidal inflows, a second crop in the Sundarbans is solely dependent on surface-stored rainwater. Combating soil salinity in the Sundarbans is achieved by keeping the tidal waters out and flushing the salts by application of water, which, in the kharif season, is done by heavy rains.

Cropping yields are also affected by low seed replacement rates. Greater emphasis is being placed on increasing productivity and market forces are pushing high-yielding varieties of paddy, which are not suitable for deep-water conditions during the kharif in the Sundarbans. Further, if rains are delayed or are deficient, salinity increases and affects high-yielding varieties of paddy more than the traditional local paddy varieties.

Frequent storms and cyclones make agriculture more risky. However, other subtler impacts of climate change are:

- Increased intensity of rainfall, including storm surges;

- Shift of rainy season by 15–20 days and lengthening of summer, and cloudy humid days leading to delayed sowing and increase in pest attacks; and
- Delay in onset of winter, leading to a shortened period for rabi crops.

The main impact of a cyclonic storm is stagnation of water in the fields and, sometimes, inundation of tidal waters, leaving the soil saline. Usually, the salinity is not permanent as the salts get washed away after a few heavy showers, and land becomes fit for cultivation. However, when events such as Cyclone Aila occur, the damage can extend beyond a season and the soil may take more than a year's rain to recover. In such cases, the loss is more extended. The typical coping mechanism at the household level is to migrate to Kolkata or other large cities in search of work and return when the soil has recovered.

A large number of cultivators in the Sundarbans are share croppers (*bargadars*) with tenancy rights over fragmented pieces of land. Their rights of tenancy are aggressively protected by a series of land reform legislations passed by GoWB. The owners cannot sell their piece of land without compensating the *bargadar*. Often, the landholding is so small that the *bargadar* does not earn enough to buy off the landowner. The net result is that the market for agricultural land has become depressed and land, as a capital asset, is underutilized. Thus, natural market forces that can help consolidation of uneconomic agricultural holdings are distorted in the Sundarbans.

### 9.2.2 Recommendations: Improving Agricultural Productivity

The potential for agricultural development seems limited, given the continual expansion of shrimp farming in the region and climate change impacts. Agricultural productivity improvements are potentially available but may be undermined by other factors such as salinization or embankment failures from poor aquaculture management, which together limit the long-term viability of agriculture in the region. Improvements in agricultural productivity can be accomplished by placing more emphasis on climate-resilient agricultural practices, including adoption of salt-resistant paddy seeds. Improvements will also require programs of training and dissemination of information regarding saline-resistant paddy varieties. Farmers can be offered combination packages of services (for example, soil and water testing, training, seed supply) as part of the effort to improve agricultural productivity.

DSA is implementing a range of schemes and programs, but better coordination, packaging, and integration of these programs is required to respond to the situation in the Sundarbans. These schemes are implemented on a statewide basis and generally achieve little, in comparison to the cost of the resources that are applied. A focus on the specific needs of the Sundarbans is often lacking, and budgetary support is needed for innovative and low-cost interventions to improve the knowledge of farmers and offer

them extension services. In the same vein, the 27 growth centers located in the Sundarbans for extension services need changes in their staffing patterns, including retraining and reorientation of the staff, and a revamped institutional delivery mechanism.<sup>11</sup>

### 9.3. Fisheries and Aquaculture

India is the second largest fish producer in the world, producing 2 million tons annually (FAO 2007).<sup>12</sup> The output of the state of West Bengal, which is the largest fish producer in India, is dominated by production in North and South 24 Parganas. Based on the total production for 2007–08, West Bengal alone would be the 19th biggest fish producer in the world. Table A9.1 shows that North and South 24 Parganas districts are the leading producers of fish and prawns, with both districts combined accounting for roughly 31 percent of the total inland fish and prawn

production. South 24 Parganas alone produced 30 percent of the total marine fish and prawn output in 2007–08. *Hilsa*, *bhetki*, *bhangon*, and mullet are the most lucrative finfish species (Chatterjee 2011).

A survey<sup>13</sup> conducted on behalf of this analytic work found that approximately 11 percent of households in the Sundarbans listed “fishing” as one of the family occupations. This percentage goes up to 60–70 percent in areas with easy access to rivers. A separate study found that the estimated total number of inland fisher families in South 24 Parganas and North 24 Parganas was 52,917 and 50,897, respectively (GoWB 2005). The main areas of traditional fishing are Sagar Island, Fraserganj, Bakkhali, and Kalisthan (Figure A9.5). The significant inland fish landing regions in the Sundarbans include Canning, Hariabhanga, and Gosaba (Chatterjee 2011).

**Table A9.1. Fish Production in West Bengal, by District, 2005–07**

DISTRICT	2005-2006			2006-2007		
	FISH	PRAWN	TOTAL	FISH	PRAWN	TOTAL
<b>INLAND</b>						
Darjeeling	342		342	1845		1845
Jalpaiguri	15000		15000	21724		21724
Coochbehar	19090		19090	20426		20426
Uttar Dinjapur	14829		14829	16005		16005
Dakshin Dinjapur	32464		32464	32992		32992
Malda	38116	10	38126	29288	5	29293
Murshidabad	72258	25	72283	83582	10	83592
Nadia	64543	22	64565	68993	20	69013
Birbhum	40251	1	40252	67518	0	67518
Burdwan	88494	1	40252	67518	0	67518
Hooghly	77712	82	77794	67009	60	67069
Howrah	32340	66	32406	47600	58	47658
North 24 Parganas	123132	45166	168298	130541	40516	171057
South 24 Parganas	181578	7572	189150	180815	9900	190715
Purulia	53631		53631	39135	0	39135
Bankura	49472		49472	52682	0	52682
Paschim Medinipur	39781	8	39789	58868	0	58868
Purba Medinipur	85870	8144	94014	108547	12871	121418
<b>TOTAL INLAND</b>	<b>1028903</b>	<b>61101</b>	<b>1090004</b>	<b>1117565</b>	<b>63440</b>	<b>1181005</b>
<b>MARINE</b>						
South 24 Parganas	39893	4408	44301	46989	6848	53837
Purba Medinipur	103109	11312	114421	114581	9680	124261
<b>TOTAL MARINE</b>	<b>143002</b>	<b>15720</b>	<b>158722</b>	<b>161570</b>	<b>16528</b>	<b>178098</b>
<b>TOTAL</b>	<b>1171905</b>	<b>76821</b>	<b>1248726</b>	<b>1279135</b>	<b>79968</b>	<b>1359103</b>

Source: Chatterjee 2011.

<sup>11</sup>None of the three growth centers visited as part of the research for this NLTA was staffed by a graduate in agriculture (or allied discipline).

<sup>12</sup>Information in this section, including facts and figures, comes from Gronnevet 2010, unless otherwise noted.

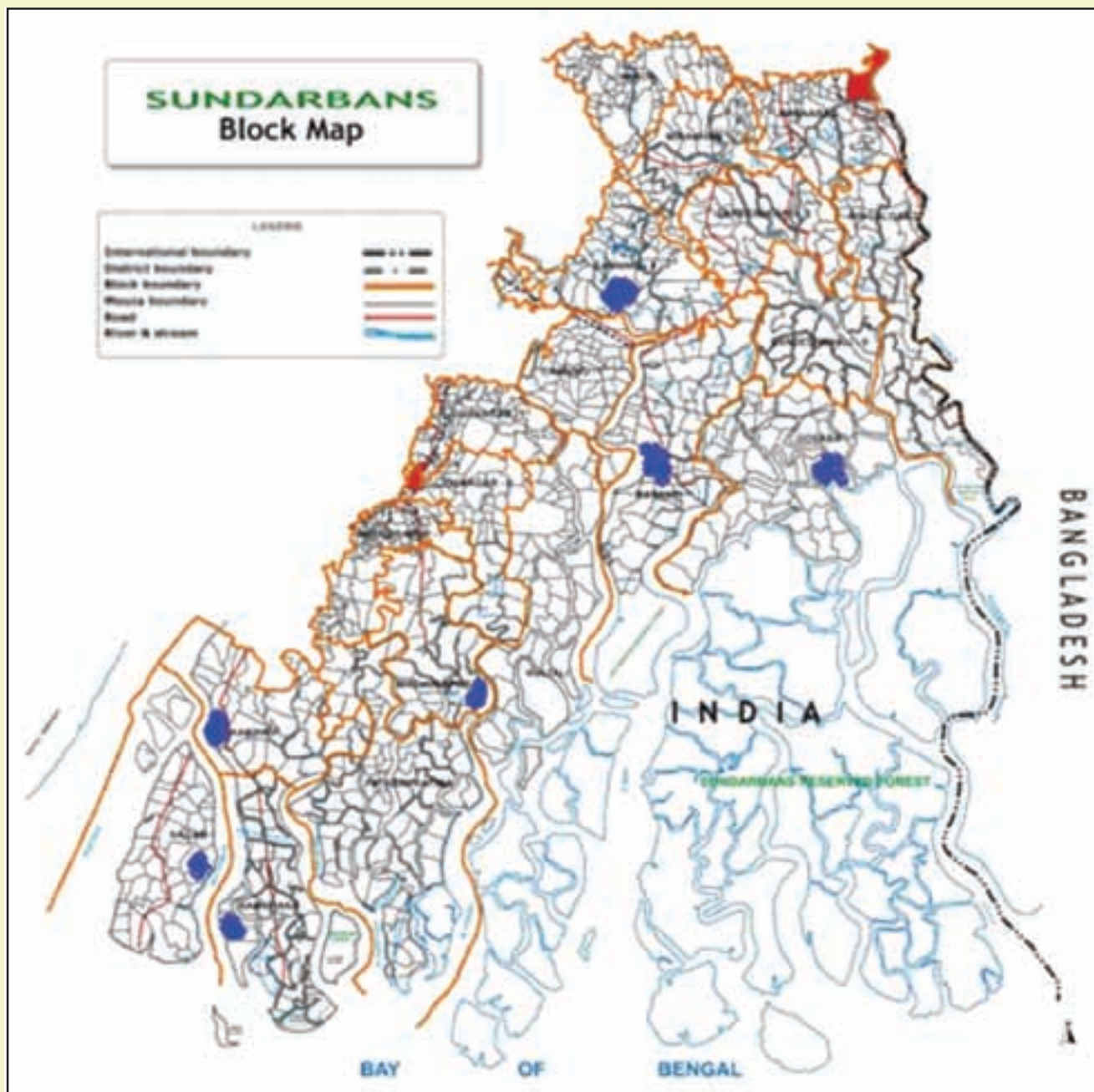
<sup>13</sup>See Annex 2.

### 9.3.1 Priority Issues in Aquaculture

Uncontrolled development along the current trajectory may, in fact, be counterproductive to the extent that it undermines ecosystem integrity (by promoting erosion and biodiversity loss). Many residents of the Sundarbans are dependent on income from gathering of natural *Penaeus monodon* postlarvae wild-caught

broodstock and seed for aquaculture. However, the collection of natural fry stock results in massive collection of by-catch species.<sup>14</sup> One study found that, at the time of a single prawn seed collection, the average number of other destroyed species is as follows: 318 (other prawns), 8 (fish), 60 (crabs), 1 (mollusc), 13 (unidentified), that is, total 400 of others (Santhakumar, et al. 2005). The formal ban on natural fry collection is not effective because fry collection is

**Figure A9.5: Location of Traditional Inland Fishing Zones (Shaded Blue)**



Source: Chatterjee 2011.

<sup>14</sup>By-catch, in this context, refers to unwanted aquatic species that are caught in fishing nets while fishing for another species. Many by-catch species are discarded by fishers back into the water.



a source of livelihood for poor people who lack other income-earning opportunities. While some producers have access to hatchery larvae sourced from hatcheries outside the region, these larvae are often not certified and thus have low survivability, which leads to lower overall productivity. Additionally, the use of destructive fishing gear is resulting in biodiversity degradation. The traditional aquaculture widely practiced today thus falls far short of its economic potential.

Currently, methods practiced for recharging aquaculture ponds result in erosion and failure of embankments. Tidal aquaculture far inland increases the demand for recharge of aquaculture ponds with estuarine waters; because such recharges increase the size of tidal prisms, they contribute to erosion and premature embankment failure in areas far removed from where the aquaculture occurs.

### 9.3.2 Recommendations: Modernizing Aquaculture Operations

Policy measures are needed that reduce the overexploitation of aquatic resources. A policy reform is recommended that would encourage collective management of tidal flows for recharge to reduce such negative impacts. Further, it could decrease reliance on the gathering of wild fry (which is dangerous for those collecting it and also detrimental to ecosystem productivity). Hatchery investments can provide higher-quality fry using modern techniques on an annual schedule that improves overall yields.

The establishment of state-of-the-art hatcheries in the prawn aquaculture sector is one option to avoid environmental degradation. In terms of biodiversity and long-term sustainability, the negative effects of prawn seed collection represent a very serious threat. The establishment of hatcheries has proven effective in other Indian states, as well as in Bangladesh and other Asian nations. Admittedly, there are special challenges due to salinity conditions and market-related problems associated with establishing hatcheries in West Bengal. Establishing such hatcheries will depend on investments by the private sector.

There is an urgent need to improve the industry's operational mode and standards by designing and implementing separate codes of conduct, such as the Code of Conduct for Responsible Fisheries, for aquaculture and fisheries. Codes of conduct are particularly important for improving the management of the aquaculture sector. Aquaculture operations in all countries have – to some degree – adverse environmental and social effects. The implementation of effective codes of conduct can be viewed as a necessary precondition to the development of semi-intensive and intensive aquaculture operations. The design and implementation of a code of conduct might help minimize the associated negative environmental and social impacts. Enhanced technical assistance and extension services for the aquaculture and fisheries sectors will be needed in the course of designing and implementing such codes of conduct. Positive livelihood enhancement possibilities associated with semi-intensive and

intensive aquaculture operations exist in other Asian countries (for example, Thailand and Vietnam) and in other Indian states (for example, Andhra Pradesh and Odisha). These countries and states have an expanding prawn aquaculture industry without the serious threat to biodiversity from the type of prawn seed collection that is widespread in West Bengal.

A dedicated program to explore the introduction of additional species could be intensified, given the specific natural conditions in West Bengal. Stakeholders in West Bengal are already considering expansion of the number of species in aquaculture operations. New species such as cobia and pangasius are now becoming valuable high-volume aquaculture species in Vietnam and other Asian nations.

Postharvest losses can be reduced by providing improved infrastructure for the storage and transport of both aquaculture yields and fish catches using traditional methods. Facilities for refrigeration, in particular, are badly needed as a mechanism for reducing losses. Finally, an improved storm warning system should also include methods for ensuring that warnings are delivered to fishers so that their cyclone-related risks can be minimized.

## 9.4. Forestry

The Sundarbans ecosystem is the basis for many of the livelihood activities that have traditionally formed the backbone of rural living, and a significant number of households depend on the forest for their livelihood and sustenance through activities such as honey collection, fishing, and timber collection.<sup>15</sup> Over 32,000 households in the Sundarbans have at least one member exploit the forest regularly for various purposes (Gupta 2010), such as collecting fuelwood, sustenance, cash income (from the sale of honey), medicinal requirements, and harvesting timber for construction of houses and boats (Gupta 2010; Roy 2011). Forest dependence is largely a result of low levels of education and skills, which prevents people from accessing better-paying jobs, and the lack of alternative income-generating opportunities available in the region. Agriculture has low income-earning potential in the region, and conversion of agricultural land into prawn farms has forced many to turn to the forest for livelihood purposes.

### 9.4.1 Priority Issues in Forestry

At least 25 mangrove species in the Sundarbans are vulnerable to extinction, currently endangered, or critically endangered, according to the IUCN 2010 Red List of Threatened Species. The mangrove species *Xylocarpus granatum* and *X. mekongensis* face significant threat due to poaching and illegal felling, as both are considered valuable sources of timber. The species of *Ceriops decandra*, *Avicennia* spp., and *Excoecaria agallocha*, which are mainly collected for fuelwood, also face extinction from illegal felling (Roy 2011; Ghosh et al. 2003).

<sup>15</sup>Information in this section is based on consultant reports prepared on behalf of this NLTA by Roy (2011) and WWF (2010), unless otherwise noted.



Mangrove restoration is an integral part of the climate change defense strategy for the Sundarbans, but should be managed with caution. From 1990 to 2010, more than 15,200 ha of mangrove were documented as planted, of which approximately 50 percent have been lost due to natural and anthropogenic causes. Governmental and nongovernmental organizations have since planted more than 2,000 ha of mangrove during 2009–10, and it is estimated that this activity required 260,000 person-days of work (Table A9.2). Mangrove restoration offers protection and livelihood opportunities and also allows local communities to become involved in conservation, sustainable management, and ecosystem rebuilding operations (Roy 2011). But increased mangrove restoration must be managed with caution, especially in areas under strong erosion influences, where it may be desirable to depend on realigned embankments. Moreover, a key constraint to ongoing sustainable community management of forests is that – because the cutting or use of any mangrove tree product is illegal – the incentive for proper management is reduced; communities have only limited indirect functions and uses (such as bioshields and fish catches) from which they can benefit.

<b>Table A9.2: Mangrove Plantations</b>		
	<b>1990 to 2010 (ha)</b>	<b>2009–10 (ha)</b>
Sundarbans Tiger Reserve	600	10
South 24 Parganas Division	7,300	1,280
North 24 Parganas Division	600	40
Forest Officer, SDB	5,300	600
NGOs	1,400	150
<b>Total</b>	<b>15,200</b>	<b>2,080</b>

Source: Roy 2011.

#### 9.4.2 Recommendations: Eliminating Illegal Forestry Activity, Promoting Mangrove Restoration, and Strengthening Institutional Capacity

The principal goal should be to eliminate all illegal income-generating activities that are currently taking place in the core forest areas. It is difficult to accomplish this using only regulation, and thus financial incentives should be employed to motivate residents to preserve the forest resources as a way of generating income for their communities. This could be done by making revenues available for programs to improve the lives of those in the transition zone contingent on attaining benchmark targets for preserving the forest. This condition would be built automatically into any revenue streams based on carbon credits, because such programs require third-party monitoring and verification to ensure that the forest remains intact.

In addition, local residents can be motivated to police the forests themselves by establishing rights to sell goods and services created in a sustainable way from forest resources. This approach can help in reducing illegal activities, such as animal poaching and timber harvesting within the Sundarbans Reserve Forest, because such illegal activity would diminish the revenues supporting the benefits for local residents. International experience has demonstrated that all these methods are best pursued in community forest management models that involve co-management by the state and local communities, each having well-defined obligations and entitlements.

Future consideration needs to be given to policy reforms and incentives for sustainable harvesting of forest products that are supported by community-based revenue-sharing mechanisms. Forestry activities in the Sundarbans should be directed away from the Sundarbans Reserve Forest, where such activities are illegal, and toward newly planted or regenerated mangroves. While mangrove harvesting remains illegal throughout West Bengal, a near-term focus should be on harvesting nontimber forest products, such as honey, fruits, or fishery products. Revenue-generating activities based on nontimber forest products and sustainable harvesting of plantations can work in tandem with schemes to share revenues from carbon financing opportunities. The central idea is that providing opportunities for a community to share in revenues from sustainable forest management can motivate the community to monitor and report activities that destroy the resource base on which community revenues depend. In the longer term, consideration could also be given to permitting sustainable harvesting or thinning of a portion of community-managed areas; such an approach is often a necessary co-requisite to effective human-induced natural regeneration of mangrove species.<sup>16</sup>

Concerted emphasis must be placed on strengthening the institutional capacity of the Forest Department and, in particular, its capacity to coordinate its activities with other departments. Although forests are among the region's greatest natural assets, the Forest Department does not have a modern approach to either biophysical or economic management of the resource. As a consequence, its potential is not fully realized. While community forest management will go some way to improving protective measures in a cost-effective manner that also benefit local residents, the forest asset also remains at risk simply because of poor coordination among departments and an inability to capture values associated with new international forest conservation efforts such as REDD-plus which, in effect, will transfer funds to countries with strong management regimes in place to conserve carbon sinks. In the Sundarbans, first steps at coordination will need to take place as the Irrigation Department embarks upon its program of embankment realignment, which potentially creates an additional

<sup>16</sup>It is noted that on June 3, 2011, the Executive Board of the Clean Development Mechanism accepted a new large-scale mangrove afforestation/reforestation methodology (AR-AM0014), which is of interest to restoration efforts in India's Sundarbans. In particular, it is the first methodology that explicitly recognizes ecological mangrove restoration techniques through its definition of "planting," which it defines to mean: "propagation of mangroves or other tree species on land subject to project activity, and includes propagation using any of the following: (i) nursery raised seedlings or saplings; (ii) propagules; (iii) direct sowing of seeds; (iv) human induced promotion of natural regeneration."

200 km<sup>2</sup> of land for mangrove restoration. Second, efforts must focus on improving internal capacity within the Forest Department to engage in modern international initiatives such as REDD-plus and typical community forest management arrangements. Third, the eventual depopulation of the transition zone will see the increased expansion of land under the Reserve Forest, but existing capacity to take on such an extra responsibility is weak and must, therefore, be strengthened.

## 9.5. Tourism

Tourism development<sup>17</sup> in the area is rapidly expanding, both as a reaction to the success achieved by pioneer developments such as the Sundarbans Tiger Camp<sup>18</sup> and as a result of increased demand for visiting the Sundarbans Tiger Reserve and the Sundarbans

National Park (Figure A9.7).<sup>19</sup> From 2003 to 2009, the number of tourists increased by roughly 101 percent, from 59,681 to 120,495. The majority of the visitors to the Tiger Reserve and National Park are domestic, suggesting that the domestic market can provide a solid base for gradual tourism development, allowing for eventual expansion into the international market as the tourism product of the region improves. However, domestic tourists are low-budget travelers and are not always aware of the ecological sensitivity of the area.

Based on a survey conducted as part of the analytic work for this NLTA, the primary objective of most surveyed tourists was “leisure/recreation,” with a small fraction of visitors (5.21 percent) coming to the Sundarbans to do volunteer work (Figure A9.7). “Voluntourism” is a growing international phenomenon

**Figure A9.6: Current Tourism Sites in Sundarbans Tiger Reserve and National Park**

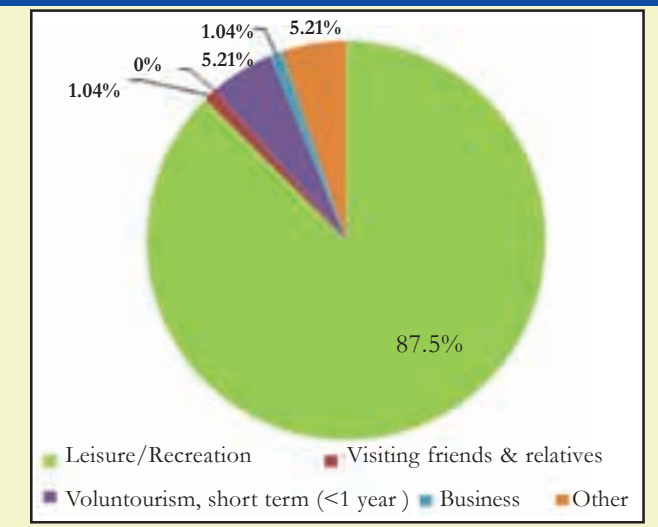


<sup>17</sup>This section is based on a consultant report prepared on behalf of this NLTA by Juan Luna-Kelser and Christine Heyniger (2010), unless where otherwise noted.

<sup>18</sup>The first lodging business to offer overnight accommodation by building a small camp with tents.

<sup>19</sup>The Sundarbans Tiger Reserve’s transition and core areas include several wildlife sanctuaries. The Sajnekhali Wildlife Sanctuary, covering an area of 362.42 km<sup>2</sup>, is known as the transition zone (sometimes called the “buffer” zone), an area outside and north of the core area. In addition, there is the Basihrat range, a subsidiary wilderness zone comprising 892.33 km<sup>2</sup>. The Forest Directorate has designated the transition zone as a multiple use zone to allow tourist visitation and for regulating the harvest of resources to meet the needs of nearby residents. There are two additional wildlife sanctuaries located to the southwest of the Sundarbans Tiger Reserve: Lothian Island Wildlife Sanctuary (38 km<sup>2</sup>) and Haliday Island Wildlife Sanctuary (5.95 km<sup>2</sup>). The gateways to the Tiger Reserve and National Park at Canning, Sonakhali-Basanti, and Gosaba (Gadkhali) are located on the islands of Sandeshkali, Basanti, and Gosaba, and form the northern boundary of the Tiger Reserve. There is a less frequented entry point at Bagna via Dhamakhali (Luna-Kelser and Heyniger 2010).

**Figure A9.7: Visitor Travel Interest in the Sundarbans**



*Source:* Luna-Kelser and Christina Heyniger 2010.

and a key market segment for emerging destinations such as the Sundarbans Tiger Reserve and National Park.

### 9.5.1 Priority Issues in Tourism

Tourism marketing efforts highlight the rare chance of sighting the Royal Bengal tiger to entice more visitors, but this is misleading because sightings are rare. Sighting a tiger is extremely difficult due to its elusive character and the density of its mangrove forest habitat. Given its natural heritage, positioning the Sundarbans as a tourism destination must be broadened to incorporate other notable characteristics of the region without centering it primarily on the Bengal tiger as the main attraction. The area should be positioned to emphasize its rich and diverse biological and cultural attributes. Specific opportunities for specialized outdoor activities that can be marketed span a range of outdoor nature-based pursuits, including bird watching, bicycling, and trekking through the villages of the Sundarbans. In addition, the villages of the transition area could generate jobs and income by training and hiring tour guides, showcasing food and other aspects of the local culture, and creating and selling locally made handicraft items.

The current market segments of tourists traveling to the Sundarbans Tiger Reserve and National Park have diverse expectations and requirements. One segment is the predominantly domestic tourist who goes for short holiday breaks and (usually) one-day excursion diversions. These visitors travel in large, multigenerational groups and are extremely budget conscious. Another segment includes foreign visitors who travel in smaller groups, stay longer, and have fewer budget constraints. Key characteristics of the destination's current market positioning include:

- Low visitor pricing scheme;
- Small number of local travel wholesalers and retailers;
- Limited distribution channels (for example, limited distribution of product information for customers, points of sale); and
- Traditional nonsegmented marketing approaches.

Sagar Island has potential for both religious tourism and bird watching, but it currently offers no substantive tourism products. Every year in January, Sagar draws thousands of pilgrimage tourists to celebrate Makar Sankranti by taking the holy dip at the confluence of the Hooghly and the Bay of Bengal. The combination of the large influx of tourists throughout the year (especially during January), coupled with the lack of lodging and sanitary facilities (with consequent effects such as the indiscriminate disposal of solid waste), has the negative effect of degrading the island.

Moreover, tourism in the region is still, for the most part, unplanned. Unregulated tourism has led to a clustering of numerous tourist lodges and an increase of mechanized vessels, which has increased water and noise pollution. The burning of large quantities of diesel fuel per vessel is increasing air pollution and contributing to global warming. Energy use at tourist facilities is many times greater than that being used by the local people. The process of transformation that is taking place in the area is beginning to compromise, critically, the physical and environmental carrying capacity of the ecosystem, biodiversity and air quality of the Tiger Reserve and National Park.

As long as tourist facilities are allowed to develop spontaneously without regulation, traditional land use and livelihoods will be impacted, with associated negative sociocultural and environmental impacts. This situation will decrease tourist demand and damage or destroy the resources on which the local residents depend, jeopardizing their livelihoods and causing resentment and anger toward tourism developments. There will also be significant negative effects on the biodiversity and air quality of the Tiger Reserve and National Park. Recognizing and understanding the detrimental impact of mass tourism on the Sundarbans will allow policy makers to adopt a sustainable ecotourism approach in the Sundarbans, an especially sensitive area with unique and precious assets.

### 9.5.2 Recommendations: Promoting a Limited Extent of High-end, Environmentally Sustainable Ecotourism

The portion of the transition area near the Sundarbans Reserve Forest can support a limited extent of high-end, environmentally sustainable ecotourism. The most important reasons for visitors traveling to the Sundarbans Tiger Reserve<sup>20</sup> and Sundarbans

<sup>20</sup>The Sundarbans Tiger Reserve comprises a total area of 2,585 km<sup>2</sup> and constitutes a major part of the 4,263 km<sup>2</sup> of the Indian Sundarbans forested area. Situated in the West Bengal coastal district of South 24 Paraganas, it was one of the first of 27 tiger reserves established in 1973 by the Indian government as part of its globally renowned Project Tiger conservation efforts (<http://projecttiger.nic.in/index.asp>).



National Park<sup>21</sup> are the opportunity to see wildlife, particularly the elusive Royal Bengal tiger, and the natural mangrove scenery and landscape. For fragile ecosystems such as the Sundarbans, only limited, low-impact ecotourism, as opposed to mass tourism, is recommended. The spread of unregulated mass tourism<sup>22</sup> will degrade the natural resources of the Sundarbans to a point at which it will no longer have any value for local people or visitors. The singular nature of the Sundarbans provides the basis to attract both domestic and international high-end and environmentally sensitive tourists, thereby increasing livelihood opportunities for communities in the transition zone without degrading the forest resources. A survey conducted as part of the analytic work for this NLTA shows that there is a demand from high-end international and domestic travelers for nature- and ecotourism-based activities in the Sundarbans. A sample of surveyed travelers<sup>23</sup> from more than 20 countries showed that English-speaking foreign tourists constituted the largest percentage (43.8 percent) of the total visitors. This group comprised tourists from the United Kingdom (24 percent), the United States of America (9.4 percent), Australia (5.2 percent), Canada (4.2 percent), and New Zealand (1 percent). The other group of travelers of notable size was from Germany (11.5 percent).

The tourism strategy for the region should be reviewed and modified to eliminate current unsustainable practices tied to mass tourism. Tourism-related interventions should be based on internationally recognized guidelines for nature tourism, such as those advocated by the George Washington University and the Adventure Travel Trade Association.<sup>24</sup> The approach should be one that explicitly recognizes limits on the carrying capacity of the most fragile parts of the ecosystem. Areas outside the transition zone (such as Sagar Island) could potentially be considered as touristic areas that offer experiences appealing to relatively large numbers of middle-income domestic tourists.

Tourism in the Sundarbans must be promoted as a seasonal activity to minimize the risks associated with adverse natural events, such as cyclones. Some of the most devastating tropical cyclones in the world have occurred in the Bay of Bengal, which has been the location of 9 of the 14 global tropical cyclones associated with the highest fatalities. Given the projected increases in the frequency and intensity of storms and cyclones in the region,

the potential future impact on environmentally sustainable, high-end ecotourism hinges on the careful promotion of tourism during times in which storm surges and cyclones are minimal. The Bay of Bengal is subject to both types of storms during both spring and autumn. However, cyclones occur more frequently in the autumn, while most major storms cause impacts in the spring. Environmental factors are important in determining the holiday destination for potential tourists (Braun et al. 1999). The climatic factors identified as having the most impact on tourism are the following: temperature, sunshine, precipitation, wind, humidity, fog, and radiation (Stern 2006; Hamilton and Lau 2004). These factors influence the tourist's assessment of his or her well-being, with implications for the success of the tourism industry (Sookram, Sandra).

The ability to draw in high-end, environmentally sensitive ecotourists requires: (a) strict conservation within the forested areas, which are the zones attractive to ecotourists; and (b) development of tourism infrastructure with minimal environmental impact (for example, tented camps) within the transition area near the Sundarbans Reserve Forest. Transport with low environmental impact should be used to carry people to and from the Sundarbans via the entry points (for example, Sonakhali via Canning, or Bagna via Dhamakhali). Currently, most visitors come from these entry points on large tour buses, autos, and motorized boats, or a combination thereof. These transport modes have high impacts on the fragile environments being traversed. In-depth analyses and design exercises should be undertaken to identify ways to effectively regulate and mitigate air pollution and noise from the existing transport modes used in reaching the Sundarbans Tiger Reserve and National Park. While tourists on vacation may expect and be prepared to pay for certain luxuries and accommodation, visitors may be willing to participate in energy reduction efforts if they do not greatly reduce their experience, if it is easy or mandatory, or if it saves them money (WTO/UNEP 2009).

Environmentally sustainable ecotourism has the potential to offer livelihood opportunities for some of the transition zone residents who wish to remain in the region. A study in two villages in Gosaba concluded that tourism can be an effective driving force to reduce poverty by improving incomes of households that have

<sup>21</sup>The Sundarbans National Park is an area that is designated within the core area of the Sundarbans Tiger Reserve, where visitors are not allowed.

<sup>22</sup>Mass tourism has been shown to be unsustainable in that it rapidly degrades natural and cultural resources. Mass tourism approaches tourism as a commodity. It emphasizes marketing, with growth takes precedence over all other considerations, including the welfare of local people and environmental conservation. According to Seema et al. (2006): "Mainstream tourism is geared towards tourist satisfaction and sustainable ecotourism, on the other hand, has conservation (of nature and culture) and livelihoods (economic and educational benefits) as essential constituents." Understanding the effects of mass tourism provides further support for adopting an ecotourism approach in the Sundarbans, an especially sensitive area with unique and precious assets.

<sup>23</sup>As part of the analytic work, a total of 96 visitors were surveyed. They stayed in three different locations: Sundarbans Tiger Camp (private); Sajnekhali Tourist Lodge (government owned); and Sundarban Jungle Camp (private). The survey questionnaire contained 24 questions on visitors' demographics, perceptions about the location, suggestions for improvements, etc.

<sup>24</sup>See <http://www.gwutourism.org/iits/ATDI.htm> for more information.

<sup>25</sup>In terms of a "trickle down [multiplier] effect", the study revealed that the households who gained income from tourism did not contribute to the economic growth of the village economy. For the tourism multiplier to have a wider economic impact, more local jobs need to be created in the area to generate more intravillage tourism service transactions.



relatively low human capital formation (Guha and Ghosh 2009).<sup>25</sup> The study examined living standards, as reflected by household monthly percapita expenditures, in Pakhiralay and Dulki villages. In comparison to Dulki (where households did not participate in tourism-related work), households engaged in tourism-related jobs in Pakhiralay had higher living standards, even though they had lower per capita landholdings and lower literacy and primary education completion rates. More generally, the tourism product now being offered in the area is not diverse and mature enough to increase the number and size of the local tourism businesses to the level that would provide full-time jobs. That would require an increase in the scale of sustainable ecotourism activities, but care must be taken to maintain a scale that does not exceed the area's carrying capacity for environmentally sustainable ecotourism. Scale could be increased via a marketing campaign to promote the attractions of the area for a number of other activities, such as bird watching and guided programs run by trained local guides that take advantage of the extraordinary range of plants, birds, and mammals that environmentally sensitive ecotourists would come to see. In addition, the villages of the transition zone that contain lodging for those tourists could generate jobs and income by training tour guides, showcasing food and other aspects of the local culture, and creating and selling locally made handicraft items.

## 9.6. Livelihood Opportunities in the Stable Zone

Facilitating growth and creating jobs in clusters of population might add significantly to livelihood opportunities. Clusters with substantial populations can be found in Hingalganj, Hasnabad, Haroa, Minakhan, Nazat, Sandeshkhali, Jaynagar-Majilpur (the only municipality in the Sundarbans), Jamtala, Raidighi, Patharpratima, Namkhana, Kakdwip, Bakhali, and Gangasagar. They are centers for trade and commerce that handle outbound flows of resources such as agricultural produce, fish, and cottage industry items, and inbound trade in agricultural inputs as well as durable and nondurable consumables (for example, mobile phones, motorcycles, televisions). Most clusters are typically well connected to Kolkata, and possess the potential to take advantage of the recent trend in industrial outsourcing to supply Kolkata-based industries. The employment growth envisioned for the stable zone would primarily be in value-added resource-based jobs, such as those linked to fisheries, but would also include commercial and light industrial employment in associated service sector activities that one would find in any urbanized economy (for example, trading, repairs, wholesale). Not all parts of the stable zone are suitable for cluster development, however, and thus care would need to be exercised to avoid promoting clusters located in zones subject to high risk from storms and sea level rise. In the context of regional economic development theory, large agglomerations such as Kolkata are sometimes called "growth poles";<sup>26</sup> and what is suggested here is the promotion of secondary

(or even tertiary) growth poles in an organized fashion, one that avoids cluster formation in areas that are likely to be unstable as a result of sea level rise and other hazards.

Consolidating clusters of livelihoods by promoting a shift for those engaged in largely uneconomic work into the small-scale industries in the existing clusters of population will not only increase incomes but will also contribute to overall economic well-being and reduce pressure on forest resources. The clusters in the stable zone could be consolidated to provide job training and support services, which could strengthen their current focus on processing and allied services for local fruits, honey, vegetables, and medicinal plants, and on production of durable or nondurable goods and local handicrafts. In addition, if development of the clusters included improved infrastructure for transport and storage of fish catches, they could promote and support sustainable fisheries. Industrial facilities in the peri-urban areas of Kolkata currently meet the outsourcing needs of firms in Kolkata. The infrastructure and services in the stable zone could be upgraded, particularly infrastructure for provision of reliable electricity and safe water supply and sanitation facilities. Labor and skills training programs for potential employees in the stable zone and those seeking economic opportunities in urban areas should also be provided. Investments in the stable zone should be made in ways that minimize negative impacts on the transition zone.

However, fostering and strengthening such clusters of populations and enhancing the potential for growth of livelihood clusters may create further incentives for in-migration, and would therefore have to be well managed. At one level, it is important to be selective in how services are preferentially delivered to some clusters of population. This implicitly requires that some areas in the hinterland will be deliberately serviced to lower levels. The town of Gosaba, for example, is a bustling port but it also remains in one of the most vulnerable parts of the Sundarbans; massive investments in Gosaba are likely to be relatively expensive, are in a vulnerable region, and would attract populations to a high-risk area, while also increasing pressure directly on the adjacent forest. It is acknowledged, however, that people may continue to migrate to places such as Gosaba even in the absence of any significant economic stimulus. Over the long term, to discourage such in-migration, other policies may need to be put into place relating to land transfers or use of local natural resources.

## 9.7. Conclusions

As different parts of the Sundarbans face varying degrees of vulnerability, it is not necessary that the same set of livelihood-related activities be initiated in all areas. For example, some areas near the mouths of rivers are very vulnerable to rising sea level, and increased frequency and intensity of cyclonic action. Therefore, rather than trying to provide an incentive for settlements to continue, the overall strategy being proposed is to help these people out-migrate. Thus, based on vulnerability to natural factors

<sup>26</sup>For more on growth poles and where they fit in the broader field of economic development, see Dawkins 2003.

and sensitivity of the area with respect to protecting the mangroves of the Sundarbans, the livelihood strategy for the Sundarbans has been classified into three zones.

**Core zone.** This is the most vulnerable zone and mostly adjoins the Sundarbans Biosphere Reserve. The key strategy for this zone is to help the population to move to less risky areas over a period of 10–15 years.

**Transition zone.** This is sandwiched between the core and stable zones and comprises high-risk areas that are along major tidal rivers. The long-term vision aims to equip the population in the transition zone with skills development, training, and education in order to encourage them to voluntarily seek alternative livelihood opportunities away from the high-risk transition zone. This process should be gradual to minimize social disruption. For those residents who choose to stay in the Sundarbans, the principal possibilities for improving livelihoods consist of opportunities in the following areas: modernized aquaculture, sustainable agriculture, ecotourism, and the exploitation of nontimber forest products. Livelihood opportunities that promote sustainability and conservation of the forest, based on the development of sectors with low environmental impact, such as high-end ecotourism, should be the main focus for those who stay in the area. As carbon financing opportunities develop, existing and new mangrove forests could provide an important revenue stream and community forest management models must become more prevalent.

**Stable zone.** This is the zone where the delta is relatively stable, further away from the mouths and tidal river courses. Most of this land is attached to the mainland and is well connected to Kolkata and other urban areas. Currently, this forms the main business hub of the Sundarbans. The key strategy for this zone is systematically to develop livelihoods using a cluster-based approach that promotes food processing and allied services, and encourages entrepreneurs to establish small-scale industries. Alongside these interventions, infrastructure investments should focus on developing this zone such that it is an attractive setting for migrants from the transition zone

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# Annex 10.

## Spatial Transformation and Increased Economic Growth Opportunities<sup>1</sup>



### Abstract

A strategy of spatial transformation of the Indian Sundarbans seeks to better link households in the region with growing economic opportunities and improved living standards in urban areas through improved mobility. These are already some of the poorest populations in West Bengal; the impact of increasingly intense cyclonic storms coupled with other natural threats will make it infeasible to support, in a sustainable way, the levels of population that currently exist. For this reason, encouraging residents to seek opportunities in other areas and discouraging in-migration are feasible ways to reduce the numbers of people at risk of suffering from the extraordinary hazards associated with life in the high-risk areas of the Sundarbans. This recommendation should be considered in the broader context of urbanization in India. Based on population projections by the McKinsey Global Institute, the number of Indian cities with populations of more than 1 million will increase from 42 in 2008 to 68 by 2030. West Bengal will move from a 2008 urbanization rate of 29 percent to an urbanization rate of 40 percent in 2030. Moreover, the population of Kolkata agglomerate is projected to increase to roughly 23 million in 2030, with a per capita income of US\$1,700 (McKinsey Global Institute 2010). Projections of increased GDP are based on an empirically based positive association between urbanization and economic development.<sup>2</sup>

### 10.1. Introduction

Growing risks to the population of the Sundarbans means that, over the long term, because of sea level rise, salinity intrusion, decreased carrying capacity of land, and growing intensity and

frequency of natural disasters, populations will find it increasingly difficult to subsist in the Sundarbans. Integrating the population of the Sundarbans blocks into areas with lower risk and greater economic opportunities is critical to ensuring socioeconomic development and poverty reduction of the Sundarbans area in the future.

A strategy based on spatial transformation of the Sundarbans builds on current trends in India as a whole, and in West Bengal, in particular, whereby economic opportunities are increasingly found in urban and peri-urban areas. This trend is expected to continue alongside the rapid pace of urbanization in the coming decades. Much of the evidence on urbanization has shown that labor force participation, income potential, and access to services improve significantly for many urbanizing populations. The strategy presented for the Sundarbans also places this area in the context of urbanizing trends in the country that are likely to occur with or without policy interventions. The discussion below puts a perspective on this increased urbanization and its positive consequences in terms of economic development.

### 10.2. Current Patterns of Spatial Transformation in the Sundarbans

In a representative household survey (2011) of the 19 Sundarbans blocks, the entire current population of 4.4 million people was classified as rural (Table A10.1). This indicates that while urbanization rates are increasing in India, West Bengal, and even the districts of North and South 24 Parganas (which cover the 19 Sundarbans blocks), the Sundarbans themselves remain relatively excluded from urban economic opportunities.

<sup>1</sup>This Annex was prepared by Anna O'Donnell, Sanjay Gupta, Ernesto Sánchez-Triana and Tapas Paul based on consultant reports prepared by Santiago Enriquez and Leonard Ortolano, and a household survey completed as part of the Non-Lending Technical Assistance.

<sup>2</sup>For details on the positive associations between GDP per capita and urbanization levels, see World Bank 2009. As another example, a study based on data for 180 countries revealed a positive cross-country relationship between the level of income and the urban population share in 2000 (Bloom, Canning, and Fink 2008).

**Table A10.1: Comparative Population Figures for India, West Bengal, North and South 24 Parganas, and Sundarbans Blocks**

Country/State/District	Population millions)	Population Rural (percent)	Population Urban (percent)	Decadal Growth Rate 2001–11 (percent)
India	1,210.0	86.84	31.16	17.74
West Bengal	91.3	68.10	31.90	13.93
North 24 Parganas	10.1	42.21	57.79	12.86
South 24 Parganas	8.2	74.39	25.61	18.05
Sundarbans blocks	4.4	100.00	0.0	17.00

Source: Census of India 2011, Provisional Population Totals, India & West Bengal (GoI 2011); 2011 household survey of 19 Sundarbans blocks.

The population of the Sundarbans blocks is primarily engaged in subsistence agriculture, and the great majority of farmers are classified as “small” and “marginal,” with typical landholdings of less than 1 ha per family. The 2011 household survey found that for more than half of all households in the Sundarbans blocks who owned their own land (55.5 percent), the size of the holding was only between 0.01 and 0.20 ha.

The Sundarbans also faces high exposure to natural disasters; around two-thirds of all households in the Sundarbans are susceptible to cyclones, storms and storm surges, or flooding. This further undermines agriculture as a predominant livelihood activity, and contributes to high levels of poverty in the Sundarbans (estimated at 50 percent).

In response to the risks faced from exposure to weather shocks, nearly 30 percent of the households send at least one member of the household in search of employment opportunities outside the high-risk areas of the Sundarbans. However, while qualitative work conducted in the Sundarbans shows that there is a dominant perception that households with at least one migrant are better off than others, the 2011 household survey found that these households continue to be in the minority. As Table A10.2 shows, around three-quarters (71.6 percent) of households surveyed did not have a household member who had migrated.

**Table A10.2: Migration of Household Members (%)**

Type of Migration	Hindu	Muslim	Total
Did not migrate	71.4	72.3	71.6
Migrated within Sundarbans	4.0	6.7	4.7
Migrated outside (not Kolkata)	8.0	5.0	7.3
Migrated to Kolkata	16.5	16.0	16.4
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Source: Household survey, 2011.

<sup>3</sup>A participant in a focus group discussion at Pakhiralay, Gosaba block, said: “Those who are migrating out are financially better off than others. They are sending their children to good schools so that they can get better education.”

<sup>4</sup>Seasonal migration refers to migration during a work season. Occasional migration (for short periods of time) refers to migration when it is required (but less than 90 days/year). Temporary migration is the out-migration of a single male (or sometimes female) member of a family, for a few days up to a year, to a particular location to work and save, and to return home for awhile until such savings run out.

<sup>5</sup>As measured by asset quintiles.

The perception of migration was largely that it provided access to income and opportunities that made households with migrants better off than households with no migrants. There was widespread recognition among focus group discussions, conducted together with the 2011 household survey, that education was critical, most notably for future generations.<sup>3</sup>

### 10.2.1 Seasonal Migration Patterns

Seasonal or temporary migration of residents refers to those migrants who were present in the household at the time of the survey. Of the 2,188 households surveyed in North and South 24 Parganas, the majority of households did not have a member who migrated out either seasonally or for short periods of time;<sup>4</sup> around 90 percent of all households surveyed said they did not use migration out of the Sundarbans as a source of income. Of those households who did have members who migrated, seasonal migration was higher for households with fewer assets,<sup>5</sup> with around 8 percent of poorer households saying they migrated on a seasonal basis as opposed to only 2 percent of richer households.

There were distinct differences between the richer and poorer households with respect to the season in which they migrated. As Table A10.3 shows, around half of the absolute poorest households (47 percent) had members who migrated between September and January, whereas among the richest quintile, this figure was only 10 percent. Similarly, the poorer households were more likely to engage in seasonal migration, as opposed to temporary migration: 36 percent of the poorest households had members who migrated for the entire year, whereas around three-quarters (77 percent) of the richest households had members who migrated for the entire year. Poorer households were probably engaging in seasonal migration for agricultural labor, whereas richer households were likely to have access to more permanent jobs in the formal sectors of the economy.

Similarly, when asked why household members migrated to other areas, poorer households were more likely to indicate that there were

**Table A10.3: Migration Patterns by Season and Asset Quintile (%)**

If You Migrate, during Which Season?	Poorest (Q1)	Second Poorest (Q2)	Poor (Q3)	Marginal Poor (Q4)	Relatively Better Off (Q5)
Jaishtha-Ashad-Sravan-Bhadra (mid-May to mid-September)	10.10	13.92	18.98	19.40	4.73
Aswin-Kartik-Agrahan-Pous (mid-September to mid-January)	47.36	28.62	36.96	20.90	10.45
Magh-Falgun-Chaitra-Baisakh (mid-January to mid-May)	6.47	9.51	7.07	12.21	7.60
All the year	36.08	47.95	36.98	47.50	77.21

Source: Household survey, 2011.

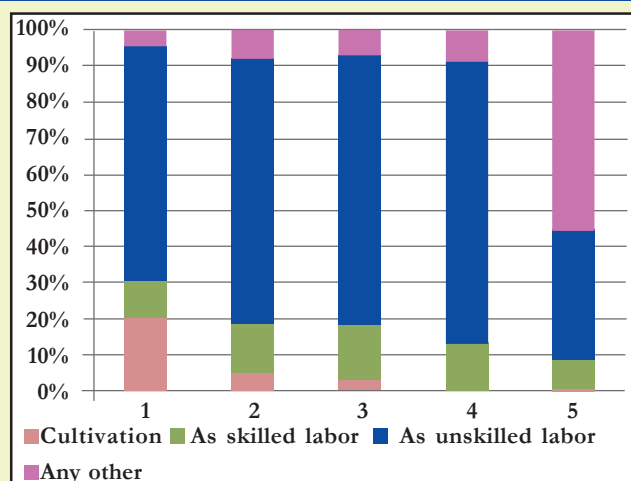
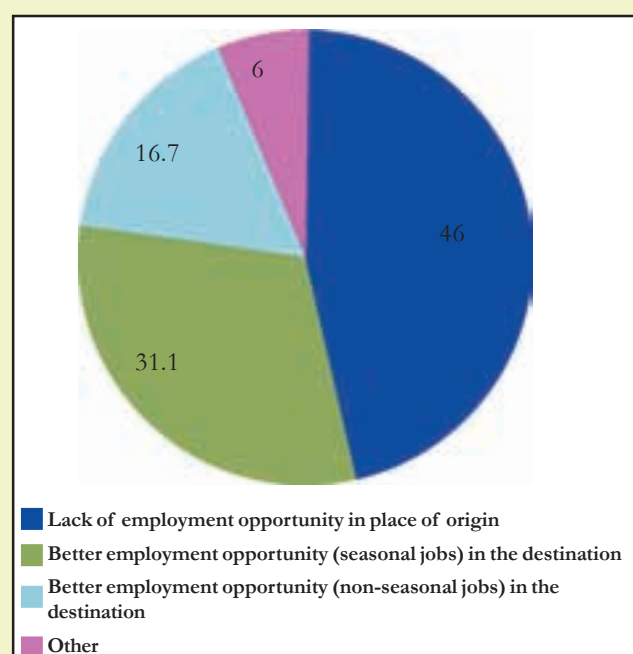
better seasonal employment opportunities; around 40 percent of the poorest quintile mentioned seasonal employment opportunities as a reason for migrating, and this percentage reduced by each quintile group to around 30 percent for the richest quintile.

The most prevalent occupation for seasonal migrants was unskilled labor (62 percent). However, there was significant variation by asset level. For example, while 62 percent of households in the lowest asset quintile engaged in unskilled labor, only 33 percent of households in the highest asset quintile cited unskilled labor as an occupational group for migrants. For households in the lowest asset quintile, the primary occupations were unskilled labor and cultivation (19 percent). For households in the second to fourth quintile, between 12 and 15 percent (approximately) of migrants were engaged in skilled labor, indicating a correlation between skilled labor and asset quintile in the Sundarbans. Around half of the migrants from households belonging to the richest quintile engaged in other occupations, indicating the possibility that these households had access to formal sector or other types of employment (Figure A10.1).

Around half of migrants from Muslim households were engaged in unskilled labor, with around a quarter (23 percent) engaged in

skilled labor, followed by about 10 percent engaged in handicrafts. This pattern was different from that of other social groups.. Around 65 and 70 percent of SC and ST migrants, respectively, were engaged as unskilled labor, but only around 7 percent and 19 percent were engaged as skilled labor.

Migrants from the Sundarbans blocks cited both push and pull factors to migration, with close to half of migrants citing better employment opportunities outside the Sundarbans in seasonal (30 percent) and nonseasonal (16.7 percent) jobs, with close to half (46 percent) citing lack of employment opportunities in the Sundarbans as the primary reason for migration (Figure A10.2). Poorer quintiles were more likely to cite the lack of employment opportunities in their place of residence (around 50 percent for quintiles 2–4), whereas only around 35 percent of the richest quintile cited lack of employment opportunities as a reason for migration. In addition, the richer households were the only ones to cite reasons such as job transfer, and although this was a relatively

**Figure A10.1: Occupation of Seasonal Migrants by Asset Quintile (1= Poorest; 5= Richest)****Figure A10.2. Primary Reason for Migration (%)**

small proportion of the households surveyed (3 percent), it was the only quintile that cited job transfer as a reason, indicating that this is the only quintile with access to the formal sector, where job transfers would be a reason to move.

More than half of all resident migrants (57 percent) went to urban areas, citing Kolkata and its environs as the primary destination for migration (Figure A10.3). The second most prominent destination was other districts in West Bengal (16 percent), followed by other locations in the Sundarbans (15 percent). There was some slight variation amongst social groups, with 71 percent of respondents from STs indicating that Kolkata was the primary destination, compared to only 49 percent from other backward classes (OBCs). While 67 percent of Muslim migrants also named Kolkata as their primary destination, most of the rest of the Muslim migrants went to other locations in the Sundarbans (24 percent), compared to 13 percent Hindu migrants. Around 15 percent of migrants belonging to the SC category indicated that they went to south India, whereas this figure was only 4 percent for STs and 1 percent for Muslims.

Most migrants end up in urban areas (78 percent), although this figure varies by poverty level; for households belonging to the

poorest quintile, around 70 percent ended up in urban areas but, for the richest quintile, this was nearly 89 percent (Table A10.4).

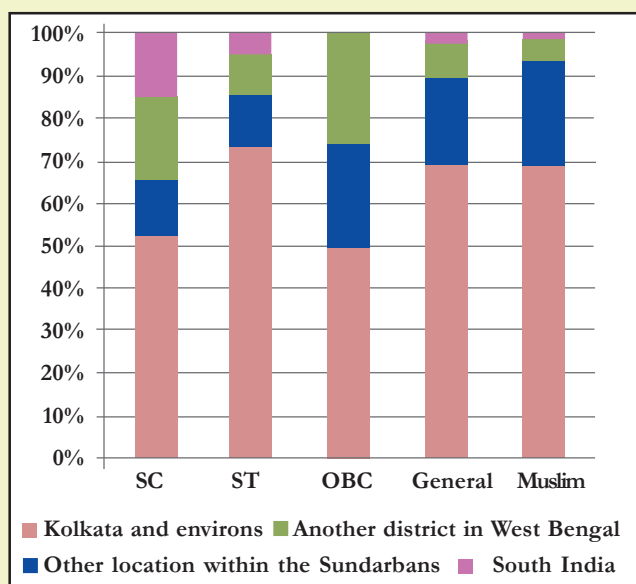
Around half of all migrants relied on family and friends to help them find work (49 percent), followed by agents and contractors (29 percent), and owners or proprietors at the place of work (12 percent). However, this pattern, too, varied significantly by poverty levels and social groups. Around 40 percent of migrants from households in the poorest quintile relied on agents or contractors to help them migrate, whereas for migrants from households in the richest quintile this proportion was only 15 percent. Migrants from Muslim households relied more on contractors and agents (44 percent) than on family and friends (32 percent), whereas SC and ST migrants relied more on family and friends (55 and 56 percent, respectively) than on contractors (26 and 37 percent, respectively).

## 10.2.2 Permanent Migration

Permanent migration typically captured more long-term and permanent out-migration patterns of residents of the Sundarbans. Around 20 percent of the 2,188 households surveyed had at least one household member who was a permanent migrant (not present at the time of the survey), and this figure was consistent across poverty levels and social groups. Typically, this was a son or a daughter of the head of the household; 79 percent of all nonresident migrants fitted this category, followed by around 11 percent that were brothers or sisters of the household head. The average age of the nonresident migrant was 22 years. This was consistent with qualitative work undertaken in the Sundarbans that showed that many young men migrated out for several years in search of employment opportunities in order to return to the Sundarbans to marry.

Around a third of migrants had completed primary school, and another third had completed junior high, although educational achievements of migrants varied by poverty levels and social group (Table A10.5). For example, almost half of all nonresident migrants from households in the lowest quintile group had completed primary school (44 percent), with just over a fifth having completed a level above in junior high (23 percent) and a level below of preschool (21 percent). In contrast, around half of all nonresident migrants from households belonging to the richest quintile completed junior high (51 percent), with around a quarter having completed high school (25 percent).

**Figure A10.3: Destination of Seasonal Migrants**



**Table A10.4: Migration Rates to Urban and Rural Areas by Asset Quintile (%)**

Do You Migrate to Urban or Rural Areas?	Poorest (Q1)	Second Poorest (Q2)	Poor (Q3)	Marginal Poor (Q4)	Relatively Better Off (Q5)
Urban	68.96	81.45	77.52	74.58	88.64
Rural	31.04	18.55	22.48	25.42	11.36

Source: Household survey, 2011.



Almost 40 percent of SC and general caste nonresident migrants had completed junior high, whereas similar figures were only around one-third for OBCs and only 17 percent for STs. Almost half of ST nonresident migrants had only completed primary school levels, compared to 28 percent of SC nonresident migrants, 18 percent of OBCs, and 32 percent of the general caste. One quarter of OBCs, on the other hand, had completed high school (25 percent). Most Muslim nonresident migrants had completed junior high (42 percent), followed by primary school (34 percent). Muslims and STs had the highest proportions of illiterate migrants, with around 10 percent and 9 percent of migrants, respectively, compared to only 2 percent and nil for SCs and OBCs, respectively.

Educational attainment was highlighted in the qualitative work as a critical issue for many families in the Sundarbans, with people citing poor access to schools and cost of education as critical barriers for the future educational attainment of children. As one focus group discussion participant (Bagnapara, Gosaba block) noted:

“The main reason for migrating out is to earn more to facilitate studies of children. To them, both boys and girls are equal. They want that education should spread equally for both boys and girls. They want that their next generation should live a better life.”

Households in the Sundarbans districts were largely supportive of a strategy to promote educational opportunities for their children outside the Sundarbans. Table A10.6 shows that there was relatively little difference between different castes and between the poor and nonpoor in their willingness to send their children to other areas within West Bengal to take advantage of educational or training opportunities.

The majority of nonresident migrants (69 percent) were in some other location within the Sundarbans, followed by around 16 percent of nonresident migrants who were in Kolkata and environs. Around 5.5 percent of migrants were in south India. Nonresident migrants were primarily in rural areas (around 68 percent), with the remainder in small urban areas or large cities. Those results were fairly consistent across poverty levels and social groups.

The primary reason for nonresident migrants to move was marriage (63 percent), followed by employment (14 percent) and joining

family (11 percent). For households from the richest quintile, however, around 5 percent of migrants indicated that they migrated for schooling or because they were transferred for a job (2 percent). Although the proportions were small, all other quintile groups had close to no migrants who cited these categories as reasons for migration, indicating that the richer quintiles had better access to education and formal employment opportunities. In addition, the poorest households were twice as likely to cite lack of employment opportunities as a reason for migration (10 percent versus 5 percent among the fifth quintile). Muslims were also most likely to migrate for marriage (76 percent), but cited employment opportunities (10 percent) as the next highest reason, followed by joining family (6 percent), whereas for nonMuslim households, marriage and joining families were the most prevalent reasons cited for migration (59 percent and 12 percent, respectively).

Most nonresident migrants that did not accompany their spouse (45 percent) were employed as domestic help (18 percent), or unskilled labor (12 percent). There was some variation in occupation among poverty levels and social groups. As is to be expected, more migrants from household in lower asset quintiles were employed as unskilled labor (15 percent) than migrants from households in the highest asset quintile (6 percent). Similarly, although the proportion of migrants from households in the highest quintile engaged in skilled labor was relatively small (5 percent), it was nearly twice as high for these migrants as for migrants from households of the lowest asset quintile (3 percent).

Occupations also differed significantly by social group. Around half of all nonresident migrants from SCs, STs, and the general caste had left because of marriage, but this figure was around 80 percent for OBCs. The second most prevalent occupation for nonresident migrants of the OBC category was handicrafts, which was negligible for other social groups. For most other social groups, unskilled labor and domestic help ranked as the two most prevalent occupations. Muslim nonresident migrants were slightly more likely to be engaged as skilled labor (9 percent versus 3 percent for nonMuslims) and were more often engaged as domestic help (23 percent versus 16 percent for nonMuslims).

Nonresident migrants from the Sundarbans did not typically send remittances, although this was probably due, in large part, to the

**Table A10.5: Education Levels of Nonresident Migrants by Asset Quintile (%)**

Education Level	Poorest (Q1)	Second Poorest (Q2)	Poor (Q3)	Marginal (Q4)	Poor Relatively Better Off (Q5)
Illiterate/no education	7.19	6.36	1.03	2.71	3.22
Preschool	21.27	10.19	3.05	11.60	0.70
Primary	44.01	38.81	36.90	24.05	10.93
Junior high	22.95	31.16	41.04	36.28	50.64
High school	4.57	10.30	15.25	20.82	25.21
University (1st or 2nd degree)	—	3.18	1.22	3.11	8.60
University (3rd degree or doctorate)	—	—	1.52	1.44	0.71

Source: Household survey, 2011.

**Table A10.6: Willingness of Households to Send Children to Kolkata or Other Parts of West Bengal for Educational Purposes (%)**

	All	Muslim	SC	ST	OBC	General	Poor	Nonpoor
Yes, for all children	84.50	80.19	84.71	86.6	93.6	83.04	85.61	83.47
Yes, but only for male children	9.70	11.87	10.05	8.54	5.44	9.57	9.09	10.19
Yes, but only for female children	0.10	0.16	0.07	—	—	0.11	0.14	0.02
No	5.80	7.78	5.18	4.86	0.97	7.28	5.17	6.32
Total	100	100	100	100	100	100	100	100

Source: Household survey, 2011.

fact that most were women who had moved, because of marriage, to their spouse's home. For those households where nonresident migrants had sent remittances, the first category that these were spent on was food (13 percent). This was particularly true for the poor households, where the percentage spent on food was 15 percent, compared to only 6 percent for the richer households.

### 10.3. Linking Residents to Economic Opportunities in Urban Spaces

The upsurge in economic opportunities in India's cities will create an attractive force that government policies cannot thwart. As noted in World Bank 2009, "The pull of agglomeration forces in prosperous places is simply too strong for any opposing measure to be sustained."<sup>6</sup>

There is evidence showing that, over multiple generations, the descendants of the rural poor who migrate to cities are better off than they would have been if their families had remained rural residents (Glaeser 2011, p. 7; Ravallion 2007).<sup>7</sup> After a few generations, many of those poor families will no longer be poor. Migration to cities may make those families worse off in the short term, but the long-term prospects for those households may be better than they would have been had they remained among the rural poor.

For residents of the Sundarbans, economic opportunities in the nearby city of Kolkata and in India's other fast-growing megacities will act as pull factors for many households seeking improved income opportunities. Given the dangers involved for the residents of the Sundarbans blocks who face exposure to natural disasters, priority should be given to removing barriers to mobility and employment through enhancing health and educational outcomes for residents and, in the medium term, encouraging the integration of the Sundarbans population into relatively better economic markets in urban areas. Given the severity of challenges facing the Sundarbans in the long term, future generations of residents will be

better off living out of harm's way outside the Sundarbans, or in other more urbanized areas within India.

#### 10.3.1 Urbanization and Economic Opportunities

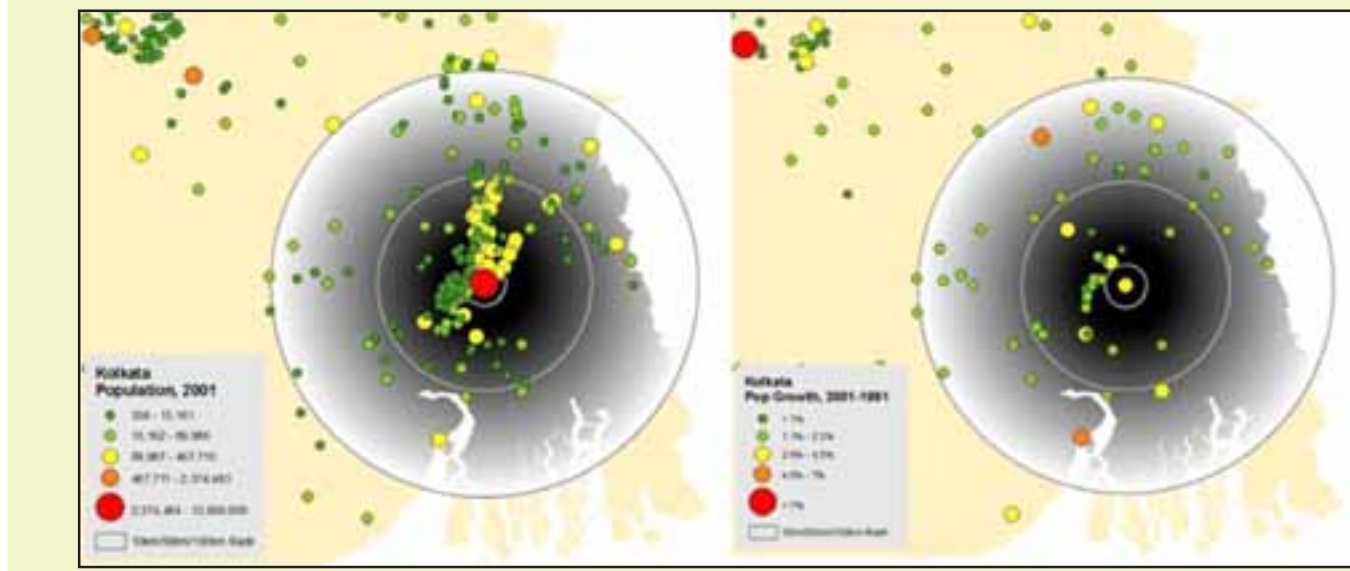
Throughout history, surges in economic activity have accompanied rising levels of urbanization. It is easy to point to historical examples, such as the United States of America between 1790 and 1960, and to contemporary examples, such as China between 1960 and the present day. Although India's rapid increase in urbanization has not yet taken place, there is every indication that it will take place soon. A report by the McKinsey Global Institute (2010) observes that whereas, in 2008, an estimated 340 million people already lived in urban India, representing nearly 30 percent of the total population, this is expected to rise to 590 million, or 40 percent of the total population, over the next 20 years. In addition, over the next 20 years, urban India will create 70 percent of all new jobs in India, and these urban jobs will be twice as productive as equivalent jobs in the rural sector. In short, the next 20 years will witness an urban transformation the scale and speed of which has not happened anywhere in the world, except in China.

West Bengal is predicted to play a prominent role in this urban expansion. According to projections in the McKinsey Global Institute study, West Bengal will move from an urbanization rate of 29 percent in 2008 to an urbanization rate of 40 percent in 2030. Like its many other metropolitan cousins, Kolkata suffered from economic stagnation in post-independence India. However, since 2000, the city has witnessed an economic rejuvenation, due to such factors as the development of the IT industry in Rajarhat in Greater Kolkata. The city's IT sector is growing at 70 percent yearly – twice the national average. The city has seen a surge of investments in the housing infrastructure sector. Moreover, the population of Kolkata is projected to rise to nearly 23 million in 2030, with a per capita GDP of nearly US\$7,400 (McKinsey Global Institute 2010) (Figure A10.4).

<sup>6</sup>World Bank 2009, p. 159. The report also observes (p. 158): "Preoccupied with urban unemployment and squalor in the fast-growing cities of the South, early research on labor migration advocated restrictions. Governments often acted on these prescriptions, instituting migration abatement policies, but to little effect: flows from the countryside to cities and from lagging to leading provinces continued unabated."

<sup>7</sup>For a more general analysis of the ways in which the lives of poor families shift over time, see Narayan, Pritchett, and Kapoor 2009.

**Figure A10.4: Population and Population Growth of Kolkata**



### 10.3.2 Urban Centers as Agglomeration Economies

Kolkata continues to attract a large number of migrants who are in search of improved economic opportunities, and continued urbanization is linked to economic growth. The projections of the McKinsey Global Institute (2010) show that, by and large, urban centers drive growth and GDP; the rises in GDP are based on an empirically based positive association between urbanization and economic development. For example, a study of urbanization in East Asia estimated that the elasticity of economic growth to urbanization rate was 2.71 (Iimi 2005). This can be interpreted to mean that a 1 percent increase in the urbanization rate raises GDP per capita by 2.71 percent. Another study, based on year 2000 data for 180 countries, showed a positive cross-country relationship between the level of income and urban population share in 2000 (Bloom, Canning, and Fink 2008). Indeed, such statistical correlations have been found in a number of studies (see, for example, World Bank 2009).

However, statistical association does not establish causality, and those who have studied the subject describe the case for causality using the following reasoning. Cities are engines for economic growth because of “agglomeration economies:”<sup>8</sup> locations of concentrated economic

activity with large and diversified labor pools and proximity to customers and suppliers. Glaeser (2011) explains the economic success of cities such as Bengaluru by arguing that these cities create a virtuous cycle in which employers are attracted by the large pool of potential employees, and workers are drawn by the abundance of potential employers; and that urban scale also makes it easier for workers to move from job to job. In highly entrepreneurial industries, workers get ahead by hopping from firm to firm.

In characterizing cities as centers for economic growth, Glaeser (2011, pp. 27–28) continues as follows:

Human capital, far more than physical infrastructure, explains which cities succeed.... The striking correlation between education and a country’s GDP may reflect what economists call human capital externalities, a term for the idea that people become more productive when they work around other skilled people.<sup>9</sup>

On the subject of human capital, note that education systems may be more effective in cities, given that educated people who can teach in schools are in greater supply (Bloom and Khanna 2007). In developing countries, educational enrollment is generally higher in cities than in rural areas, with even urban slums outperforming rural regions. Similarly, female literacy rates are, on average, 35 percent

<sup>8</sup>The term “agglomeration economies” includes two subclasses. One consists of “localization economies” (also called infra-industry or within-industry economies), which “arise from a larger number of firms in the same industry in the same place.... spatial proximity helps because immediate access to competitors in the same sector allows firms to stay abreast of market information in negotiating with customers and suppliers. Clustered firms can also share a larger and more dependable pool of specialized labor.” A second subclass of agglomeration economies consists of “urbanization economies” (also called inter-industry or between-industry economies). These “arise from a larger number of different industries in the same place.... [For example, a] management consulting company can benefit from locating near business schools, financial service providers, and manufacturers” (World Bank 2009, p. 129).

<sup>9</sup>Glaeser elaborates on the importance of cities in building human capital as follows: “People who come to urban areas don’t experience higher wage gains overnight. Year by year, workers in cities have higher wage growth as they accumulate the skills that make them successful. Wage growth is particularly faster in cities with more skilled workers. Two decades of extra job-market experience is associated with 10 percent more wage growth in skilled metropolitan areas than in nonmetropolitan America, but only 3 percent more wage growth in less skilled metropolitan areas” (p. 36).

higher among urban populations than among rural populations. Moreover, urbanization has other economic advantages. Larger pools of urban healthcare workers and greater specialization in medical activities – which can lead to higher returns on healthcare investment – all result in urban residents enjoying generally better health than their rural counterparts.

There are other ways to characterize the link between cities and economic growth. For example, in summarizing the arguments given for the causal relationship between urbanization and economic growth, Quigley (2008) first introduces the historical significance of internal economies of scale.<sup>10</sup> High-density settlements allow firms to operate industrial plants at scales for which the average costs could be reduced by taking advantage of division of labor and specialization. He then goes on (p. 3) to detail the modern explanations for the economic significance of urbanization in the following terms:

[The] importance of cities to the modern economy hardly emphasizes internal scale economies at all, but rather external effects, spillovers, and external economies of scale. And these factors have become more important with increased industrialization, technical progress, and with economic development. These external effects can be characterized along a variety of dimensions, and there are many taxonomies. One useful taxonomy distinguishes among productivity gains arising from specialization; those arising from transactions costs and complementarities in production; those arising more generally from education, knowledge, and mimicking; and those arising simply from the proximity to large numbers of other economic actors.

Quigley acknowledges (p. 12) that it is not possible to prove a tight causal link between urbanization and economic development, and that urbanization is certainly not a sufficient condition for economic development to occur....Nevertheless, it seems quite clear that productivity is enhanced by the localization and urbanization features of cities, in developing economies as well as industrialized countries. The cumulative evidence is overwhelming.

Elsewhere (p. 1), he argues: “Policies to facilitate, not inhibit, urbanization will improve economic conditions in developing countries.”

## 10.4. Managing Urban Spaces to Promote Human Development

However, the effects of urbanization processes are not all positive

because negative external effects can overtake the above noted advantages, particularly if the process of urbanization is not well managed. The adverse effects of poorly managed urbanization on quality of life are well known: congestion, environmental pollution, urban slums, crime, and so forth. And even though urbanization may increase incomes, it is also linked to increases in urban poverty, with the rate of growth of the world’s urban poor exceeding the growth rate of the world’s urban population.<sup>11</sup> In India, in particular, the adverse externalities associated with urbanization (for example, congestion and pollution) are painfully present in the larger cities. For example, a 2008 news account entitled “Kolkata is now India’s pollution capital” noted that:

More than 18 persons per one lakh people in Kolkata fall victim to lung cancer every year, compared to the next highest 13 per one lakh in Delhi, according to environmental scientist and advisor of Chittaranjan National Cancer Institute, Twisha Lahiri.<sup>12</sup>

The conditions of India’s urban slums are as arduous as they are in slums of many other countries, but government investments in urban infrastructure can be used to help accommodate the needs of poor residents and speed the process of moving them out of poverty. The types of actions taken by governments around the world to deal with rapid growth of cities are detailed in the 2009 *World Development Report* (World Bank 2009). There, it is argued (p. 229) that appropriate actions for governments should take the following general forms:

- In areas of incipient urbanization, the objective should be to facilitate a spatial transformation. The core policy instruments are spatially blind institutions that facilitate density in some locations. These instruments include secure land tenure and property rights, basic and social services, and economic policies that do not favor one productive activity over another. Policy makers should aim for neutrality between rural and urban areas;
- In areas of intermediate urbanization, the rapid growth of some cities creates congestion. In addition to spatially blind policies to facilitate density, connective policies to tackle congestion and economic distance become necessary. They include investments in transport infrastructure (to enhance connectivity both within and between cities) and encouragement of socially efficient location decisions by firms; and
- In areas with advanced urbanization, divisions within cities caused by formal settlements and slums and by grime and crime add to the challenges of density and distance. In addition to spatially blind and spatially connective policies, spatially focused policies

<sup>10</sup>In general, the term “economies of scale” is defined as follows: “The increase in the efficiency of production as the number of goods being produced increases. Typically, a company that achieves economies of scale lowers the average cost per unit by increasing output, which spreads fixed costs over an increased number of goods produced. There are two types of economies of scale: (1) external economies – the cost per unit depends on the size of the industry, not that of the firm; and (2) internal economies – the cost per unit depends on the size of the individual firm” (<http://financial-dictionary.thefreedictionary.com/Economies+of+Scale>). Here is how a recent World Bank report defined the term: internal scale economies “arise from the larger size of a plant to better exploit fixed costs.... [For example, a] larger steel mill can get volume discounts from suppliers – implying fixed costs of transport and trade – and reap the benefits of dividing labor within the firm” (World Bank 2009).

<sup>11</sup>This paragraph is based on Bloom and Khanna 2007.

<sup>12</sup>Rediff India Abroad, “Kolkata is now India’s pollution capital,” May 28, 2008 (<http://www.rediff.com/news/2008/may/28pollute.htm>).



for addressing intracity divisions are necessary to target the difficulties of slums, crime, and the environment – and to improve livability.

## 10.5. Conclusion

Current trends within India, in general, and in West Bengal, in particular, show rapid economic growth driven in large part by growing opportunities in urban areas. However, at present, the residents of the Sundarbans blocks of North 24 Parganas and South 24 Parganas remain relatively isolated from these opportunities. Migration remains largely seasonal and in reaction to weather and other shocks to households. Short-term migration can serve to temporarily bolster incomes of households, but in the medium to long term much of this migration will probably result in increased social disruption. The overall potential outcome would be a population that does not have the adequate level of human capital and resources to live productive lives outside their original homes.

A strategy of spatial transformation would seek to better link households in the Sundarbans with the growing opportunities in urban areas through improved mobility. A long-term and gradual integration of the Sundarbans population into urban areas is the goal of this approach. This strategy reduces human vulnerability by educating residents of the dangers of living in the transition zone and aims to first improve health and educational standards so that, in the longer term, Sundarbans residents can successfully integrate themselves into cities away from the Sundarbans Reserve Forest. Evidence shows that, over multiple generations, the descendants of the rural poor who seek livelihood opportunities in urban areas are better off than they would have been if their families had remained rural residents (Glaeser 2011, p. 7; Ravallion 2007; Narayan,

Pritchett, and Kapoor 2009). The de facto long-term results should be a significantly reduced population at risk in the transition zone, reduced morbidity and mortality, and improvements in livelihoods for the entire Sundarbans population.

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# Annex 11.

## Spatially-based Approach to Infrastructural Development in the Sundarbans<sup>1</sup>



### Abstract

This annex discusses infrastructure needs in the Indian Sundarbans and presents recommendations to improve infrastructure, taking into account the short- and long-term effects that such improvements could have on the overarching goal of this NLTA to enhance the social and ecological resilience of the Sundarbans. It focuses on four main topics: transport, energy, water supply, and sanitation. For each of these topics, the annex discusses a potential approach to improve infrastructure provision and identifies short- and longer-term trade-offs, recognizing the different challenges of the various regions within the Sundarbans: the core area, closer to reserve forests; a transition zone that is expected to become increasingly unstable and inhospitable; and a stable zone that is closer and better connected to Kolkata.

### 11.1. Introduction

Physical infrastructure for transportation, energy, water supply, and sanitation is sparse in the Sundarbans. GoWB has targeted the stable zone, which is far from the Sundarbans Reserve Forest, for physical infrastructure, and thus infrastructure in that area is expected to improve in the coming years. In the islands, however, the cost of building, operating, and maintaining infrastructure is relatively high due, primarily, to the difficult terrain, seasonal flooding, and periodic cyclone events.

Islands with low levels of physical infrastructure are often in the transition zone, adjacent to biodiversity-rich portions of the Sundarbans Reserve Forest, and are liable to suffer major damage from sea level rise and cyclones. In most such areas, major investments in physical infrastructure would not be economically efficient, because the areas will probably be inundated in the next few decades. Moreover, significant investments in physical

infrastructure in the transition zone might encourage residents to remain in an increasingly unstable area and even attract migrants, placing more pressure on the forest and more people at risk of extreme weather events. Investments should, therefore, be made in ways that are sensitive to the increased risks due to cyclones, sea level rise, and other extreme weather events, and they should be consistent with long-term plans to encourage voluntary migration of residents out of the transition zone.

This annex discusses the challenges to the provision of infrastructure and possible options for improvements. Section 2 examines land- and water-based transportation and section 3 describes energy-related issues. Sections 4 and 5 describe the deficiencies in water and sanitation services, respectively, and offer options for improving these services.

### 11.2. Transportation

#### Background

Transport via waterways has been the backbone of the overall transport system of the Sundarbans for centuries, and it plays an essential role in the southern coastal areas.<sup>2</sup> Boats of various types constitute the primary mode of transport, but service provision is inadequate and has been worsening as a result of increasing waterway siltation, neglect of the system, and shortfalls in service. The siltation problem is a major bottleneck. Dredging needs remain unmet due to lack of budget allocation. The river vessels need to ply through alternative longer routes as siltation has made many regular routes impassable. A 2011 stakeholder survey (completed for this NLTA) reported that there was no fixed timetable for launch operations.

Hundreds of villages in the Sundarbans still cannot be reached by regular boat service. Moreover, boats often need to wait five or six hours for the tide to rise before they can ply. A passenger trip by

<sup>1</sup>Ernesto Sánchez-Triana, Tapas Paul, Leonard Ortolano, Santiago Enriquez, Jean-Noel Guilloso, Sanjay Gupta and Surbhi Goyal prepared this annex based on the following consultant reports: on transport prepared by Ishtiaque Ahmed; on water supply and sanitation prepared by D.M. Mohan; on challenges facing women prepared by Nirmala Banerjee, and on energy prepared by the West Bengal Green Energy Development Corporation Ltd.

<sup>2</sup>This section is based on Ahmed and Guilloso 2011.



*Bhatbhat*<sup>3</sup> from Nazat to Jogeshganj Bazar requires about four-and-a-half hours and costs about INR 25 (for a distance of 60–70 km). The ticket fare is not high, but the travel time required, including the waiting time, makes the journey arduous. A stakeholder consultation survey carried out as part of this NLTA found that inland water transport service users were dissatisfied with many aspects of the service.<sup>4</sup> The absence of porter service on river jetties makes travel inconvenient for the elderly. Inadequate lighting facilities at night are a safety problem for night time navigation. Lack of restroom facilities adds to traveler difficulties, especially for women. Long waiting times are common, as is overloading of launches, which has implications for safety.

Road transportation services are available from Kolkata to several cities that provide access to river transport in the Sundarbans, but travel from Kolkata to any of these cities requires at least one-and-a-half hours, and travel to the furthest city, Namkhana (120 km from Kolkata), requires at least three hours. However, a recent survey showed that the public transport tariffs were perceived to be reasonable to low in the area: users pay INR 25 and INR 30 for traveling from Canning to Godkhali and Jharkhali, respectively, by a Tata Magic service.<sup>5</sup> People who live in the area often commute to Kolkata and other cities in West Bengal for work, school, and other activities. The importance of daily commuting was emphasized by survey respondents. However, in many villages, there may be only one bus that passes by each day, and some towns (for example, Patharpratima) are as much as 44 km away from the nearest railway station. And, as with boats, vehicles are often overcrowded and waiting times are long.

There are basically three exit or entry points that can be considered as major gateways to the Sundarbans. Another important gateway to the Sundarbans is via Canning, which can be reached by road transport through two routes: (a) via Garia-Baruipur; and (b) via Ghatakpur (on SH-3)-Jibantala-Taldi.

Bus terminals are also important transport gateways. There are 14 bus terminals in the study area that can be considered as major hubs connecting the Sundarbans: Bakkhali, Narayanpur, Kakdwip, Barpali Bazar, Raidighi, Ramganga, Jamtala, Jaynagar, Canning, Sonakhali, Dhamakhali, Haroa, Nazat, and Hasnabad. Bus services are convenient for long-distance trips, particularly to and from the Sundarbans; the bus network has better coverage than the rail network, and private cars are limited in number. For travelers using major towns as hubs for transport to and from the

Sundarbans, bus services are available from state operators such as the Calcutta State Transport Corporation, West Bengal State Transport Corporation, and South Bengal State Transport Corporation, as well as from private operators. Over time, the Calcutta State Transport Corporation service has dwindled to a minimum level.

NH-117, which is the only National Highway in the Sundarbans (Figure A11.1), connects Howrah, Kolkata, and Diamond Harbor to important businesses, institutions, and trade centers (for example, Kulpi, Kakdwip, Namkhana, and Bakkhali), as well as to the port of Kulpi and tourist spots in Diamond Harbor and Bakkhali. However, the NH-117 road network has several deficiencies, particularly: (a) capacity constraints, with existing lanes severely congested in localities such as Amtala, Sharisha, Kakdwip, and Namkhana; (b) uncontrolled ribbon development along the highway; (c) poorly constructed bridges; and (d) an inadequate number of bypasses and bridges. Overall, in the Sundarbans, 65 percent of the total village roads need improvement. South 24 Parganas has significantly higher village road density than North 24 Parganas in terms of both area (km per 100 km<sup>2</sup>) and population (km per million population).<sup>6</sup>

Railway<sup>7</sup> connectivity in the Sundarbans includes two railway routes that are under the jurisdiction of Indian Railways.<sup>8</sup> There are at least nine blocks in the Sundarbans located 10 km or more from the nearest railway station (Table 11.1). For example, Patharpratima and Sagar blocks are located 44 km and 36 km, respectively, from the nearest station.

**Table A11.1: Block Headquarters with Long Distances to Nearest Railway Station**

Block Headquarters	Distance (km)
Basanti	16
Canning II	13
Gosaba	36
Kultali	25
Mathurapur II	16
Namkhana	28
Patharpratima	44
Sagar	36
Hingalganj	20

<sup>3</sup>Motorized boats in the Sundarbans.

<sup>4</sup>Stakeholder consultation surveys conducted in February and March 2011.

<sup>5</sup>The Tata Magic is a microvan launched by Tata Motors, India in June 2007.

<sup>6</sup>For road density in terms of area, the figures are as follows: South 24 Parganas has 293 km per 100 km<sup>2</sup>, and North 24 Parganas has 161 km per 100 km<sup>2</sup>. In terms of population, the figures are as follows: South 24 Parganas has 4,229 km of road per million population and North 24 Parganas has 740 km per million population (GoWB 2009).

<sup>7</sup>One of the major rail routes is between Baruipur station and Namkhana station via Kakdwip (83.3 km); it is the gateway to the southwestern part of the Sundarbans, especially for access to Sagar Island. There are 17 railway stations on the route from Sealdah to Namkhana. The rail route between Sonarpur station and Canning (29 km) is the gateway to the tourist attraction areas towards Gosaba. Five railway stations are on the route between Sealdah and Canning. Most rail lines were built to meet the official needs of the British administration in the late 1800s.



**Figure A11.1: National Highway NH-117 South of Kolkata**



DSA and SDB<sup>9</sup> have supported the development of transport infrastructure, including some 50 km of black topped roads (bituminous concrete), 100 km of cement concrete roads, and 3,000 km of brick-paved roads, as well as around 30 small, medium, and large bridges in various locations to improve connectivity

between the islands and the mainland. Construction of another five bridges was in progress in March 2011, when data for this report were collected. The locations identified for bridges are mainly on silted-up rivers that have lost connectivity during low tides and face problems with water transport.

<sup>8</sup>Source: General Manager's Office, Eastern Railways at BBD Bag, Kolkata.

The engineering wing of SDB comprises five divisions and nine subdivisions. The chief engineer heads the engineering wing. Of the five divisions, four are working divisions that directly implement the civil works scheme of the Board. The fifth division – the Survey, Investigation, and Design Division – was created in 2003 to prepare drawings, designs, and estimates for different schemes and projects undertaken by the Board. Although most of the technical staff members are deputed from other agencies, they usually remain there for a long time (having the opportunity to live in Kolkata with family and commute to the work site daily). The chief engineer and his or her staff are responsible for the survey, design, and implementation of all communication infrastructure projects, and the budget allocation to the area is increasing.

Interventions that were being planned by GoWB in March 2011 to improve transport infrastructure provision in the Sundarbans included the following: (a) a proposed port at Sagar Island, which is expected to increase connectivity and boost the local economy, leading to greater population density in the area; (b) proposed bridges (for example, over the Muriganga River), enabling more efficient transport systems and connecting urban centers with clusters of livelihoods in the stable zone; and (c) expansion of the railway network in the Sundarbans toward the south, with further studies approved.

## Recommendations for the Transport Sector

**Developing roads to connect the stable zone to outside urban markets:** Given that the development of transport infrastructure may likely facilitate access into the Sundarbans and, hence, place greater stress on the fragile ecosystem, transport infrastructure needs to be planned in ways that promote the integration of residents into the relatively safer stable zone and peri-urban areas located more inland. Hence, developing and improving road infrastructure between the stable zone and urban areas can encourage residents residing in the more environmentally dangerous areas of the transition zone to take advantage of the opportunities that the road network will provide in giving families easier access to urban markets. Transport infrastructure can help connect residents to urban markets, where there are greater economic opportunities, access to public services (health and education), higher wages, and lower vulnerability to environmental risk. However, if developed without careful planning and supervision, transport infrastructure can generate negative effects, such as in-migration leading to increased settlements and associated vulnerability in the transition area, air and noise pollution, loss of natural landscape, and easier access to natural resources, possibly resulting in more pressure on the biodiverse core zone.

The transport study, completed under this NLTA, reached the following main conclusions:

In general, strategic transport interventions for the Sundarbans should be developed to fit into the overarching sustainable development strategy for the area. For example, the planning of roads in the stable area should be coordinated with the construction of multipurpose cyclone shelters and embankments to facilitate access in the event of a natural disaster. Also, transport services should make it possible to reach healthcare facilities quickly in medical emergencies;

- The railway and highway networks should aim to improve connectivity between the more densely populated stable zone and urban and peri-urban areas;
- All households in or near the transition zone should maximize the use of transportation with minimal environmental impacts, such as nonmotorized vehicles. In locations where the tops of

embankments are flat and wide enough for walking or nonmotorized vehicles, households might use the crests of embankments as a medium for transportation;

- Promoting inland water transport, particularly in the transition and stable areas, should be a priority. Inland water transport is an essential mode of transportation in the Sundarbans, and it is often the only transport mode in the transition zone;
- Demand-based analysis and environmental and social impact assessments should play a role in planning and designing transportation interventions;
- Investments are needed to build the capacity of agencies planning transport interventions in the region so that they can effectively gather data, manage information, and conduct analyses of demand and environmental and social impacts; and
- Safety issues related to road and inland water transport are major concerns for residents of the Sundarbans, and interventions are needed to improve safety.

## 11.3. Energy<sup>10</sup>

The total energy expenditure in the Sundarbans is dominated by biomass (73 percent), followed by kerosene (14 percent), electricity (4 percent), and diesel (4 percent). Of 1,064 villages, 589 have less than 10 percent of households using electricity and are, therefore, considered unelectrified villages, as per the new definition of village electrification by the Ministry of Power. Households without access to grid electricity, located in remote areas, are connected to renewable energy plants (consisting of 16 solar photovoltaics, two wind, and three biomass gasifiers), which provide four to six hours of daily power supply. About 20,000 solar home systems have been distributed to households through government schemes or by NGOs. Over 110 small-scale diesel sets (less than 25 kilowatts capacity) are operated by independent power producers to meet the needs of small markets and selected commercial users.

### 11.3.1 Energy for Cooking

About 90 percent of the population in the Sundarbans uses wood and biomass (straw, shrubs, and grass, agricultural crop residues, and animal dung) as the primary cooking fuel. About 70 percent of this population cooks primarily indoors and 30 percent cooks primarily outdoors.<sup>11</sup> Cooking outdoors reduces but does not eliminate exposure to air pollution from use of solid fuels.<sup>12</sup>

Cooking stoves that burn biomass should be replaced by alternative cooking devices, such as biogas cooking stoves and smokeless *chulas*. Replacement of biomass-based cooking stoves will yield significant decreases in household air pollution, which has substantial adverse health effects, particularly among young children

<sup>10</sup>This section is based primarily on West Bengal Green Energy Development Corporation 2011, a report prepared as part of this NLTA.

<sup>11</sup>Based on rural average in West Bengal; see Larsen 2011.

<sup>12</sup>Two studies in southern India found that air particulate matter from outdoor cooking was 35–50 percent lower than that from indoor cooking for the cook and 50–60 percent lower for other household members (Balakrishnan et al. 2002, 2004).

and adult women, as these groups tend to spend the most time in household environments.<sup>13</sup> Combustion of biomass tends to generate the most smoke, followed by wood, and coal or charcoal.

According to an assessment carried out under the NLTA, an estimated 1,850 deaths and nearly 370,000 cases of acute lower respiratory infection, acute upper respiratory infection, and chronic obstructive pulmonary disease were caused in the Sundarbans by household air pollution due to use of wood and other biomass fuels for cooking in 2008. Around 520 of the deaths were from acute lower respiratory infection among children under five years of age, and 1,330 deaths were from chronic obstructive pulmonary disease, cardiovascular disease, and lung cancer among adult women. The annual cost of these health effects is estimated in the range of INR 1.5–3.8 billion.

Biogas, which is largely methane, is a low-cost form of energy derived from renewable sources, such as animal manure, agricultural residue, human waste, and other organic materials. The main strategy for cooking should focus on improved cooking stoves (for example, biogas cooking stoves and smokeless *chulas*), which decrease indoor air pollution and provide energy services at higher efficiency than traditional biomass-based cooking stoves. Expanded use of gas as a cooking fuel might be promoted using resources from the current scheme that subsidizes biogas plants.

A program to promote use of improved cooking stoves can be based on lessons learnt from recent international experiences. In order for a program to be successful, it should have the following characteristics (World Bank 2010):

- Provision of a wide range of stoves with proven efficiency, the ability to reduce indoor air pollution, and good durability and safety;
- Publicity to inform households of the benefits of improved cooking stoves in terms of reduced particulate concentrations, improved fuel use efficiency, savings in time and labor, and reduced need for firewood. Information on other benefits, such as savings due to faster cooking, improvements in living conditions, and enhancement of soil fertility by returning the crop residues saved to the field, should also be addressed and explained to households;
- Targeted marketing directed at households facing fuelwood scarcity or high costs of purchasing wood;
- Sale of stoves by entrepreneurs and NGOs with solid business models and use of carbon financing, and a range of user financing programs, including microfinancing, grants, and low-income loans for targeted populations; and
- Stove performance monitoring, provisions for proper maintenance of stoves, and a rigorous program of stove testing and certification.

<sup>13</sup>Indoor air pollution due to use of traditional biomass-based stoves for household cooking is associated with harmful health effects that include acute respiratory illness, chronic obstructive pulmonary disease, lung cancer, tuberculosis, and other diseases. Also, household smoke, from use of wood, charcoal or coal, dung, and straw for cooking causes an increase in blood pressure, which, in turn, increases risk of cardiovascular disease and mortality.

<sup>14</sup>Feeder lines, in this context, are the branch lines of a grid network system.

<sup>15</sup>Transformers are devices that step up or down the voltage level.

### 11.3.2 Electricity: Existing Supply

Roughly 1.5 million people, about one-third of the population of the Sundarbans, have access to some form of electricity. Approximately 17 percent of the population has access to grid electricity. The Sundarbans blocks of Basanti, Gosaba, Kultali, Sagar, and Patharpratima are the least electrified blocks. Annual per capita electricity consumption in the Sundarbans (58.4 kilowatthours (kWh)) is roughly one-12th that of India (717 kWh) and one-sixth that of West Bengal (381 kWh). Even when grid electricity is available, around 85 percent of electrified households face power cuts of four to nine hours per day, and the remaining households face power cuts of between nine and 14 hours per day. These cuts generally occur during peak evening hours. Even in the intensively electrified villages (villages in which 50 percent or more of households have access to grid electricity), many households rely on kerosene (4 liters per month per household) for lighting during power cuts.

The total installed electricity capacity in the Indian Sundarbans amounts to 66.4 megawatts (MW). In the islands, 84 percent comes from the grid, 7 percent from solar home lighting systems, 6 percent from renewable energy power plants, and 3 percent from diesel generator sets. The West Bengal Renewable Energy Development Agency, in association with the Indian Ministry of New and Renewable Energy, has implemented a number of renewable energy-based generation plants (particularly solar, wind, small-scale hydro, and biogas) to provide electricity in the Sundarbans (Figure A11.2). The Sundarbans has more than 20 percent of the share of the total off-grid capacity in India. The 83 percent of households without access to electricity depend largely on solar photovoltaic panels, but maintenance costs for these are substantial.

The 55-MW capacity of existing substations is insufficient to cater for the increasing demand. The state government has proposed extension of the grid to almost all of the remaining villages by the year 2015. However, this approach would prove very costly because of the dispersed nature of the settlements in the islands. Other problems with this approach include very low voltages caused by use of long feeder lines<sup>14</sup> (sometimes extending over 50 km) and an inadequate number of distribution transformers.<sup>15</sup>

Solar household systems amount to 7 percent of the installed capacity. The main constraint for solar systems is the high cost of batteries, which generally must be replaced every five years. Existing renewable power plants, such as photovoltaic, wind power, and biomass gasifier plants, account for 6 percent of the total installed capacity, and are located mainly in the islands. Significant operation and maintenance problems (for example, the need for replacement of batteries) are disincentives to the use of these electricity sources. There is potential to develop a 40-MW grid-connected wind power generation systems in the Sundarbans.



Figure A11.2: Location of Alternative Energy Systems in the Sundarbans



Source: West Bengal Green Energy Development Corporation 2011



The Rajiv Gandhi Grameen Vidyutikaran Yojana<sup>16</sup> and SDB have plans to provide electric grid connections to 270,000 Sundarbans households. These national and state programs aim to give priority to villages located on the mainland and on Sagar Island for purposes of increasing electric grid coverage, reducing transmission and distribution losses, upgrading and augmenting the number of substations, implementing energy efficiency measures, institutional strengthening, and institutional reform.

### 11.3.3 Augmenting Electricity Supply via a Market Segmentation Approach

In the islands, a high demand for electricity is indicated by an average load of connected households of 375 watts, which is 25 percent higher than standards adopted by the Rural Electrification Corporation. According to the West Bengal Green Energy Development Corporation (2011), Willingness to pay per month for electricity by average households amounts to about US\$3.50 (approximately INR 168) per month, which is roughly 75 percent higher than the current average monthly electricity bill paid in the Sundarbans of US\$2.00 (INR 95) per household per month. Notwithstanding that average monthly expenditure on energy for rural households in the Sundarbans is higher than that of households in most other rural areas in India, estimated demand growth for electricity in the Sundarbans is substantial (Figure A11.3).

Increased energy infrastructure could bring a number of benefits to households in the Sundarbans, enhancing their welfare and offering opportunities to build human capital. However, the provision of energy infrastructure can also constitute an incentive for people to

stay in the transition zone, and even attract more migrants to the high-risk zone. In contrast, providing reliable electricity supply in the stable area may be one of multiple elements that could make the stable zone more attractive for people living in the Sundarbans. Depending on the energy source, increased access to electricity may generate other impacts, such as air pollution. In order to enhance the potential benefits of increased energy infrastructure while minimizing its potential negative effects, its development should employ a market segmentation approach, based on proximity to the Reserve Forest and its transition zone.

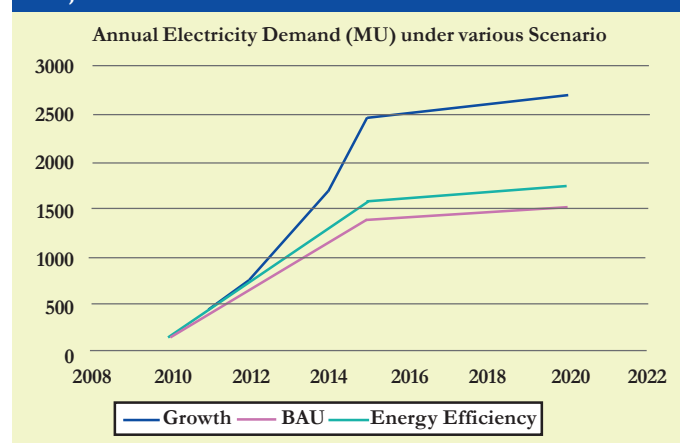
For households in more populated areas of the stable zone, far from the transition zone and near the mainland, priority should be given to connecting all households and commercial activities to the existing electric power grid to encourage clustering of population and development of new livelihood opportunities. For these areas, improving grid infrastructure, thereby reducing transmission and distribution system losses, is a priority. The following are among the measures that can be taken to decrease losses in the subtransmission and distribution systems in the grid-connected part of the Sundarbans region:

- Network reconfiguration through installation of new links to minimize the length of the trunk line within a feeder and installation of interlinking lines to change the area of feed from one substation to another and balance the load among the substations;
- Resizing conductors, by replacement of existing conductors on the feeder with an optimal conductor size for optimal length of the feeder;
- Better management of distribution transformers, for example, by adding transformer capacity in key locations, and relocating distribution transformers closer to load centers;
- Load balancing and load management; and
- Installation of capacitors to improve power factors.

For households in the transition area, GoWB might consider the use of energy generation technologies with low or no environmental impacts, such as solar home lighting systems and photovoltaic schemes for battery recharge of mobile telephone units based on the Global System for Mobile Communications, a digital cellular phone technology.

Households relatively far from the Sundarbans Reserve Forest and nearer to the mainland may consider systems that are connected to small local power plants using appropriate technologies in locally connected grids. This is referred to as decentralized distributed generation (DDG), and involves use of small, modular, decentralized, off-grid energy systems located in or near the place where energy is used. A DDG approach can provide effective and reliable service for households engaging in light commercial activities for their

**Figure A11.3: Electricity Demand (Million Units) Projections under Various Scenarios**



*Note:* In India, “MU” represents a million units of energy, which is equivalent to a gigawatt-hour. *Source:* West Bengal Green Energy Development Corporation Ltd. 2011.

<sup>16</sup>The India Ministry of Power launched the Rajiv Gandhi Grameen Vidyutikaran Yojana as its flagship program in March 2005 with the objective to electrify over 100,000 unelectrified villages and to provide free electricity connections to 23.4 million rural BPL households. Under the program, an electricity distribution infrastructure was envisaged that would establish a rural electricity distribution system with 33/11 kilovolt substations, a village electrification infrastructure with at least a distribution transformer in each village or hamlet, and stand-alone grids with generation where grid supply was not feasible.

livelihoods, and for areas with tourist facilities and light industries. The biomass plant in Gosaba provides an example. A proposal to electrify 37,564 households has been prepared under the renewable energy-based DDG scheme. The West Bengal Green Energy Development Corporation has designed a 10.1-MW DDG project for US\$25 million. The project aims to supply electricity for 12–16 hours per day to 39 villages with renewable energy technologies.<sup>17</sup>

There is potential for additional DDG schemes to be implemented. Renewable power sources can be connected at locations at the tail end of the grid to improve overall grid performance. Except for one wind power plant, all other renewable electricity plants in the Sundarbans are off-grid power plants. Grid-interactive solar, wind, and biomass-based renewable energy plants utilizing local renewable energy sources installed at the tailend of the grid can provide voltage support to strengthen the grid and to provide additional power.

In summary, reliable access to energy supplies should be facilitated to households and commercial establishments, but following an approach that minimizes the risk that energy infrastructure will attract more migrants to the transition zone and instead incentivizes voluntary migration towards the stable zone. A customized strategy that relies on market segmentation, based on proximity to the Sundarbans Reserve Forest, could be devised to speed the provision of energy to households. For lighting and other home appliances, all households in the forest fringe could make greater use of low environmental impact technologies and decentralized renewable sources of energy, such as solar energy. Households outside the forest fringe and near the mainland, areas with light commercial activities in livelihood clusters, and tourist facilities outside the transition area could rely more on DDG systems. For households in more populated areas far from the Sundarbans Reserve Forest and near the mainland, priority should be given to electrification via grid extension for all households and commercial activities; this would encourage clustering of population and development of new livelihood opportunities. In addition, measures can be taken to manage demand, enhance energy efficiency (for example, through replacement of incandescent bulbs with compact fluorescent lamps and efficient tubelights), and improve revenue collection (for example, through use of prepayment meters).

## 11.4. Water Supply

According to a study conducted under the NLTA, there were an estimated 1,925 deaths and over 1.5 million cases of diarrhea in the Sundarbans caused by inadequate household water supply,

sanitation, and hygiene in 2008.<sup>18</sup> Around 1,700 of these deaths were among children under five years of age. The annual cost of the health effects is estimated in the range of INR 3.1–4.0 billion, of which INR 2.7–2.9 billion are from health effects among children under five years of age and INR 0.4–1.1 from health effects among the population five years of age and over (Larsen 2011).

Only 32 percent of households in the Sundarbans are covered by piped water supply (28 percent of the population). Piped water supply connections to households in South 24 Parganas blocks range from 3 percent to 40 percent, and the range for North 24 Parganas blocks is 21 percent to 57 percent (Figures A11.4 and A11.5). Piped schemes, which deliver water via public standpipes, supply an average of 40 liters per capita per day, while spot sources (tubewells with handpumps) supply an average 5 liters per capita per day. An added constraint is that piped water supply schemes in the Sundarbans require electricity for pumping and many blocks are subject to frequent power outages. The majority of households in the Sundarbans rely on spot sources for water, and 6 percent are without either of these types of water sources (Larsen 2011). Apart from providing only 5 liters per capita per day, spot sources are subject to salinity intrusion and are prone to coliform formation during floods. According to DLHS 2007–08, only 11–12 percent of the rural population in North and South 24 Parganas had piped water for drinking (IIPS 2009).<sup>19</sup>

Table A11.2 summarizes household water supply in the Sundarbans, and Figure A11.6 shows the status of piped water supply schemes. A recent survey<sup>20</sup> conducted as part of this NLTA found that over 90 percent of households used public tubewells and, of those, over 25 percent spent more than 30 minutes per day collecting water. In general, in islands on which there are no water sources for drinking or irrigation, women travel longer distances (taking up to three to four hours daily) to collect drinking and cooking water for their family.

The following are the main problems in the provision of water supply in the Sundarbans: (a) scarcity of sweet water due to salinity

Table A11.2. Household Water Supply in the Sundarbans	
Water Source	Percentage of Households Surveyed
Public tubewell	91.5
Pond	6.4
Other	2.1

Source: Banerjee 2011.

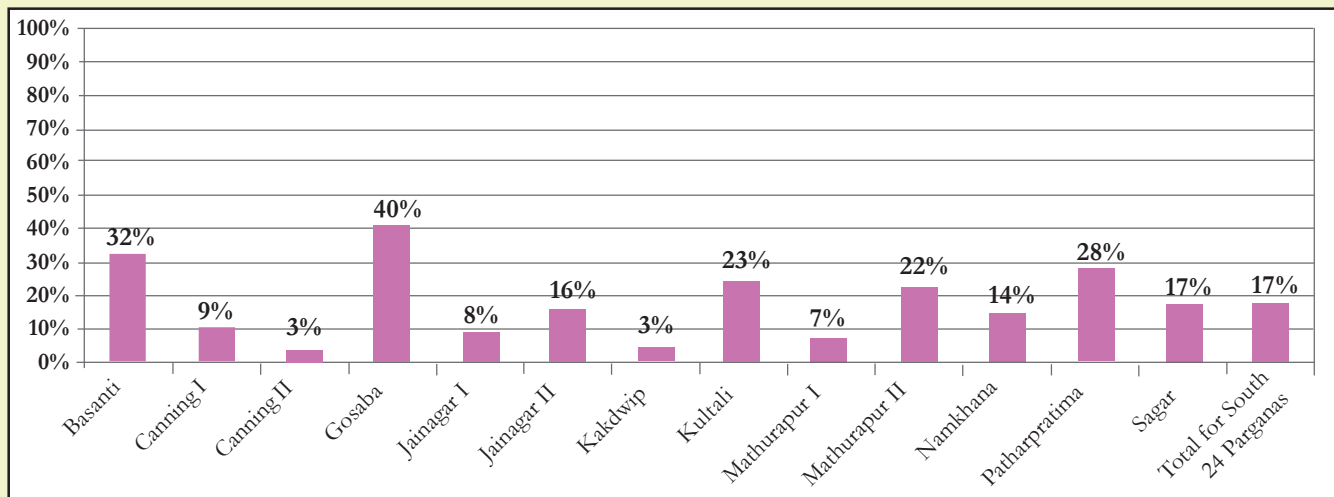
<sup>17</sup>The proposal includes four biomass gasifier-solar photovoltaic schemes, two biomass boiler turbine generators, and three biodiesel-solar photovoltaic schemes.

<sup>18</sup>The content of this section is from Building Resilience for Sustainable Development of the Sundarbans through Estuary Management, Poverty Reduction, and Biodiversity Conservation: A Non-Lending Technical Assistance, Final Report (2012) based on a consultant report prepared by D.M. Mohan (2011).

<sup>19</sup>The DLHS is carried out periodically in West Bengal. The most recent available survey is from 2007–08 (DLHS-3). About 1,100 households were surveyed in North 24 Parganas and about 1,300 in South 24 Parganas (IIPS 2009).

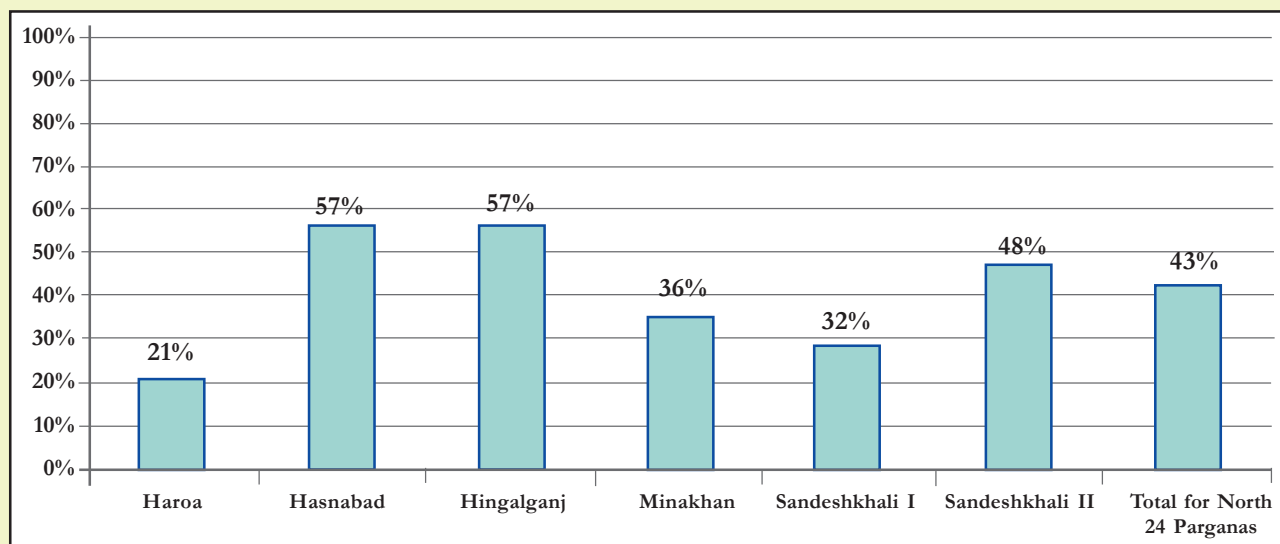
<sup>20</sup>Survey administered by Nirmala Banerjee as part of this analytic work (2009–10). Roughly 340 households in eight blocks/subdivisions (seven in South 24 Parganas and one in North 24 Parganas) were covered in the survey.

**Figure A11.4: Percentage of Households with Piped Water Supply in South 24 Parganas**



Source: Mohan 2011.

**Figure A11.5: Percentage of Households with Piped Water Supply in North 24 Parganas**



Source: Mohan 2011.

intrusion into surface water (ponds and rivers) and limited availability of sweet water aquifers;<sup>21</sup> (b) restricted yields from sweet water aquifers; (c) shortage of lands for excavating new ponds for storing rain water and providing flood banks to prevent entry of saline water during floods into the ponds; (d) submergence of water sources due to cyclones and floods; (e) logistical difficulties in supplying disinfectants; (f) acute and chronic institutional weaknesses; and (g) lack of community management.

The quality of drinking water varies by location, but salinity intrusion is an ongoing challenge. Typically, a tubewell is the source of a piped water supply scheme, and tubewells generally have depths of about 300 m, where nonsaline water is usually available. Traditional river-based surface water schemes cannot be employed in the context of tidal rivers. Salinity intrusion is causing tubewell sources (used in both piped and spot source systems) to become saline, especially during cyclonic storms and floods. A few pond-based surface water

<sup>21</sup>Salinity is more than 1,000 mg per liter (mg/L), even beyond 300 m in depth, and sweet water is often only available at 1,000 m in depth. Drilling and extracting drinkable water from such depths is a challenging task.

schemes have been constructed, but most were affected by saline water intrusion following Cyclone Aila.

As spot source tubewells are often submerged and inaccessible during floods, PHED is implementing a program to raise their height by 3–4 m. The floor levels of pump houses of piped systems should also be raised to prevent submergence during floods. In addition, pond sources need to be protected by raising bunds around the ponds to prevent saline intrusion during floods. Pilot projects have successfully recharged aquifers with rainwater to reduce the salinity of drinking water from spot source tubewells. However, there is a lack of information on the number of households that have unsafe drinking water and access to aquifers and ponds. As a start, PHED could consider undertaking a geophysical survey to identify regions with aquifers, and assess aquifer water quality and quantity.

A number of alternate technology options exist. Desalination is technically feasible but costly. The average rainfall in the Sundarbans is 1,750 millimeters (mm) per year, with most rain falling in the period June to December. Rainwater harvesting pilot studies in the villages of Beliachandi and Jharkhali have proven partially successful. Storing rainwater in new ponds is feasible, but such schemes are hampered by the shortage of land available for excavating new ponds. The per capita cost for water supply schemes with ponds as a source is estimated at INR 3,000. Roof water harvesting is potentially another viable option. A few solar pumps have been installed, but their performance has not been good. A desalination plant with reverse osmosis (RO) has been implemented and is working well. Although it is expensive, RO provides a technically feasible basis for providing saline-free water. In arsenic-prone zones, PHED is providing safe water through an arsenic mitigation plan.

To achieve full coverage of safe water supply in the Sundarbans, different technologies will need to be used in different blocks, based on consideration of geographic, geophysical, and population factors; technical feasibility; and cost-effectiveness.

Several options exist for increasing access to water supply and sanitation in the Sundarbans, but before deciding on options, PHED should identify the households requiring provision of safe water. In addition, while increasing access to water supply and sanitation would generate significant benefits for local communities, including significant reductions in illnesses, it may also increase vulnerability by encouraging people to stay in the area or migrate into it. The following are among the options that should be considered:

- Using a case-by-case approach, and depending on the economic efficiency of each intervention, for areas in which water supplies are highly saline, PHED might consider RO plants that are provided with a pretreatment phase and ultraviolet radiation for disinfection. Solar power (as opposed to diesel generator sets) could be considered to run these facilities;
- Ponds that collect rainwater could be piloted to provide safe water. Bunds can be provided around ponds to prevent entry of saline water during cyclones, and the water can be treated using pressure filters; disinfection via hypochlorite solutions could be fed through handpumps;

- Wherever economically feasible, shallow tubewells should be recharged by harvesting roof water; this option should also be piloted first; and
- Tubewell maintenance is not carried out on a regular basis and should be improved. PHED staff currently undertakes the maintenance, but consideration should be given to regularizing tubewell maintenance by outsourcing it to experienced NGOs; this is expected to reduce water contamination problems to some extent.

PHED can also enlist the services of NGOs in disseminating information regarding the availability of handpump mechanics and banks of spare parts, as well as for ensuring the participation of the community in the operation and maintenance of water supply schemes. A caveat is in order: in some cases, it is clear that further investment in physical infrastructure would yield few long-term benefits, as the affected areas will likely be inundated in the next 50 years. In other cases, investment might lead to increased settlement in the area, putting more pressure on the Sundarbans forest and placing more people at risk of the negative consequences associated with climate change. Thus, while the recommendations above concern investments in infrastructure, those investments should be made in ways that are sensitive to the increased risks due to more intense cyclonic storms. Moreover, increased levels of salinity may cause particular threats to the habitability of some areas.

## 11.5. Sanitation

Only 66 percent of the population has access to a toilet facility in rural South 24 Parganas, compared to 90 percent in rural North 24 Parganas (Mohan 2011). The Total Sanitation Campaign (now called Nirmal Bharat Abhiyan) has been implemented in all blocks of the Sundarbans to promote construction of household toilets, school toilets, community sanitary complexes, *anganwadi* toilets, and solid and liquid waste management facilities. Under this campaign, 156,413 BPL households in North 24 Parganas and 281,649 in South 24 Parganas were provided with toilets, and implementation of the campaign has reduced the practice of open defecation. Coverage of school and *anganwadi* toilets and community sanitary complexes has been on target, but progress on solid and liquid waste management has been slow.

Challenges to the building and maintenance of toilets include difficulty in the transport of materials to remote islands, lack of saline-free water facilities, space constraints, high incidence of poverty, submergence of toilet blocks by floods, and destruction of low-cost toilet structures by storms. After floods, some toilets have had to be relocated, a process that requires considerable expenditure by households. Maintenance of school toilets and community sanitary complexes has also posed problems.

The need for education regarding domestic hygiene is evident in the context of domestic water treatment and handwashing practices. Less than 10 percent of the 313 households surveyed in eight blocks used appropriate drinking water treatment methods, such as boiling



**Figure A11.6: Status of Piped Rural Water Supply Schemes**



*Source:* Public Health Engineering Department, GoWB. 2010.

or filtering.<sup>22</sup> Nearly 20 percent strain water through a cloth and 70 percent do not treat water at all prior to drinking (Figure A11.7). These low rates of appropriate water treatment are a public health concern, as are deficient household hygiene practices, such as handwashing without soap, which are known to have a direct correlation with incidence of diarrheal diseases.<sup>23</sup> In 2009, diarrhea was the most prevalent disease in the southern portions of the Sundarbans, with the blocks of Kakdwip and Namkhana having the highest levels of diarrhea. Enteric fever, which is another waterborne disease, is a severe health hazard in Sandeshkhali I, Minakhan, and Hasnabad blocks of North 24 Parganas (Mohan 2011). Interventions should be undertaken to help educate women, who are typically in charge of domestic water supply and hygiene issues, on the impact of boiling water and employing effective household hygiene practices in reducing disease, especially among young children.

GoWB should consider the following recommendations for enhancing sanitation services in the Sundarbans:

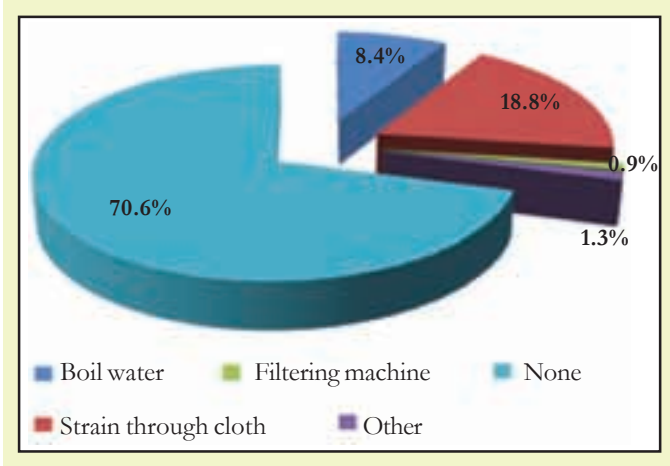
- Sanitation in the Sundarbans should continue to be improved via the implementation of the Nirmal Bharat Abhiyan (earlier called the Total Sanitation Campaign), and comprehensive programs should be implemented at the district level to improve sanitation facilities in rural areas with a broader goal to eradicate the practice of open defecation;
- Particular problems deserving attention involve the adverse effects on toilet facilities of cyclonic storms and shortfalls in maintenance of community-level toilet facilities;
- Priority should be given to improving water supply and latrines at schools; and
- Campaigns for hygiene education should be conducted to encourage handwashing and to improve household sanitation in food handling and preparation, and domestic drinking water treatment.

## 11.6. Conclusions

Transport infrastructure is needed to connect the more densely populated areas far from the Sundarbans Reserve Forest to urban centers where economic opportunities are available. For the residents who choose to stay in the more vulnerable portions of the Sundarbans, infrastructure improvement will give those residents a chance to access emergency shelters and escape the ravages of the frequent flooding and cyclonic storms, thereby reducing the probability of loss of life and property.

Improved energy systems can help enhance productivity and the quality of life. The market segmentation approach proposed herein relies on grid extension for those parts of the Sundarbans that

**Figure A11.7: Household Treatment of Drinking Water in the Sundarbans**



Source: Banerjee 2011.

can be reached feasibly by lines from the grid. For the transition zone, relatively far from the Sundarbans Reserve Forest, DDG systems will be more appropriate. However, for parts of the transition zone close to the Reserve Forest, it would be preferable to rely only on renewable energy systems operable at the household level. Moving away from traditional biomass-based stoves to more efficient cooking devices, especially those using fuels other than biomass, will decrease morbidity and mortality.

Finally, improvements in water supply and sanitation will not only decrease morbidity and mortality (by reducing rates of diarrhea and acute respiratory infections) but will also yield benefits in practical, economic terms: a more productive labor force, fewer resources spent on healthcare, and savings in time for parents and caregivers.

The provision of basic infrastructure is necessary to improve living conditions and enable communities to build the social capital that they would need once they move to the stable zone or to urban or peri-urban locations. For example, household air pollution caused by the use of biomass as fuel for cooking, as well as inadequate water supply, sanitation, and hygiene, are associated with significant negative health impacts on children, affecting their educational outcomes and thus reducing their opportunity of obtaining better jobs in the future. There is, therefore, a strong case for addressing infrastructure provision gaps in the stable zone and in urban or peri-urban areas. However, the development of additional infrastructure will constitute an incentive to stay in the increasingly unstable transition zone. Improving the capacity of sectoral agencies for planning and assessing the environmental and social effects of alternative projects will be key to developing infrastructure in a way that is aligned with the long-term vision proposed in this document.

<sup>22</sup>Household survey conducted by N. Banerjee as part of this NLTA, as cited in Larsen 2011.

<sup>23</sup>Appropriate household treatment of drinking water is found (globally) to reduce diarrheal illness by 30–50 percent. International research has shown that handwashing with soap reduces diarrheal illness on average by more than 45 percent (Curtis and Cairncross 2003).

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# Annex 12.

## Regulatory Instruments and New Market-based Incentive Mechanisms to Preserve Biodiversity<sup>1</sup>



### Abstract

Natural and anthropogenic factors are placing increasing stress on the integrity of the Sundarbans ecosystem. The cumulative effects include losses in aquatic species, reduction in the density of mangrove species, and changes in habitat structure. The estimated cost of environmental damage accounts for about 5 percent of the Sundarbans GDP in 2009. The losses stem from a combination of factors associated with unsustainable and inefficient economic activities, including mangrove destruction, reduced agricultural yields, unsustainable fisheries, and loss of protection against cyclones and other ecosystem services. Planning and adopting measures for preserving biodiversity need to consider how natural and anthropogenic processes impact biodiversity in different areas of the Sundarbans. Given biodiversity's important cross-sectoral linkages, the findings suggest that there is an urgent need to improve efforts for the conservation of biodiversity through a combination of interventions that include regulation, promotion of incentives for forest preservation, and collaboration and research sharing.

### 12.1. Introduction

The Sundarbans region is one of the richest ecosystems in the world. The region contains arguably the world's largest remaining area of mangroves, and is known for its exceptional biodiversity, including numerous threatened species such as the emblematic Royal Bengal tiger and several species of river dolphin. The inhabited portions of the Sundarbans contain over 4.4 million people, who constitute one of the most impoverished and vulnerable populations in India. About one half of this population lives below the poverty line, with poverty incidence highest in the blocks close to the vast mangrove forest.

The Sundarbans suffers from environmental degradation due to extreme population pressures, indiscriminate aquaculture practices, pollution, high salinity levels, and adverse natural events. The estimated cost of environmental damage associated with ecosystem degradation and biodiversity loss is about INR 6.7 billion<sup>2</sup> annually, accounting for about 5 percent of the Sundarbans GDP.<sup>3</sup> Reliance on forest resources is high, as limited education and lack of employment opportunities in the area force many to exploit forest and aquatic resources; indeed, several species of mangroves<sup>4</sup> face significant threat due to poaching and illegal felling. The intensity of cyclonic storms and sea level rise are projected to increase over the coming decades, posing an increased threat to mangrove communities. Reductions in freshwater flows to the delta due to upstream diversions of the Ganga and its tributaries are increasing salinity in the region. Moreover, huge discharges of untreated industrial effluents and domestic wastewater entering the ecosystem are impacting aquatic habitat and biodiversity.

The threat to biodiversity has a direct impact on the living conditions of people in the Sundarbans. Mangroves serve as buffers against storm surges and cyclones, and provide protection to people not only in and around the ecosystem but as far upstream as Kolkata. Mangrove losses expose coastal communities to hazardous weather events. Villages that were well protected by mangroves suffered less in terms of economic and human losses than villages that were less protected by mangroves during Cyclone Aila. Moreover, unsustainable fishing practices lead to a “tragedy of the commons” situation, in which aquatic species continue to be overexploited and will become scarce for future generations. Currently, there are no incentives or alternatives to prevent the overuse and depletion of aquatic species. The formal ban on natural fry collection has been difficult to enforce. Given the enforcement challenges, compliance is unlikely because many shrimp fry collectors do not have practical alternative employment opportunities.

<sup>1</sup>This annex was prepared by Anupam Joshi and Anurag Danda, based on consultant reports prepared by the World Wildlife Fund and Pranabesh Sanyal.

<sup>2</sup>Estimated using average exchange rate in 2009 of US\$1 = INR 45.

<sup>3</sup>Because of lack of relevant data, this estimate of total damage only partly captures losses due to mangrove degradation and overfishing.

<sup>4</sup>Species of mangroves facing extinction include *Xylocarpus granatum* and *X. mekongensis*.

There is an urgent need for increasing efforts to conserve biodiversity, given its important cross-sectoral linkages. India's strategies for the conservation of ecosystems include provision of special status and protection to biodiversity-rich and environmentally fragile areas.<sup>5</sup> India's commitment to conserving biodiversity is apparent in its participation and involvement in major international measures and initiatives on environment issues, including the Convention on Biological Diversity.<sup>6</sup> The key objectives of the Convention are conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits arising out of the utilization of genetic resources. In accordance with the Convention, India has passed environmental measures such as the Biological Diversity Act (2002), which aims to regulate access to biological resources.<sup>7</sup> The National Environmental Policy (2006) provides the basis for increasing forest coverage from 23 percent to 33 percent of the Indian national territory by 2012.<sup>8</sup> While GoWB has invested in protecting fragile systems such as the Sundarbans, recent analyses conducted as part of this NLTA show that many serious deficiencies in biodiversity conservation in the Sundarbans region remain. Figure A12.1 presents a matrix showing the main threats to various components of the ecosystem.

This annex is divided as follows. Section 2 provides an overview of the biodiversity in the region, including spatial populations and trends. Section 3 describes the natural and anthropogenic factors that contribute to biodiversity loss in the region. Section 4 evaluates current management practices and, based on the analysis, presents recommendations that can be complemented by stricter regulation in order to better protect biodiversity. The findings suggest that there is an urgent need for dynamic policies that provide feasible, long-term protection to the ecosystem, based

on a combination of measures that include regulation, promotion of incentives for forest preservation, and collaboration and research sharing.

## 12.2. Current Status of and Trends in Biodiversity

### 12.2.1 Species Richness

The studies by Mukherjee (2004) and Ghosh et al. (2003) reveal that there are roughly 105 mangrove plant species in the Sundarbans Biosphere Reserve area out of the total of 111 mangrove plant species found in India. These species belong to the following categories: true mangroves (25 species); mangrove associates (30 species); back mangroves (37 species); beach flora (six species); and parasites and epiphytes (seven species). Of all the coastal mangroves in India, the Sundarbans harbors the highest number of species of minor mangroves and mangrove associates, and is marginally behind the Andaman and Nicobar Islands in the number of major mangroves species (Figure A12.2).

The Sundarbans ecosystem also contains numerous species of algae, lichens, fish, insects, amphibians, reptiles, birds, and mammals (see Table A12.3). In some groups, for example, mollusks, the Sundarbans has a very high number of species, genera, and families compared to similar ecosystems.

### 12.2.2 Species Distribution and Population Trends

There are declining trends in certain biodiversity groups. The tiger prawn population has been declining over time as a result of

**Figure A12.1: Sundarbans Species Threat Matrix**

Threats	Microbes	Algae	Phytoplanktons	Lichens	Mangrove	Non-mangrove	Mollusca	Protozoa	Polychaets	Crustacea	Xiphosarans	Insects	Mites	Spiders	Fish	Herpetofauna	Aves	Mammals
Pollution																		
Prawn seed collection																		
Resource extraction within protected area																		
Upstream fresh water diversion and extraction																		
Lack of baseline data for sustainable utilization																		
Relative sea level rise and net land loss																		
Ocean acidification due to increased CO <sub>2</sub>																		
High intensity events																		

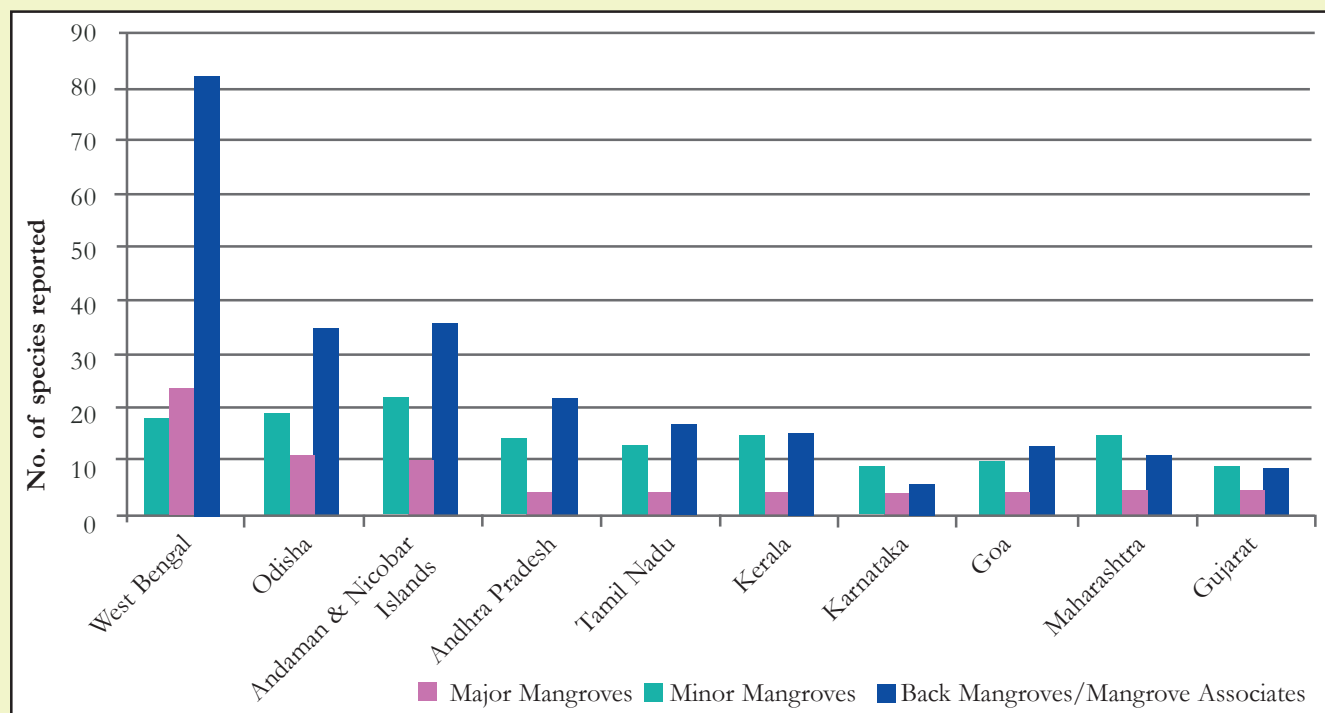
<sup>5</sup>Convention on Biological Diversity: India country profile. <http://www.cbd.int/countries/?country=in>.

<sup>6</sup>India played an important role in developing the agreed text for the Convention on Biological Diversity and became a Party to it in February 1994.

<sup>7</sup>In accordance with the provision of Article 15 of the Convention on Biological Diversity.

<sup>8</sup>Convention on Biological Diversity: India country profile. <http://www.cbd.int/countries/?country=in>.

**Figure A12.2: Diversity of Mangroves in Indian Sundarbans and Other Locations**



overfishing in open-access rivers. The per capita minimum catch decreased from 70 in 1991 to 27 in 1995 (Santhakumar, Haque, and Bhattacharya 2005). Mechanized modern trawlers and other harmful fishing methods are adversely affecting the stocks of fish species in the Sundarbans. Despite the reduced catch, the number of individuals engaged in fishing continues to increase because of a lack of alternative livelihood opportunities.

The faunal composition is undergoing changes, with more species being included in the Red List of Threatened Species of the IUCN as a result of habitat degradation and ecological changes.<sup>9</sup> Over the last several decades, a number of animals have become extinct<sup>10</sup> and many others are threatened.<sup>11</sup> The Sundarbans also harbors a number of globally threatened animals, including tiger, estuarine crocodile, fishing cat, salvator lizard, Gangetic dolphin, river terrapin, king crab, and marine turtles (such as the olive ridley turtle, green turtle, and hawksbill turtle). The existence of such a wide array of globally threatened animals significantly increases the value of the Sundarbans in the context of the global commons. The presence of the emblematic Bengal tiger also increases the ecosystem value of the Sundarbans; however, tigers are facing a range wide threat to their survival. The last census

in 2001 placed the number of tigers in the Indian Sundarbans at 274. The latest estimates released by the National Tiger Conservation Authority of India in 2011 put the number of tigers in the Indian Sundarbans at 70, a figure that is contested by GoWB.

## 12.3. Natural and Anthropogenic Factors Contributing to Biodiversity Loss

### 12.3.1 Mangrove Loss

More than 40 percent of the original Indian Sundarbans have been wiped out by human intervention since 1770. Until 1770, the total area of the Sundarbans in India and Bangladesh combined was 36,000 km<sup>2</sup>. In 2000, it was 25,000 km<sup>2</sup>, a decline of roughly 30 percent.<sup>12</sup> The Indian portion of the Sundarbans covered 9,630 km<sup>2</sup> in 1770, and an area of around 5,366 km<sup>2</sup> has been cleared of forests and used for human settlements. According to a later study covering 2000–08, the forest area in the Indian Sundarbans was reduced from 2,168 km<sup>2</sup> to 2,132 km<sup>2</sup> during that period (a decrease

<sup>9</sup>IUCN Red List of Threatened Species, at <http://www.iucnredlist.org>.

<sup>10</sup>Javan rhino, wild buffalo, swamp deer, barking deer.

<sup>11</sup>Fifteen species of mammals, eight of birds and 17 of reptiles are listed in Schedules I and II of the Wildlife (Protection) Act, 1972; in addition, 14 species are included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

<sup>12</sup>Hazra, S., K. Samanta, R. Dasgupta, and G. Sen (2004). A Preparatory Assessment of Vulnerability of the Ecologically Sensitive Sundarban Island System, West Bengal, in the Perspective of Climate Change. *Proceedings of the workshop on vulnerability assessment and adaptation due to climate change on Indian water resources, coastal zones and human health*. MoEF, GoI, New Delhi.

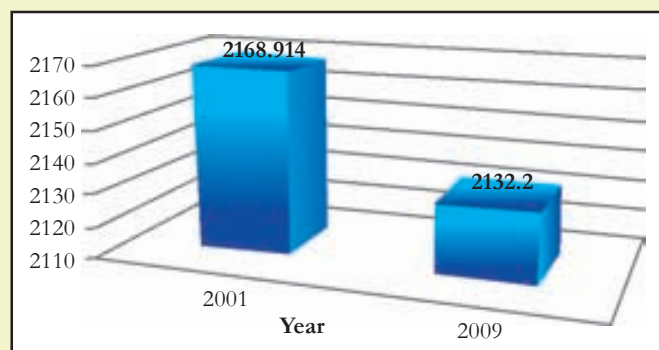
of 1.66 percent) (Figure A12.3). The study revealed that there was a marked increase in the area of saline banks, which had increased from 38.93 km<sup>2</sup> to 74.79 km<sup>2</sup> (World Wildlife Fund 2011).

Natural events in the form of storms and sea level rise have increased salinity levels, affecting mangrove growth and leading to the loss of sundari (*Heritiera fomes*) and nipa palm, which are species with low salinity tolerance. The Sundarbans is currently characterized by reduced stands of the mangrove species of *Excoecaria agallocha*, *Aegiceras corniculatum*, and *Ceriops decandra*. In comparison, the Bangladesh portion of the Sundarbans still contains extensive stands of *Heritiera fomes* (Sahgal et al. 2007). At least 25 mangrove species in the Indian Sundarbans are vulnerable to extinction, currently endangered, or critically endangered, according to the IUCN 2010 Red List of Threatened Species. The mangrove species of *Xylocarpus granatum* and *X. mekongensis* face significant threat due to poaching and illegal felling, as both of are considered a valuable source of timber. The species *Ceriops decandra*, *Avicennia* spp., and *Excoecaria agallocha*, which are mainly collected for fuelwood, also face extinction from illegal felling (Sahgal et al. 2007).

From 1880 to 1980, the following changes of land use and population had an impact on the natural habitats of the Sundarbans, within both India and Bangladesh (Bhattacharyya 1990):

- Settled and built-up areas increased by 292 percent and arable land by 37 percent;
- Wetlands decreased by 53 percent and forest and woodland by 43 percent; and
- Total population of the affected districts<sup>13</sup> increased by 353 percent from just over 5.5 million to more than 25 million.

**Figure A12.3: Total Forest Cover Changes in the Indian Sundarbans**



<sup>13</sup>The affected districts comprise South 24 Parganas and North 24 Parganas in West Bengal, India; and Khulna and Bakarganj in Bangladesh (Bhattacharyya 1990, p. 34).

<sup>14</sup>The total estimated number of people in the Sundarbans who are classified as fishers is 666,812: 15 percent of the 4.4 million people that inhabit the area. Disaggregating this figure, 519,069 people are engaged in inland fisheries and 147,743 in marine fisheries. The numbers of inland fishers active in both North and South 24 Parganas is approximately the same. However, the vast majority of marine fishers are found in South 24 Parganas – 127,217 people in total (data from Department of Fisheries and Aquaculture).

### 12.3.2 Decline in Fish and Shrimp Species

Reductions in freshwater flows to the delta due to upstream diversions of the Ganga and its tributaries, and indiscriminate fishing practices are reducing fish populations. Catch data from estuarine fisheries reveal an increase in the yield, but a decrease in the catch per unit effort (CPUE) (Santhakumar, Haque, and Bhattacharya 2005). The freshwater flow of the Ganga has decreased, and this has led to increasing salinity of the estuarine water and soil, threatening freshwater species (World Wildlife Fund 2011). Population pressures on aquatic resources are a major cause of concern, especially as 14.5 percent of the 4.4 million people that inhabit the Sundarbans engage in fishing, with the majority active in inland fishery zones (World Wildlife Fund 2011).

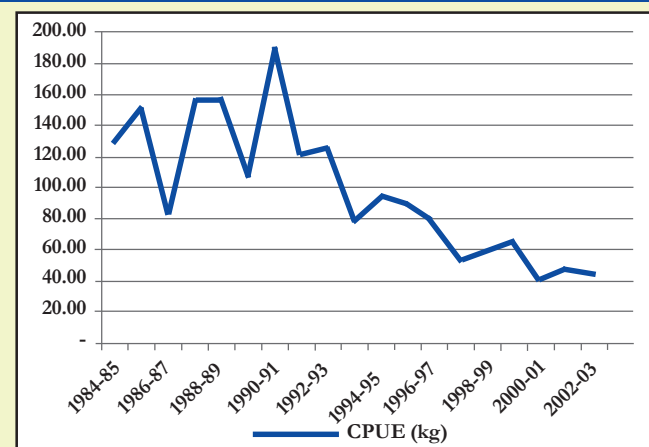
Indiscriminate seed collection results in the loss of a variety of other aquatic species. Thousands of untrained workers<sup>14</sup> who collect shrimp fry from the sea, channels, and rivers cause significant losses to the fry of other species. Often, collectors discard nonshrimp fry back into the water, which is a major cause of the gradual decline in the populations of different fish species as fish species are being discarded dead rather than alive (Baer 2001). In addition, the use of fishing craft and gear such as big bull trawlers, mechanized boats, and trawl and bag nets made of PVC are degrading the natural environment, especially at places such as Canning, Diamond Harbor, Kakdwip, Namkhana, and Raidighi, where activity is concentrated (Das 2009).

Prawn seed collection is a highly destructive practice with a high by-catch rate that results in the capture and discard of nontarget species and exerts a heavy toll on the sustainability of marine, estuarine, and freshwater fish species. The Department of Fisheries and Aquaculture (2007) reports an alarming decline in various fish species; catch data from estuarine fisheries reveal an increase in yield but a decrease in CPUE (Figure A12.4). For every tiger prawn seed collection, the average number of other destroyed species is as follows: 318 (other prawns), 8 (fish), 60 (crabs), 1 (mollusc), 13 (unidentified), that is, total 400 of others. Among fish species, the most threatened fish in the Sundarbans is the boal, followed by pangus, nadosh, and bhargon (Santhakumar et al. 2005).

Aquaculture has a significant potential for development but its intensification is problematic, using current practices. The uncontrolled development and expansion of shrimp farms is counterproductive as it undermines ecosystem integrity (by promoting erosion and biodiversity loss). However, due to a lack of alternative livelihood opportunities in the region, many residents of the Sundarbans are dependent on income from gathering of



**Figure A12.4: CPUE of Winter Migratory Bag Net Fisheries 1984–2003**



natural *Penaeus monodon* postlarvae wild-caught broodstock and seed for aquaculture, despite the formal ban on natural fry collection. While some producers have access to hatchery larvae sourced from hatcheries outside the region, these larvae are often not certified and thus have low survivability, which leads to lower overall productivity.

### 12.3.3 Increases in Salinity

Salinity is emerging as a significant underlying ecological factor with high potential to impact biodiversity. It could alter vegetation

distribution patterns and underlying patterns and processes of ecological communities. Salinity levels may rise across the aquatic systems within the Sundarbans as a result of limited anthropogenic release of freshwater into the system coupled with increased salinity ingress associated with sea level rise. The transboundary character of this issue, both national and international, increases the complexity associated with salinity dynamics within the Sundarbans. There are distinct trends of increasing salinity emerging in parts of the Sundarbans estuary. A comparison of past data (1984) with more recent data (2001) reveals a marked increase in the salinity of the outer estuary (26 parts per thousand (ppt) to 36.2 ppt) and mid-estuary (20 ppt to 26 ppt) for the summer data of the eastern sector. Salinity trends, as observed, for both surface waters and groundwater with respect to estuary location are given in Table A12.1.

An analysis of salinity trends indicates that communities living in the following regions will suffer from increasing salinity:

- Western sector outer estuary and inner estuary (Sagar and Mathurapur blocks);
- Central sector mid-estuary (Kultali block); and
- Eastern sector mid and inner estuary (Gosaba and part of Basanti blocks, Sandeshkhali block).

Salinity changes could impact biodiversity in several ways. Ecosystem composition is likely to change due to increasing levels of salinity, which could cause physiological stress for many species. Increasing salinity alters species composition of plant and animal

**Table A12.1: Salinity Trends in the Sundarbans**

Estuary Position		Seasonal Trend (Increasing/Decreasing)		Pearson Correlation	
Sector	Out/Mid/In	Premonsoon (N=)	Monsoon (N=)	r value	P =
<b>Pattern of changes in surface water salinity 1980–2010</b>					
Western	Outer	Insignificant (16)	Insignificant (16)	0.1/0.28	–
	Middle	Insignificant (5)	Insignificant (7)	0.07/0.45	–
	Inner	Increasing (7)	Insignificant (9)	0.97/0.06	0.001
Central	Outer	Increasing (7)	Increasing (6)	0.69/0.83	0.08/0.04
	Middle	Decreasing (3)	Insignificant (5)	–1.804878	0.47
	Inner	Increasing (7)	Insignificant (4)	0.87/0.64	0.02/0.34
Eastern	Outer	Insignificant (6)	Increasing (7)	0.64/0.70	0.04
	Middle	Insignificant (11)	Increasing (5)	0.43/0.93	/0.01
	Inner	Increasing (26)	Insignificant (16)	0.58/0.23	0.002
<b>Pattern of changes in groundwater salinity 1980–2010</b>					
Western	Outer	Increasing (7)	Increasing (11)	0.83/0.75	0.022/0.009
	Middle	Insignificant (7)	Insignificant (9)	0.5/0.13	0.253
	Inner	Insignificant (4)	Increasing (4)	0.76/0.95	0.237/0.046
Central	Outer	Data lacking	Data lacking		
	Middle	Increasing (5)	Insignificant (5)	0.993	0.001
	Inner	Increasing (4)	Increasing (4)	0.75/0.79	0.024/ 0.021
Eastern	Outer	Data lacking	Data lacking		
	Middle	Insignificant (3)	Increasing (4)	0.91/0.996	0.004
	Inner	Increasing (8)	Increasing (9)	0.86/0.75	0.008

communities, and can trigger gradual extinction of species intolerant to high salinity levels, including some mangrove species. The composition of the mangrove ecosystem is quite sensitive to salinity levels. Studies on the impact of salinity on mangroves in Bangladesh have found that inadequate fresh water is responsible for the spread of top-dying disease affecting the sundari (*Heritiera fomes*) (Iftekhar and Islam 2004). During the course of the salinity study conducted as part of this NLTA, two compositional changes in biodiversity in the Indian Sundarbans were observed: (a) the mangrove trees of the species *Rhizophora apiculata* are being replaced by more salt-tolerant *R. mucronata*, as observed at the outer estuary of the central region of Kalas Island; and (b) the dolphins sighted during the field study conducted as part of this NLTA were all blunt-snouted salt-tolerating Irrawaddy dolphin, replacing the long-snouted Gangetic dolphin. Rises in salinity are also causing migration of tigers to the transition zone, which increases the risk of human–tiger conflict. During the period 1986 to 1994, tigers strayed into villages, on average, an estimated 10 times per year; however, during the five years previous to this study, the straying rate had increased to 36 times a year (Deuti and Choudhuri 1999).

### 12.3.4 Tiger Habitat Fragmentation and Increase in Animal–Human Conflict

The human–wildlife conflict in the Sundarbans is increasing. Conflicts between wildlife and humans arise due to human dependence on forest resources, poaching, unregulated mass tourism, and extensive loss of natural habitats due to natural events. The spread of unregulated mass tourism is degrading the natural resources of the Sundarbans. The poaching of tiger parts continues to threaten the emblematic species of the Royal Bengal tiger, and the straying of tigers into villages increases both human

and tiger deaths. Incidents of straying have increased sharply over the last two decades, mainly due to increased human incursion into the tiger's range, destruction of its habitats, and decline in prey population as a result of cyclones and storms. Residents who enter the forests risk being attacked and mauled by tigers. Between 1985 and 2009, 789 persons were attacked by tigers, of which 666 succumbed to their injuries.<sup>15</sup> Some 59 percent of the tiger attack victims were residents of Gosaba block. Tigers are also increasingly straying into villages. Such incidents tend to increase in the aftermath of natural disasters, when both the tiger's habitat and its usual prey population suffer decline.

### 12.3.5 Increases in Pollution

Discharges of untreated industrial effluents and domestic wastewater are impacting aquatic habitats and biodiversity. Studies on the pollution status of the different biota in the Sundarbans delta have revealed the presence of high concentrations of heavy metals such as zinc and copper (Table A12.2), as well as organic pollutants in sediments (Sarkar and Bhattacharya 2003). While mangroves are hardy plants, heavy metals, organochlorines, and other toxic metals are threatening their health and, indeed, that of the entire ecosystem. Shrimp farms are an increasing source of toxins; wastes contaminated with antibiotics and chemicals, used to contain viral epidemics in shrimps, negatively affect aquatic life forms (Sahgal et al. 2007).

### 12.3.6 Climate Change Impacts

Climate change forecasts suggest that future hazards associated with cyclonic storms and sea level rise will become even more severe. With a rate of 5.5 km<sup>2</sup> per year, coastal erosion is reshaping the islands of the Sundarbans, with particular impact on sandy beaches

**Table A12.2: Toxic Metals Affecting Various Species in the Sundarbans (mg/liter)**

Species	Type	Pb	Cu	Cr	Cd	Fe	Zn
<i>Macomabirmanica</i>	Mussel	8.9	40.5	3.6	1.6	909	259
<i>Meretrixmeretrix</i>	Mussel	8.3	61.1	13.4	2	2840	92.8
<i>Saccostreacuncullata</i>	Rock oyster	2.8	1986	3.1	13	435	3317
<i>Cerithideacingulata</i>	Gastropod	1.1	331	4	0.7	754	176
<i>Thais lacera</i>	Gastropod	0.8	25.5	4.8	16	249	106
<i>Telescopiumtelescopium</i>	Gastropod	0.7	405	1.9	0.7	524	131
<i>Neritaarticulata</i>	Gastropod	4.1	2036	2.6	37	58	925
<i>Harpodonneberens</i>	Bombay duck	1	38.6	1.1	0.2	164	75.7
<i>Trichuris</i> spp.	Ribbon fish	0.7	31.4	2.4	1	96	131
<i>Boleophthalmuss</i> spp.	Gobid fish	0.6	3	2.8	0.03	50	42.9
<i>Daysciaenaalbida</i>	Bhola,bhetki	1	23.6	10.3	0.7	459	95.1

Key: Pb lead, Cu copper, Cr chromium, Cd cadmium, Fe iron, Zn zinc.

Source: Data obtained from WWF monitoring activities.

<sup>15</sup>The tiger victim data for the period quoted reveal that Jhila (21.1 percent), Pirkhali (19.72 percent), Chandkhali (11.72 percent), and Arbesi (9.35 percent) were the four most vulnerable forest blocks, accounting for more than 60 percent of human injuries and deaths caused by tiger attacks.

and mud flats. Even islands with dense mangrove on the east (Dalhousie, Bulcherry, Bhanga, Mayadwip) have been significantly eroded. Over time, mangrove populations are expected to be progressively reduced with each successive generation. Changes in sea surface temperature will directly impact phytoplankton populations, whose decline will, in turn, negatively affect fish production and diversity. Increased frequency and intensity of cyclonic storms could threaten large mammals through destruction of their habitats.

## 12.4. Management Strategies and Recommendations

### Supporting and Synergizing Current GoWB Efforts in Conservation of the Sundarbans

GoWB has been providing substantial allocations for the protection of the Sundarbans Biosphere Reserve. It has undertaken successful ventures in the Sundarbans that have aimed at biodiversity conservation while simultaneously providing local communities with alternative livelihoods in areas further away from the core zone in order to prevent further biodiversity degradation. For example, in 2009-2010, the Ministry of Environment and Forests (MoEF) provided a total of INR 11 million under the

Biosphere Protection and Management scheme, which was used primarily to relocate people from the core zone of the Biosphere Reserve and to develop alternative means of livelihoods.<sup>16</sup>

There are numerous important Action Plans implemented with grants from the state and union governments that are aimed at biodiversity conservation in Sundarbans Biosphere Reserve. They are: (i) the Annual Management Action Plan; (ii) Conservation and Management of Mangroves; (iii) Conservation and Management of Sundarban Wetland; and (iv) surveillance and patrolling activities for the protected areas. Descriptions of the key schemes as well as relevant funding are detailed in Table A12.3.

Given the various policies and agencies working to promote biodiversity conservation in the region, institutional synergy is needed which requires greater collaboration between agencies, including coordination amongst agencies to prevent them from working at cross-purposes and to promote efficient usage of funds channeled towards biodiversity conservation from the central to the local levels.<sup>17</sup>

The conservation status of the Sundarbans has evolved over the years. The objective of management has shifted considerably from production forestry (timber harvesting) to biodiversity protection. Of the total Indian Sundarbans forest area of 4,263 km<sup>2</sup>, an area

<sup>16</sup>MoEF. January 10, 2010. "Ministry of Forest and Environment Visit Sundarbans. Press release, available at: [http://moef.nic.in/downloads/public-information/Sunderbans\\_press\\_release.pdf](http://moef.nic.in/downloads/public-information/Sunderbans_press_release.pdf)

<sup>17</sup>According to MoEF (2013), as far as legal protection of the Sundarbans area is concerned, GoI notified the Wetland (Conservation Management) Rules-2010 vide notification no. GSR-951 (E), dated December 4, 2010. Sundarban has not yet been notified under the said rules, but options exist to notify Sundarban under this specific rule. As per the Wetlands Rules, some activities are prohibited in the notified wetlands and some are allowed with the approval of the Central Wetland Regulatory Authority (CWRA) which need to be taken into account while synergizing activities in the area; details of prohibited activities and those with approval of CWRA are:

#### Prohibited Activities:

- Reclamation of wetlands;
- Setting up of new industries and expansion of existing industries;
- Manufacture or handling or storage or disposal of hazardous substances;
- Solid waste dumping; existing practices to be phased out within a period not exceeding six months;
- Discharge of untreated wastes and effluents from industries, cities or towns and other human settlements: prevailing practices to be phased out within a period not exceeding one year;
- Any construction of a permanent nature, except for boat jetties, within 50 m from the mean high flood level observed in the past 10 years, calculated from the date of commencement of these rules; and
- Any other activity likely to have an adverse impact on the wetland to be specified in writing by the Authority.

#### Activities with Approval of CWRA:

- Withdrawal, impoundment, diversion or interruption of water sources;
- Harvesting of living and nonliving resources;
- Grazing to the level not to have an adverse effect;
- Treated effluent discharges from industries, cities or towns, human settlements and agricultural fields falling within the limits laid down by the Central Pollution Control Board/State Pollution Control Boards;
- Plying of motorized boat not detrimental to the nature and character of the biotic community;
- Dredging only in areas impacted by siltation;
- Construction of boat jetties;
- Activities that may directly affect the ecological character of the wetland;
- Aquaculture, agriculture, horticulture activities within the wetland;
- Repair of existing buildings or infrastructure; and
- Any other activity to be identified by the Authority.
- Notwithstanding anything in sub-rule (1) or sub-rule (2), the Central Government may permit any of the prohibited activities or nonwetland use in the protected wetland on the recommendation of the Authority.
- No wetland to be converted to nonwetland use without the approval of the central authority.

**Table A12.3: Funding Details of Key Schemes Implemented in the Sundarbans**

Name of Scheme	Source	Estimated Annual Budget (in million)
Conservation and Management of Sundarbans Mangroves	GoI	15.0
Conservation and Management of Sundarbans Biosphere Reserve	GoI	11.0
Conservation and Management of Sundarbans Wetland	GoI	26.0
Project Tiger	GoI	44.5
State Plan (Annual Plan)	GoWB	42.0
Intensification of Forest Management	GoWB	0.4
13th Finance Commission	GoWB	78
Rashtriya Krishi Bikash Yojana	GoWB	16.8
Rural Infrastructure Development Fund	GoI	28.0
MGNREGA	GoI	22.5
	<b>Total</b>	<b>214.0</b>

Source: India's Periodic Review, 2011, Report of Sunderban Biosphere Reserve.

### Box A12.1: Government Schemes Implemented for Biodiversity Protection in the Sundarbans

**Conservation and Management of Sundarban Biosphere Reserve:** The scheme primarily focuses on the afforestation of the Sundarbans with nonmangrove species. It also implements education programs to raise awareness of conservation efforts in the region. Eco-development, and training and capacity building activities have also been conducted under this program.

**Conservation and Management of Sundarban Mangroves:** Given the important productive and protective functions of mangroves, GoWB has made significant strides in promoting mangrove development. MoEF has been releasing funds for intensive mangrove conservation and management in the Sundarbans. Decline in mangrove cover had been stopped by 1990s, and between 1997 and 2007, the mangrove coverage in West Bengal, almost entirely in the Sundarbans, increased from 2,123 km<sup>2</sup> to 2,152 km<sup>2</sup>, an increase of 29 km<sup>2</sup>, according to the India State of Forest Report prepared by the Forest Survey of India.

**Conservation and Management of Sundarban Wetland:** The Sundarbans wetland is one of the identified wetlands under the National Wetland Conservation Program. The Sundarbans wetland serves as a breeding ground and nursery for a large number of aquatic species. However, the wetland is threatened due to overexploitation, uncontrolled fishing, pollution, and unregulated tourism. To date, an amount of INR 87.7 million has been allocated to the GoWB for conservation and management of the Sundarbans wetland. This amount includes a sum of INR 9.25 million released during 2012-13. The funds have been provided for activities such as wetland mapping, habitat improvement, restocking of aquatic fauna,

development of alternative livelihoods, public awareness, and monitoring and research.

**Project Tiger:** This initiative helped increase the tiger population in the “tiger reserve” areas from 268 tigers in nine reserves in 1972 to 1,576 tigers in 27 reserves in 2003. The project has also been successful in eliminating exploitation of natural resources by humans in the specially constituted tiger reserves areas. Currently, wireless communication systems and patrol camps have been developed in the tiger reserves and, as a result, poaching has been reduced significantly. Voluntary village relocation, especially from the core areas, has also been carried out in many reserves. To reduce population pressures on forests, villages were provided with alternative agricultural lands and other benefits to relocate away from the tiger reserves.

**Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA):** This major government program, launched in 2005, aims at enhancing the livelihood security of people in rural areas by guaranteeing 100 days of wage employment in a financial year to each rural household whose adult members demand work. The employment work under this program gives priority to the following activities: water harvesting, groundwater recharge, and drought proofing. In the pre-Aila period, most activities under this scheme were directed toward irrigation activities and water conservation for improving agricultural production. However, Cyclone Aila damaged nearly 1,000 km of embankments, and salinity intrusion inflicted substantial economic losses. As a result, program activities were then directed at embankment rehabilitation (Sharkhel 2013).



of 2,585 km<sup>2</sup> has been designated as the Sundarbans Tiger Reserve.<sup>18</sup> While administration of the Tiger Reserve falls under the wildlife wing of the Forest Department, constituted after the enactment of the Indian Wildlife (Protection) Act of 1972, the remaining part of the Reserve Forest constitutes a territorial division governed by the Indian Forest Act, 1927. Within the Sundarbans Tiger Reserve, 1,330 km<sup>2</sup> is designated as the Sundarbans National Park, one of the legally protected areas that is included in the core zone of the Sundarbans.<sup>19</sup>

The Sundarbans are a result of a complex set of interactions between geomorphological, biological, biophysical, and socioeconomic factors, and thus any attempt to manage its resources needs to be sensitive to the ecosystem's inherent complexity. In view of Articles 6 (General Measures for Conservation and Sustainable Use), 8 (In-situ Conservation), 10 (Sustainable Use of Components of Biological Diversity), and 11 (Incentive Measures) of the Convention on Biological Diversity, recommendations for biodiversity conservation herein: (a) take into consideration the varied geography of the Sundarbans; (b) acknowledge that any ecosystem has a carrying capacity within which it could sustainably provide ecological goods and services; (c) seek to exploit opportunities that help build ecosystem resilience; and (d) recognize that interventions and investments will differ in the short, medium, and long terms with respect to the biological, physical, and climate change impacts and adaptation components.

As the region becomes increasingly inhospitable to human life, shifts in populations away from the transition zone are expected in the intermediate future. The recommendations that emerge from the findings of the studies conducted under this NLTA advocate a strategy of conservation of the core areas and progressive transformation of the transition zones to protected and reserve areas to further reduce population pressures on the fragile ecosystem. For those residents who decide to stay in the transition zone, the focus should be on stimulating economic growth by introducing livelihood opportunities that promote the conservation of the forest. However, improvements in human capital in the short term, combined with opportunities created to generate revenue streams from the forest over a longer period, may attract migrants from other areas to the Sundarbans, thereby undermining conservation efforts.

#### 12.4.1 Short-term Measures

##### **Declare the Sundarbans Reserve Forest as a combination of areas legally protected for conservation**

As a short-term measure, the present Sundarbans Reserve Forest

should be given a higher level of protection by declaring it a combination of areas legally protected for conservation (that is, wildlife sanctuaries and national parks). In that context, all economic activity in the existing Reserve Forest should be gradually reduced. This should be complemented by a long-term, gradual transformation in which increasing portions of the transition zone are designated as protected and reserve forest areas.

##### **Improve forest regulation**

Activities such as illegal poaching of tigers, clearing of mangroves, and settlement in protected areas are still prevalent, and must be tackled through traditional enforcement approaches. The interventions for traditional enforcement approaches further support GoWB's efforts to strengthen legal protection of the Sundarbans. For instance, forest regulations herein are expected to foster tiger conservation in the core area and will complement the ongoing Centrally Sponsored Scheme of Project Tiger (CSS-PT) (GoWB, 2012; MoEF 2013). For the core area, the main goal should center on eliminating the illegal harvesting that is currently taking place in the forest. To reduce population pressures on the forest, the Forest Department is implementing a permit allocation system to control entry into the forest. Forest entry permits could be reissued annually or biannually. To ensure transparency, details of the permit system should be publicly disclosed. A near-term focus should be on harvesting nontimber forest products, such as honey, fruits, or fishery products. As a short-term measure, the present Sundarbans Reserve Forest should be given a higher level of protection by declaring it a combination of areas legally protected for conservation, as outlined in the previous subsection.

##### **Develop mechanism for bilateral cooperation between Bangladesh and India**

Given that the Sundarbans region cuts across both India and Bangladesh, a mechanism of bilateral cooperation concerning Sundarbans biodiversity research needs to be established. It is recommended that MoEF and GoWB take the initiative by designing and implementing such a mechanism, and working to obtain bilateral agreement on a system for cooperation that would encourage enhanced information sharing between the two countries on a host of environmentally related and biodiversity issues, such as management of forested areas, ecotourism, and women's empowerment. It can also facilitate trust building, and sharing of lessons and experiences that can benefit the Sundarbans ecosystem as a whole.

The government has made significant strides in giving the Sundarbans legal protection. As for legal protection for the Sundarbans forest, the entire Sundarbans has been declared a

<sup>18</sup>Established in 1973 as part of Project Tiger to maintain, conserve, and restore the tiger population and its habitats, the Tiger Reserve has a total area of 2,585 km<sup>2</sup>, with 1,600 km<sup>2</sup> consisting of land and 985 km<sup>2</sup> of water bodies. Both the Sundarbans National Park and the Sajnekhali Wildlife Sanctuary are located within the Tiger Reserve.

<sup>19</sup>In the context of this report, the "core zone" refers to all the legally protected areas of the Sundarbans (the National Park, Wildlife Sanctuaries, and the Reserve Forest) which are contiguous and do not have any human habitation. Roughly 40 percent of the Reserve Forest area has been brought under protected area status.

'Reserve Forest' long ago under the provisions of Indian Forest Act, 1927. An area of 1,700 km<sup>2</sup> has been declared as 'Critical Wildlife Habitat'. An area of 2,585 km<sup>2</sup> has been declared a 'Tiger Reserve' in the year 1973 (MoEF, 2013; GoWB, 2012). Important steps toward bilateral cooperation on biodiversity conservation have already been taken on several fronts. A bilateral cooperation effort has begun already with the formation of the Ecosystem Forum on the Sundarbans, which was initiated by the Governments of India and Bangladesh. The Forum intends to create a broad program for biodiversity conservation that is synchronized so that the two countries are not following individual plans acting at cross-purposes. This transboundary platform for conservation of the Sundarbans could result in:

- Joint research, coordinated planning, and enhanced protection of the Sundarbans, and development of joint patrolling and tiger estimation protocols;
- Assessment of the advantages of Bangladesh's sustainable ecosystem management strategy and an opportunity for India to adopt a similar strategy (Iftekhhar and Islam 2004);
- Exploration of opportunities to improve regulation and control of (legal and illegal) timber harvesting and other resource extraction in the forest;
- Bilateral efforts to deal with the prawn seedling by-catch problem by considering, simultaneously, increased use of certified seeds from hatcheries and feasibility of establishing hatcheries, and facilitating improved methods of prawn seedling collection during the interim period in which hatcheries are established; and
- Improvement of information-sharing mechanisms between forest offices in India and Bangladesh and regular exchange of technical knowledge for conservation and management of mangrove forests, including exchange visits and joint capacity-building programs.

A Memorandum of Understanding<sup>20</sup> between the two countries was signed on September 6, 2011, in which both countries recognize that the Sundarbans represents "a single ecosystem divided between the two countries." Specifically, both countries recognize the need to: (i) monitor and conserve the Sundarbans; (ii) adopt appropriate joint management and monitoring systems; (iii) explore the possibility of implementing conservation and protection efforts; (iv) develop a long-term strategy for ecotourism opportunities; (v) better understand the relationship between human settlements and the ecosystem; (vi) identify opportunities for livelihood generation that do not adversely affect the ecosystem; (vii) identify and catalog the diversity of flora and fauna; (viii) carry out research to develop a common understanding of the impacts of climate change and to

determine appropriate climate change adaptation strategies; and (vx) sharing of relevant information and technical knowledge.

### Develop environmentally sensitive ecotourism

The tourism strategy for the region should be reviewed and modified to eliminate current unsustainable practices, which are tied to mass tourism. The spread of poorly regulated mass tourism will degrade the natural resources of the Sundarbans Reserve Forest and the transition zone to a point at which the area would have little value for high-end, environmentally friendly ecotourism, and the local environment would suffer adversely. Tourism-related interventions should be based on internationally recognized guidelines for nature tourism, such as those advocated by the George Washington University and the Adventure Travel Trade Association.<sup>21</sup> The approach should be one that explicitly recognizes limits on the carrying capacity of the most fragile parts of the ecosystem. Areas outside the transition zone (such as Sagar Island) could potentially be considered as touristic areas that offer experiences appealing to relatively large numbers of middle-income domestic tourists.

### 12.4.2 Medium-term Measures

#### Introduce economic incentives based on carbon financing

The use of economic incentives funded by revenues from climate change mitigation programs can play an important role in enhancing the effectiveness of regulatory enforcement in the near term. Although still at a pilot stage, emerging climate change mitigation programs (for example, carbon financing) provide a basis for generating revenues that can be shared at the community level or throughout West Bengal. Sustainable forestry practices provide a basis for accessing these funds because of their ability to conserve biodiversity and prevent deforestation, thereby retaining forests for sequestering atmospheric carbon. By preserving the forest, it will be possible to take advantage of funding opportunities that have been (and will be) created in the context of carbon reduction efforts under the Kyoto Protocol's Clean Development Mechanism; voluntary carbon markets; and the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD). Under UN-REDD, a native forest will be eligible for carbon credits once it can be demonstrated that the forest would have been degraded or deforested in the absence of targeted interventions. Funds generated in the Sundarbans via REDD-plus and various other carbon financing schemes can be used to support a number of initiatives aimed at enhancing biodiversity by reducing the pressure that residents near the Sundarbans Reserve Forest are placing on forest resources.

A number of additional revenue streams, such as the Climate Investment Funds, can also be explored as sources of funding.

<sup>20</sup>The Memorandum of Understanding between India and Bangladesh on Conservation of Sundarbans, September 6, 2011, can be accessed at <http://www.hcidhaka.org/pdf/5.MOU%20between%20India%20and%20Bangladesh%20on%20Conservation%20of%20the%20Sundarban.pdf>

<sup>21</sup>See <http://www.gwtourism.org/iits/ATDI.htm> for more information.

The Climate Investment Funds have a Pilot Program for Climate Resilience,<sup>22</sup> which is a potential funding source for biodiversity conservation and climate change adaptation measures. A number of climate resilience pilots are being supported by these funds, including a pilot program in Bangladesh of which a large part involves the Bangladesh side of the Sundarbans. Assuming that the Climate Investment Funds are replenished, they could serve as new and additional sources of funding for biodiversity conservation and climate change adaptation within the Indian portion of the Sundarbans. Moreover, GoI may have opportunities to access a number of other sources of global climate finance for the Sundarbans, such as the Green Fund being developed under the auspices of the UNFCCC, and the Special Climate Change Fund (which could be a source of co-financing and leverage). Other climate-related funding sources include programs developed by bilateral and multilateral aid institutions.

Climate-related revenues are not the only potential new funding sources. The Sundarbans region could possibly benefit from creating PES programs, which are becoming increasingly popular as a means of ecosystem conservation. Countries such as Brazil, Costa Rica, Mexico, Lesotho, and Nigeria have established mechanisms through which landowners and municipalities can receive financial compensation by adopting sound management practices that deliver ecosystem services. The specific services that have been recognized by PES programs include maintaining water quality for consumption; climate change mitigation; catchment area services (for example, reducing sedimentation, and preventing floods and landslides); and forest conservation. As an example, a PES mechanism could be established so that the central government, and Kolkata and other urban areas, pay for the conservation of wetland forests in the Sundarbans, which have notable effects in reducing vulnerability to extreme weather events.

### **Establish property rights on forest resources**

An innovative approach for generating revenue that should be further explored involves creating property rights on forest resources in ways that yield funds for programs benefitting individuals in the transition zone, thereby giving them incentives to conserve forest resources and to help ensure that residents and illegal entrants do not engage in poaching or facilitate such activities. The potential revenue streams are linked to sustainable uses (for example, honey collection and fruit harvesting) as well as those associated with nonextractive uses (for example, tiger viewing and carbon sequestration, both of which generate revenues that can be shared with local communities). In broad terms, the central idea is to create new revenue streams from previously nonmonetized products or services tied to the forest, and to allow local communities and individuals to benefit from these new revenues. For example, revenues could fund conditional cash transfer

programs that allowed communities on the edge of the forest to send their members to vocational training programs in the stable zone (or in Kolkata). This use of innovative property rights would create incentives for residents of communities near the forest to become custodians and co-managers of the forest, thereby decreasing direct pressures on the forest and reducing the need to spend scarce public resources on enforcement.

### **Establish state-of-the-art hatcheries**

The establishment of hatcheries in the prawn aquaculture sector can help avoid environmental degradation, particularly the by-catch problem. In terms of biodiversity and long-term sustainability, the negative effects of prawn seed collection represent a very serious threat. The establishment of hatcheries has proven effective in other Indian states, as well as in Bangladesh and other Asian nations. Hatcheries are able to produce a steady supply of postlarvae, which is crucial in times when there are shortages in their supply. Admittedly, there are special challenges due to salinity conditions and market-related problems associated with establishing hatcheries in West Bengal. Establishing such hatcheries will depend on investments by the private sector. Increased efforts should be made to deal with the prawn seedling by-catch problem by considering, simultaneously, greater use of hatcheries together with improved methods of prawn seedling collection during the interim period in which hatcheries are established.

### **Introduce community-based mangrove restoration programs**

Mangrove restoration is an integral part of the adaptation strategy for the Sundarbans. In retreating embankments to protect coastal communities from erosion and climatic events, the areas between old (abandoned) and new (retreated) embankments will become unprotected. Mangroves should be allowed to naturally regenerate in these areas to create a bioshield to attenuate wave energy. Mangrove forests are effective bioshields in the event of a cyclone, and they can serve to protect populations that have withdrawn further inland. Mangrove restoration offers livelihood opportunities and also allows for local communities to become involved in conservation, sustainable management, and ecosystem restoration operations. Local communities receive financial assistance as direct payments from both the central and state governments in return for engaging in activities that include raising nurseries, planting of mangroves, maintaining old plantations, among others.<sup>23</sup> As carbon financing opportunities develop, existing and new mangrove forests could provide an important revenue stream to fund investments or programs for residents of the Sundarbans, including programs to equip residents with the necessary means to access employment opportunities in the stable zone and outside the region. As new mangroves are regenerated, it is recommended that these be designated as

<sup>22</sup>The Pilot Program for Climate Resilience aims to identify ways to mainstream climate resilience considerations into national development planning. For more information, see <http://www.climateinvestmentfunds.org/cif/ppcr>.

<sup>23</sup>India's Periodic Review 2011, Report of Sunderban Biosphere Reserve.



community reserves<sup>24</sup> or conservation reserves<sup>25</sup> in order to shift the focus from exploitation of forest resources to management based on sustainability considerations. Private sector involvement may be helpful in the coastal zone for better promoting employment opportunities linked to conservation and management of coastal resources.

### Develop a research center on biodiversity

Conservation efforts in the Sundarbans should be driven by research and development, and it is recommended that a research center be established with the formal task of conducting research to inform policy makers as to the state of affairs in the Sundarbans. This research center should be administratively separate from DSA, and the sole mandate of the center should be to conduct research that fits into and informs the planning process for the Sundarbans. The studies conducted under this NLTA can serve as background papers or baselines for this institute, particularly for biodiversity, as a comprehensive report was prepared by collecting information on the current status of all species present in the Sundarbans. The center can initiate a detailed inventory and baseline population assessments of key species representing the 18 groups that were covered under the report (Table A12.3). Biannual population assessments and development of monitoring protocols of key stone species can be undertaken. Such a research institute could collaborate with Bangladesh on similar research efforts to ensure an overall and comprehensive view of the Sundarbans.

## 12.4.3 Long-term Measures

### Increase the extent of protected forest area in the transition zone

Designating the existing Sundarbans Reserve Forest for conservation protection is a measure that should be complemented by a long-term, gradual transformation in which increasing portions of the transition zone are designated as protected and reserve forest areas. As mentioned, short-term improvements in livelihood options and disaster management in

the transition zone, combined with opportunities created to generate revenue streams from the forest over a longer period, may encourage potential migrants to enter the transition zone. This would increase pressures on the forest, thereby undermining conservation efforts, and subjecting more people to loss of life and assets due to cyclonic storms and floods. The long-term transformation, encouraging the integration of residents into the relatively safer urban areas, will further reduce population pressures on the fragile ecosystem and lead to a smaller number of people under threat of suffering the ravages of cyclonic storms and floods.

### Create a marine reserve

In the long run, the bilateral cooperation between India and Bangladesh should be expanded to include the co-management of a marine reserve area to protect the coastal and inland areas of the Sundarbans in both countries. It is recommended that, on the West Bengal side, the reserve should include the following: the Sundarbans National Park in the southern part of the Sundarbans, and the delta area and parts of the Bay of Bengal. As with other marine reserves in India, this would be managed by MoEF. As the process unfolds, a bilateral agreement should be sought with Bangladesh, leading eventually to a marine reserve involving both countries. The marine reserve will allow for the preservation of diverse aquatic species, including whales and dolphins.

## 12.5. Conclusion

Broadly speaking, the most successful approach would entail the use of a number of different policies and instruments aimed at promoting biodiversity conservation. Positive incentive measures should not be viewed as alternatives to conservation laws or other traditional regulatory techniques in place, but rather as a means to support and complement them (OECD 1996). Education campaigns, further, have complementary roles to play alongside regulatory and incentive-based measures. Evidence greatly suggests

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<sup>24</sup>Under the amended Wildlife (Protection) Act, 2002, “the State Government may, where the community or an individual has volunteered to conserve wildlife and its habitat, declare any private or community land not comprised within a National Park, sanctuary or a conservation reserve, as a community reserve, for protecting fauna, flora and traditional or cultural conservation values and practices.” Once such a reserve is declared, its land use cannot not be changed, except in accordance with a resolution passed by the management committee and its approval by the state government. A community reserve management committee is constituted by the state government, which shall be the authority responsible for conserving, maintaining, and managing the community reserve. This committee has five representatives nominated by the village Panchayat (institution of local self-governance), or where such a Panchayat does not exist by the members of the Gram Sabha (village assembly) and one representative of the state forests or wildlife department under whose jurisdiction the community reserve is located. This committee is the competent authority to prepare and implement the management plan for the community reserve and to take steps to ensure the protection of wildlife and its habitat in the reserve. Source: Wildlife (Protection) Act, 1972, as amended in 2002.

<sup>25</sup>“The State Government may, after having consultations with the local communities, declare any area owned by the Government, particularly the areas adjacent to National Parks and sanctuaries and those areas which link one protected area with another, as a conservation reserve for protecting landscapes, seascapes, flora and fauna and their habitat. Provided that where the conservation reserve includes any land owned by the Central Government, its prior concurrence shall be obtained before making such declaration.” A conservation reserve management committee is constituted by the state government to advise the chief wildlife warden to conserve, manage, and maintain the conservation reserve. This committee consists of a representative of the forest or wildlife department, who shall be the member secretary of the committee, one representative of each village Panchayat in whose jurisdiction the reserve is located, three representatives of NGOs working in the field of wildlife conservation, and one representative each from the department of agriculture and animal husbandry. Source: Wildlife (Protection) Act, 1972, as amended in 2002.



that people are willing to take proper action when they are more aware of what is under threat, and the importance of the protection of a good or service, such as mangrove systems. Programs of risk communication and interventions to enhance the mobility of Sundarbans residents through improvements in educational attainment and health outcomes further serve to reduce population pressures in the transition and core zones, which, in turn, will help contribute to biodiversity protection in the region.

In the long term, the sought-after result would be to have no people living in the high-risk portions of the transition zone (the belt on the periphery of the forest that includes areas impacted by Cyclone Aila),<sup>26</sup> a significantly reduced population at risk in the transition zone as a whole, and overall greater integration of all Sundarbans residents (from both stable and transition zones alike) into urban areas.

**Table A12.4: Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No.	Biodiversity Group	No. of Species	Importance	Threats	Impacts on Sundarbans Ecosystem	Limitations and Gap Areas	Management and Technical Interventions
1.	Microbes	Bacteria: 34 genera Fungi: 5 genera	Nutrient transformation and role in energy flow; biogeochemical cycles  Consume gases that effect global climate  Destroy pollutants and treat waste  Potential sources for medicine, agriculture, and industry	Changes in habitat and land use	Plant productivity  Impact on decomposition process	Potential discovery of unknown microbes and the methods needed for culture  In situ conservation techniques	Carry out research, particularly on the integration of phenotypic, genetic, and ecological information  Promote bioprospecting efforts with share to local biodiversity management committee  Encourage involvement of biotechnology industries  Examine pathogenic microbes
2.	Algae	270	Contribute as primary producer group and serve as food for fish  Fuel detrital food chain  Succession of algae (blue-green algae, green algae, diatoms) increases sediment accretion to support the growth of herbs, grass, and tall mangrove trees: a new typical mangrove succession	Increase sea surface temperature and pollution  Change in water quality of rivers, estuaries, and other aquatic bodies	Impact on nursery grounds of aquatic population in the wild  Impact on natural fish food	Diversity studies to determine the present status of algal resources  Detailed taxonomic study needs to be done	Critically evaluate species inhabiting Sundarbans  Carry out extensive monitoring on spatial and temporal scale  Address industrial pollution and knowledge gaps

<sup>26</sup>In the Sundarbans, reference is sometimes made to a “high-risk zone,” which is an area that overlaps with both the core area and the transition zone. The high-risk zone includes all legally protected areas, the Reserve Forest, and the fringe area (the belt on the periphery of the forest and the area impacted by Cyclone Aila). Legally, there should be no residents in the core area. Thus, the concern is with removing people from the parts of the transition zone impacted by Cyclone Aila.

**Table A12.4 (continued): Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No. Biodiversity Group	No. of Species	Importance	Threats	Impacts on Sundarbans Ecosystem	Limitations and Gap Areas	Management and Technical Interventions
		Effectively alter the physicochemical status of the soil; act as pollution remediators, biofertilizers, and bio-indicators of soil reclamation		As primary colonizers, alteration of physicochemical properties of soil		
3. Phytoplankton	Diatoms: 76 Copepods: 52	Support primary productivity Remineralization of organic matter Help in transfer of energy flow	Rise in atmospheric CO <sub>2</sub> concentration: alters physico-chemical conditions Acid base imbalance, reduced oxygen transport capacity	Impact on rich fishery resources; lead to large-scale ecological disasters Impact on assemblage pattern of phytoplankton due to change in temperature and salinity	Little information on sensitivity of cyanobacteria to more realistic CO <sub>2</sub> scenario Few studies on potential effect of CO <sub>2</sub> release on planktonic life	Monitor impact of climate change, in particular effects of changing carbonate chemistry and ocean acidification on phytoplankton Establish digital image repository Address knowledge gaps
4. Lichens	167	Pioneers in habitat colonization Fix nitrogen and fertilize forest soil Sequester carbon; 30 percent of body weight Accumulate toxic chemicals or radioactive nucleotides; act as bio-indicator Medicinal usage, from secondary metabolites Primary producer Home for invertebrates and provide benefits to insects – camouflage and mimicry	Decline in vegetation cover Developmental activities Fuelwood collection Impact of climate change	Impact on ecosystem energetics	Lack of information on ecological role, such as community dynamics and succession patterns and trends due to mentioned threats	Set up lichen reserves Encourage multiculture forestry practices, including lichen-rich mangrove phorophytes Address knowledge gaps
5. Mangroves	105	Promote wide array of ecosystem services, including: Act as buffer against natural calamities	Devoid of any high-elevation zone (landward side) for the species to	Land mass vulnerable to tropical cyclones Absence of substrate for	Inaccessibility of terrain and exorbitant costs involved in detailed manual surveys	Make space for natural regeneration to cope with sea level rise Put in place remote sensing and geographic

**Table A12.4 (continued): Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No. Biodiversity Group	No. of Species	Importance	Threats	Impacts on Sundarbans Ecosystem	Limitations and Gap Areas	Management and Technical Interventions
		<p>Mangrove swamps support wide variety of aquatic, benthic, and terrestrial organisms</p> <p>Mangrove detritus acts as substrate for microbial activity and nutrient generation, thus a nutrient and carbon sink</p> <p>Provide nonwood and nontimber forest products to forest-dependent community</p> <p>Medicinal importance</p> <p>Promote ecotourism</p>	<p>reestablish due to sea level rise</p> <p>Habitat degradation due to industrial pollution</p> <p>Timber poaching and fuelwood collection</p>	<p>microbial activity, thus impact on nutrient dynamics of estuarine ecosystem</p> <p>Possible change in mangrove community due to destruction of lichen species characteristic to the habitat</p>	<p>Long duration in carrying out manual surveys in hostile terrain</p> <p>Lack of infrastructure and manpower in Forest Department</p>	<p>information system technology coupled with ground truth verification to prepare detailed stock maps</p> <p>Undertake massive mangrove plantation in degraded areas with local community participation</p> <p>Address industrial source pollution</p> <p>Stabilize shore along sea-facing forested islands</p>
6. Non-mangroves	145	<p>Coastal stability through increasing planktonic productivity</p> <p>Initiation of island formation and development of niche</p> <p>Formation of dunes</p> <p>Excessive salt removal from soil</p>	<p>Anthropogenic disturbances along beaches</p>	<p>Successional stages of plant communities would be impacted</p> <p>Habitats for a number of faunal resources would be impacted</p>	<p>Reason behind the depletion of 12 orchid species is not known</p>	<p>Consider for conservation non-mangroves that are distributed toward the inland areas and human-inhabited regions</p> <p>Undertake intensive studies on the causes of depletion of orchids and their restoration measures</p>
7. Mollusca	177	<p>Role in formation of organic detritus in estuaries</p> <p>Source of birdfood</p> <p>Aesthetic, commercial, gastronomic, biomedical importance</p>	<p>Habitat and shoreline change</p> <p>Indiscriminate exploitation and collection of undersized specimens</p> <p>Commercialization of marine shells</p> <p>Industrial pollution</p>	<p>Impact on energy flow in food chain</p>	<p>Impact of habitat disturbance on population of mollusca</p>	<p>Regulate catches</p> <p>Demarcate noncollection zones</p> <p>Improve collection methods</p> <p>Control on exports</p> <p>Commence mariculture practice</p>

**Table A12.4 (continued): Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No.	Biodiversity Group	No. of Species	Importance	Threats	Impacts on Sundarbans Ecosystem	Limitations and Gap Areas	Management and Technical Interventions
8.	Protozoa	67	Initiate decomposition process Ecologically important in carbon cycling Role in food chain; preyed upon by zooplankton, fish, and invertebrates Act as bio-indicators	Change in seasurface temperature Industrial pollution	Impact on energy flow in food chain	No studies to ascertain status or predict change in community with reference to climate change and pollution	Address gap areas
9.	Polychaetes	57	Diet of fish (demersal) and invertebrates Act as an indicator of status of benthic community	Anthropogenic and climate change impact in shore habitat	Impact on energy flow in food chain Impact on detritus food chain	No cosmopolitan positive or negative indicator species to identify a community as healthy	Carry out periodic environmental monitoring to assess population status, density, and diversity
10.	Crustacea	329	Recycling of minerals and organic matter Maintain balance of productivity of oceans Degradation of plant matter to detritus particles Aquaculture and fisheries are very much dependent upon them	Destruction of habitat Change in salinity and erosion Pollution from inland waters (oil pollution) Shrinking of tiger prawn population	Impact on detritus food chain Impact on livelihood	No baseline data for sustainable utilization	Assess present stock and study impact of salinity on population Decide permissible limit for annual catch
11.	Xiphosurans	2	Play a vital role in the ecology of estuarine and coastal communities Carapaces frequently serve as substrate for encrusting invertebrates and algae Biomedical research and traditional usage	Change in shoreline and formation of undulating terrain Red crabs destroy their nests and breeding grounds	No information on Sundarbans impacts	No success in captive rearing (for medical research, etc.)	Monitor population in identified breeding ground



**Table A12.4 (continued): Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No.	Biodiversity Group	No. of Species	Importance	Threats		Limitations and Gap Areas	Management and Technical Interventions
12.	Insects	497	<p>Ecology of forest ecosystems</p> <p>Role in nutrient cycles, nutrient availability in soils, and biogeochemical cycles</p> <p>Role in carbon cycle during decomposition process</p> <p>Pollination</p>	<p>Climatic variability (trends in precipitation, soil temperature, moisture, and organic carbon, thus affecting trophic cascade of detrital web)</p> <p>Impact of pesticides on nontarget species</p>	<p>Significant impact on tree growth, form, survivorship curve, reproductive output, and forest ecology</p> <p>Impact on pollinator-dependent host plants</p>	<p>No comprehensive work on insect ecology and inputs to dynamics of ecosystem</p> <p>No comprehensive list of pollinators of mangrove forest in Sundarbans</p>	<p>Identify potential indicator taxa and carry out monitoring</p> <p>Conduct research on pollinators, based on flowering time</p>
13.	Mites	121	<p>Decomposer and helps in nutrient cycling</p>	<p>Impact on population of mites due to changing trends in precipitation, soil temperature, moisture, and organic carbon, thus affecting trophic cascade of detrital web</p>	<p>Impact on detritus food chain</p>	<p>No systematic study of ecology and impact on trophic cascade</p>	<p>Identify potential mite species and address gap areas</p>
14.	Spiders	114	<p>Regulate insect populations</p> <p>Ecological indicators of overall biodiversity in many terrestrial communities</p>	<p>Change in composition and properties of mangrove flora</p> <p>Extremely sensitive to small changes in habitat structure, including habitat complexity, litter depth, and microclimate characteristics</p>	<p>Impact on pest population and detrital food chain</p>	<p>No systematic time series data</p>	<p>Monitor population diversity patterns in mangrove ecosystem, given the impacts of climate change</p>
15.	Fish	364	<p>Major source of livelihood for local community</p>	<p>Pollution from inland waters (oil pollution)</p> <p>Usage of destructive fishing gear, such as mosquito nets</p> <p>Indiscriminate seed collection</p>	<p>Socioeconomic, and reduced protein source</p>	<p>No baseline data for present stock</p>	<p>Follow up on research needs, including:</p> <p>Assess present stock</p> <p>Set permissible limit for annual catch</p> <p>Identify appropriate fishing techniques</p> <p>Assess possible impact on fishery resources of closed and open season</p>

**Table A12.4 (continued): Status, Threats, and Recommended Interventions for Sustainable Management of Biodiversity in Sundarbans**

No. Biodiversity Group	No. of Species	Importance	Threats	Impacts on Sundarbans Ecosystem	Limitations and Gap Areas	Management and Technical Interventions
16. Herpetofauna	Amphibia: 11 Reptiles: 71	Indicators of microhabitats in ecosystems Determine relative health of ecosystem Role in energy flow	Increase in salinity Industrial pollution	Impact on energy flow in food chain	Determining status of species population and spatial pattern of diversity	Model ecological niche to predict probability distribution Raise awareness of people to differentiate between venomous and nonvenomous snakes
17. Aves	234	Nutrient transport to or from ecosystem Pollination	Habitat disturbance, land use change Sea level rise Unplanned tree plantation at mud flats Climatic variability	Impact on ecosystem energetics Impact on mangrove species that are dependent on bird pollinators	Complexities of interactions of species, given climate change threats	Model populations Monitor bird populations at certain locations
18. Mammals	47	Serve as primary, secondary, and tertiary consumers Crucial member of local food web Recycle nutrients, agents of pollination and germination, seed dispersal, modification of vegetation structure and nutrition pathways Disperse seeds and mycorrhizae	Urbanization Change in crop pattern Breaches in embankments along riverbanks due to flood	Impact on large predators and prey base	Species composition in the forested tracts and relative abundance Ecological distribution and study of population dynamics	Monitor population trends and introduction, invasion, or migration of mainland species Assess and follow up on conservation program of selected species, including dolphins, lesser cats, ungulates, wild boar Undertake habitat study Reintroduce lost species, for example, barking deer

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# Annex 13.

## Institutional Approaches for Addressing Priority Challenges in the Sundarbans<sup>1</sup>



### Abstract

The current institutional context of the Sundarbans region is characterized by the existence of: (a) interrelated instruments regulating the types of activities that can take place in different portions of the ecosystem; and (b) multiple national and state-level agencies and local governments, most of which operate based on a traditional sectoral approach that does not explicitly recognize the unique and changing conditions of the Sundarbans.

This annex identifies institutional capacity-building options to address the priority challenges of the Sundarbans. Key interventions recommended to align the institutional framework with the approach proposed under the NLTA include strengthening the capacity of existing organizations to develop tailored responses to the challenges presented by the Sundarbans and coordinate with other sectoral agencies; strengthening the role of DSA in monitoring and evaluation of government programs in the region; consolidating and upgrading the protected status of the core area of the Sundarbans; strengthening the engagement of the newly created West Bengal Coastal Zone Management Authority; establishing a new spatially oriented government organization with a formal mandate to set priorities, facilitate interagency cooperation, and coordinate implementation efforts; and creating a mechanism for bilateral cooperation between India and Bangladesh concerning the Sundarbans.

### 13.1. Introduction

The institutional framework of the Sundarbans was designed and implemented by the British during the late 19th and early 20th centuries. That institutional framework, still in place in the Sundarbans, addresses problems found before India's

independence. Currently, many government agencies from three levels of government – central, state, and local – operate within the Sundarbans region. Each governmental entity operating in the region has its own set of incentives, goals, and resources. While having a broad range of governmental organizations in the region could potentially help to address a wide array of development challenges, experience to date indicates that current efforts are hampered by lack of coordination, absence of adequate data to guide policy efforts, and a dearth of monitoring and evaluation programs.

This annex analyzes the institutional framework of the Sundarbans region.<sup>2</sup> It focuses on four key areas that are crucial for the sustainability of the ecosystem and are fundamental for making the approach proposed by the World Bank's NLTA operational. They are the: (a) rules governing biodiversity protection, coastal zone management, and development of climate change responses; (b) capabilities and limitations of the organizations that are active in the region; (c) interagency coordination needed to adopt the spatially differentiated approach that is recommended by the NLTA to address the unique challenges of the Sundarbans; and (d) need for innovative institutional arrangements that facilitate the implementation of long-term plans under evolving and unprecedented circumstances. The body of this annex comprises four sections: the first provides a historical perspective on forest management in the region; the second describes the region's institutional context; the third includes recommendations to bolster the institutional framework of the Sundarbans; and the fourth presents some conclusions.

### 13.2. Background

For centuries, the Sundarbans region has been subject to human

<sup>1</sup>This annex was prepared by Santiago Enriquez and Jack Ruitenbeek, based on stand-alone consultant reports prepared by Santiago Enriquez, Gautam Gupta, and Snehashish Raichowdhury.

<sup>2</sup>According to North (1990), "Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction." Institutions can be formal (such as laws) and informal (including conventions and codes of behavior). North further states that "the formal and informal rules and the type and effectiveness of enforcement shape the whole character of the game." Organizations, which are different from institutions, can be thought of as the players of the game.

interventions, many of which have affected its natural resource base. Though the institutional framework of the Sundarbans has continuously evolved, many of the rules in place were shaped decades or even centuries ago, when the region's conditions differed significantly from those of the present day.

The push by the region's early Muslim rulers, and later by the British East India Company, to extract land rents from those who cleared forests and began farming the cleared land is of central importance in understanding the human transformation of the Sundarbans ecosystem. The following summary (based on Sen 2007) provides an overview of the events that eventually led to restrictions on the transformation and use of the forest:

- The Sundarbans ecosystem, in its natural state, included vast expanses of grassland, saline marshes, and tropical wetlands containing one of the world's largest stretches of high-biodiversity forest. These forests were rich in wildlife, including elephant, tiger, gaur, leopard, wild buffalo, three species of rhinoceros, seven species of deer, and a wide variety of other fauna;
- The first inhabitants may have appeared in the 5th century B.C. Human settlement continued until the 11th century, when the area was abandoned for a brief period, apparently due to shifts in river channels and widespread epidemics;
- Forest lands were converted to rice fields during the Bengal sultanate period (1204–1575). The forest conversion process continued during the Mughal era (1575–1765) and, by the end of that period, settlement had spread through much of the forest zone up to the boundaries of Kolkata;
- Despite that settlement process, by 1757, the year in which the British East India Company established headquarters in Kolkata (then Calcutta), the Sundarbans forest still stretched largely uninterrupted for 19,200 km<sup>2</sup> and retained much of its diversity. However, for about 100 years after the start of British rule in India in 1765, the British moved forward vigorously with forest clearing to create agricultural lands. A particularly significant decline in the diversity of large mammals began soon after 1830, when the British East India Company, having assumed proprietary rights to the forest (in 1828), began leasing tracts of the forest for reclamation. This process continued for about 50 years, throughout which the indigenous inhabitants were permitted to access forested portions of the Sundarbans; and
- A change occurred in 1878, when the still existing forest was declared as either “reserved” or “protected.” This policy shift occurred after British assessments indicated that the products from the increasingly scarce forestlands had become more valuable than agricultural produce. The Indian Forest Service, which had been established in 1865, was made responsible for facilitating appropriation of forests by the state in order to generate revenues from forest resources. Thus began the legal restrictions on the transformation and use of forest resources in parts of the region.

The rules of forest management and extraction of forest products have changed significantly over time, ranging from an initial

emphasis on facilitating exploitation of the forest as an economic resource to the relatively recent focus on forest conservation. For many years, *bhawalis* (woodcutters) of the Sundarbans maintained a prescriptive right to fell forest timber without providing revenues to the government. After commercial forestry emerged in the 1830s, free access for woodcutting was limited to the subsistence needs of the local people. After that, the role of the *zamindars* (landowners) in controlling access by their peasants to the forest changed from deciding the principles of determining access to the forest to imposing taxes on the resource extractors; the latter increasingly came with commercial interests from areas further from the forest (Mitra 2000). Access to forest products changed later, after the state created the Sundarbans Reserve Forest and established restrictions on the use of forest and, more generally, managed the forest as a commonpool resource. Notwithstanding an unsuccessful government effort (in 1868) to privatize the right to dole out fisheries in tidal waters to private persons, the right to fish in the watercourses of the Sundarbans has remained in the realm of common pool, and no revenue is collected on behalf of the government from fishers.

The focus of forest policy and legal instruments has recently placed greater emphasis on protecting the ecosystem and recognizing the rights of local communities. This is illustrated by the contrast between the 1952 Forest Policy, which encouraged monoculture plantations and emphasized forest exploitation by industries, and the 1988 Forest Policy, which discouraged monocultures and stressed protection of the environmental stability of forests. Also, since the 1990s, GoI has promoted joint forest management with local communities, and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act (2006) included provisions to award ownership rights over forestland and other resources in India to traditional forest dwellers. Some of these developments have generated broad controversies, partly because of differences in perspective between conservationists and those advocating the rights of forest dwellers (Krishnan 2007; Sanhati 2011).

### 13.3. Current Institutional Framework of the Sundarbans

#### 13.3.1 Biodiversity Conservation

The current institutional context of the Sundarbans regions is characterized by the existence of: (a) interrelated instruments regulating the types of activities that can take place in different portions of the ecosystem; and (b) multiple national and state-level agencies and local governments. This section begins by describing, briefly, the key policy and legal instruments for biodiversity protection, coastal zone management, and climate change, that have been adopted in West Bengal and other parts of India. The section then describes activities carried out by GoI in relation to these three issues – biodiversity protection, coastal zone management, and climate change – and discusses the role of state-level agencies in the Sundarbans region in the context of these issues.

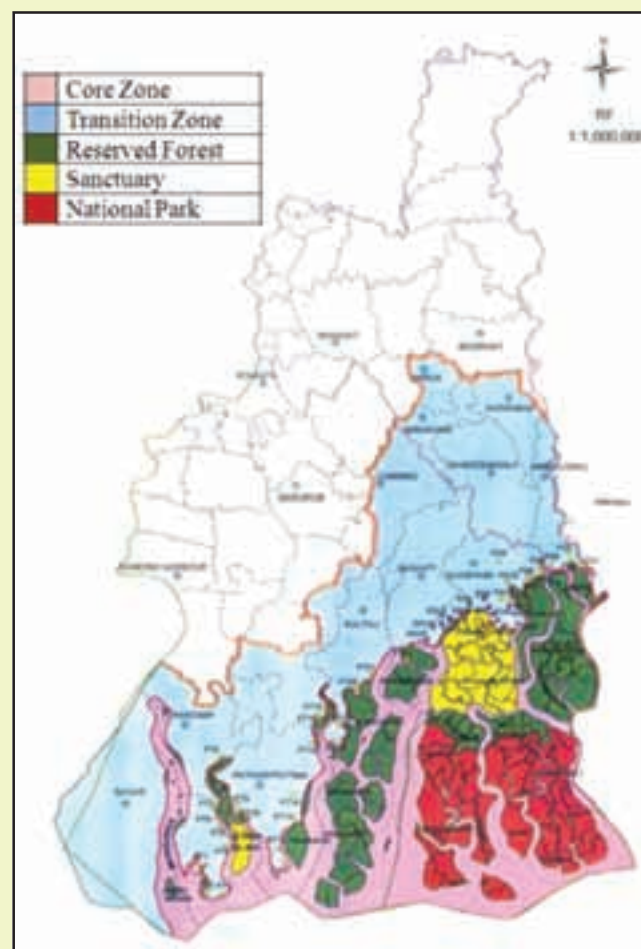
Over the last four decades, several types of reserve areas have been declared within the Sundarbans, with the main objective of protecting forest resources and the region's rich biodiversity. These consist of the Sundarbans Biosphere Reserve; reserve forests; the Sundarbans National Park; wildlife sanctuaries; and the Sundarbans Tiger Reserve. The rules governing a large section of these areas are mostly directed toward protection and conservation of natural resources and landscapes. A description of the main reserve categories of the Sundarbans, which often cover overlapping geographic areas (Figure A13.1) follows:

- **Sundarbans Biosphere Reserve.** Established in 1970 by MoEF, GoI, the Sundarbans Biosphere Reserve comprises the entire 9,630 km<sup>2</sup> of the Sundarbans. The geographic area considered as the “core zone” of the Sundarbans region by the World Bank's NLTA consists of the 40 percent of the Sundarbans Biosphere Reserve in which only biodiversity conservation and low-impact activities can take place. The remaining 60 percent consists of what the NLTA refers to as the “transition zone,” which is where income-generating activities take place and urban settlements are found;
- **Reserve forests.** These are forested lands where logging, hunting, grazing, and other activities may be permitted on a sustainable basis to members of certain communities. Explicit permission from the forest authority is required to engage in these activities. The extent of mangrove reserve forests in the Sundarbans is approximately 4,260 km<sup>2</sup>, of which 55 percent is land and the remaining 45 percent is under water or in the intertidal zone. About 40 percent of the Reserve Forest has been declared a “protected area” under one of the following two designations: national park and wildlife sanctuary;
- **Sundarbans National Park.** Covering an area of 1,330 km<sup>2</sup>, the park is located within the core area of the Sundarbans Biosphere Reserve. In general terms, Indian national parks consist of large natural or near-natural areas set aside to protect large-scale ecological processes, and the species and ecosystems characteristic of the area. Indian national parks also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational, and visitor opportunities. Within India, national parks have the most stringent levels of protection;
- **Wildlife sanctuaries.** Three wildlife sanctuaries are located within the core area of the Sundarbans Biosphere Reserve, covering a total area of 406 km<sup>2</sup>: Sajnekhali Wildlife Sanctuary (362 km<sup>2</sup>); Lothian Island Wildlife Sanctuary (38 km<sup>2</sup>); and Haliday Island Wildlife Sanctuary (6 km<sup>2</sup>). Wildlife sanctuaries typically consist of an area of ecological, faunal, floral, geomorphological, natural, or zoological significance that is adequate for the purposes of protecting, propagating, or developing wildlife or wildlife habitat. Protection measures are stringent in wildlife sanctuaries and activities within its boundaries are usually restricted to: (a) study of wildlife and purposes ancillary or incidental thereto; (b) photography; (c) scientific research; and (d) low-impact tourism; and
- **Sundarbans Tiger Reserve.** Established in 1973 as part of

Project Tiger, the Sundarbans Tiger Reserve is intended to maintain, conserve, and restore the tiger population and its habitats. The reserve has a total area of 2,585 km<sup>2</sup> with 1,600 km<sup>2</sup> consisting of land and 985 km<sup>2</sup> of water bodies. Both the Sundarbans National Park and the Sajnekhali Wildlife Sanctuary are located within the Tiger Reserve.

GoWB's Forest Department and GoI's MoEF play crucial roles in the management of the protected areas. The Wildlife Division of the Forest Department is responsible for managing the Sundarbans National Park, Sajnekhali Wildlife Sanctuary, Lothian Island Wildlife Sanctuary, and Haliday Island Wildlife Sanctuary. The Forest Department is also responsible for the reserve forests in the two districts of North and South 24 Parganas; in that context, its duties include operating the lease and permit system through which authorizations for forest exploitation are awarded. MoEF oversees a number of what are referred to as centrally sponsored schemes, such as Project Tiger, and they provide the majority of the Forest Department's budget.

**Figure A13.1: Main Categories of Reserve Areas in the Sundarbans**



Source: Sundarbans Biosphere Reserve: [http://www.sundarbanbiosphere.org/html\\_files/sunderban\\_biosphere\\_reserve.htm](http://www.sundarbanbiosphere.org/html_files/sunderban_biosphere_reserve.htm).



### 13.3.2 Coastal Zone Management

India's coastal zone regulations impose additional controls on the types of activities that can be undertaken in the Sundarbans. The Coastal Zone Notification of 2011 classified coastal zones under five categories: Coastal Regulation Zone (CRZ)-I, ecologically sensitive areas; CRZ-II, built-up municipal areas; CRZ-III, rural areas; CRZ-IV, aquatic areas; and a separate category for areas requiring special consideration. According to the 2011 Notification, the entire Sundarbans region falls under category CRZ-I (ecologically sensitive areas),<sup>3</sup> which implies that the region must adopt very strict controls on construction and development activities. In addition, the Notification recognizes the Sundarbans, in common with "other identified ecologically sensitive areas," specifically as a "critical vulnerable coastal area." Such areas are required to have integrated coastal zone management plans to ensure conservation and management of mangroves, as well as to address the communities' socioeconomic needs. The legal status of the Sundarbans region under the 2011 Notification is significantly different from that conferred by the Coastal Zone Notification of 1991, under which 14 community development blocks and legally defined urban areas of the Sundarbans in South 24 Parganas district were classified as CRZ-III. Some state officials have argued that the inhabited portion of the Sundarbans should have been kept out of the CRZ-I classification because that designation constitutes an obstacle to socioeconomic development.

India's National Environmental Policy, 2006, recognizes that mangroves and coral reefs are important coastal environmental resources, as they provide multiple services, including habitat for marine species; protection from extreme weather events; and a resource base for sustainable tourism. The Policy underlines the need to mainstream the sustainable management of mangroves into the forestry sector regulatory regime, and to adopt a comprehensive approach to integrated coastal zone management, something that is yet to be done in the Sundarbans.

Integrated coastal zone management efforts have already been undertaken in the region and could inform further actions. The World Bank-funded Integrated Coastal Zone Management Project has a component on the coastal zone management aspects of the Sagar Island within the Sundarbans. The objective of the project is to help the coastal state governments and union territories to rehabilitate degraded mangrove areas and increase mangrove cover by replanting mangroves in open mud flats. Activities supported by the program include survey and demarcation, afforestation, restoration, alternative or supplementary livelihoods, protection

measures, and education and public awareness. As part of these efforts, the West Bengal Coastal Zone Management Authority, created in 2008, is piloting integrated coastal management approaches.

In West Bengal, the Coastal Zone Management Authority is "emergent" in the sense that its functions have only been vested recently and are now being strengthened through the Integrated Coastal Zone Management Project. Within the next five years, West Bengal and two other pilot states (Gujarat and Odisha) will have effective institutions in place under the support of this project; all coastal states in India are expected to form such entities over a similar time frame. The Coastal Zone Management Authority is well positioned to enforce and oversee the national regulations within the Sundarbans, which are established through MoEF and are to be enforced nationally and through the state coastal zone management authorities.

However, the existing institutions will most likely be insufficient to respond to the continuously changing circumstances and broad-ranging challenges in the Sundarbans. Countries across the globe are increasingly recognizing that deltas will face new, significant challenges in the future due to climate change and as a result of past interventions that have reduced the resilience of ecosystems and increased the number of people that will be exposed to risks.

An institutional innovation that is taking place and is a relevant example for the Sundarbans is the Netherlands Delta Committee, established in 2007, to move forward the process of managing the transition of a degrading estuary system dependent on rural agriculture into a sustainable area that supports socioeconomic development while also promoting the conservation of regionally important wetlands.

While numerous differences exist between the Netherlands and West Bengal, the Delta Committee also embraced the idea of building resilience and supporting the capacity to adapt in the face of a resource base that had been degraded as a result of earlier interventions. The Committee also considered the future threats of climate change in carrying out its work, and adopted, as a main goal, the development of "future-proof" interventions that addressed priorities while creating the maneuvering space to accommodate future responses based on how changes materialize, as well as on the economic and social preferences of future generations.<sup>4</sup> The Committee, therefore, organized its work under concrete measures out to 2050, a clear vision out to

<sup>3</sup> The "areas that are ecologically sensitive and the geomorphological features which play a role in maintaining the integrity of the coast," and are between the low tide line and the high tide line, are designated as CRZ-I. This zone includes areas containing mangroves, national parks, sanctuaries, reserve forests, wildlife habitats, and biosphere reserves, all of which exist in the forested part of the Sundarbans.

<sup>4</sup> In 2008, the Delta Committee completed its report, with proposals for long-term planning (Delta Committee 2008). The report called for an increasing reliance on natural systems (dunes, tidal dynamics, bioshields) to protect high-value areas while abandoning some productive but lower-value areas; it also identified an extensive set of enabling laws and regulations that would need to be implemented to realize this vision. A related report also promoted a "Faster and Better" principle as a means to address the problem that "the need in our consensus-based culture to unite the virtually irreconcilable in many cases [...] does not advance because of the administrative and political incapacity to take decisions or, once a decision has been taken, to actually implement it" (Elverding et al. 2008).



2100, and option on the very long term, beyond 2100. This is precisely the type of long-term planning that might be called for in the Sundarbans.

DSA was created exclusively to look after the socioeconomic and developmental needs of the region. SDB, now under DSA, has also been in place since 1973. DSA may have been originally conceived with these functions in mind, but the current challenges in the region far exceed the mandate and capacity of that agency. However, the state government can create a high-level Steering Committee at the state level to coordinate developmental activities and to enforce various regulations related to the region. The Sundarbans Steering Committee could be created as a spatially oriented government organization with a mandate to set regional priorities, facilitate interagency cooperation, and coordinate implementation efforts, the lack of which have been major obstacles to addressing development needs, as discussed further below. If created, the institution would be given responsibility for anticipatory planning and selection of effective and efficient interventions, along with a coordinating role that ensured various sectoral agencies were doing their part.

The working approach of the Delta Committee is “Faster and Better,” which was interpreted operationally as a way to speed up decisionmaking.<sup>5</sup> If adopted for the Sundarbans, this approach could overcome potential stagnation from existing processes and institutional norms. To provide a foundation for further consideration of the idea of creating the Sundarbans Steering Committee as a new entity, it is recommended, as a first step, that officials working in the Sundarbans study how estuary management is being pursued by related institutions in the Netherlands, and potentially in other jurisdictions.<sup>6</sup> The knowledge gained from international and national experiences could then drive the discussion of whether and how the Sundarbans Planning and Risk Management Authority could be created. Other aspects that should be taken into account include the need to provide such an organization with the incentives and resources to adhere to a long-term vision, without succumbing to short-term political or economic needs. A first step in the Netherlands was enacting a Delta Act that provided the organization with a formal mandate, defined responsibilities and accountability mechanisms, and created a fund to support long-term investments.

### 13.3.3 Climate Change

The Sundarbans is affected by sea level rise and the occurrence of storms, cyclones, and other weather hazards. Available evidence

indicates that these extreme weather events will increase in intensity and sea level will continue to rise over the coming decades as a result of climate change. Despite the evidence, the Sundarbans has not been identified as a national priority for climate change adaptation efforts. GoI, under the leadership of the Prime Minister’s Council on Climate Change, has drafted a National Action Plan on Climate Change (NAPCC).<sup>7</sup> The plan includes eight national-level missions to develop plans for climate change adaptation in several priority areas, such as the Himalayas and sustainable habitats. At present, the Sundarbans is not listed as a priority area within this plan.

However, the Sundarbans has been identified as a priority region under the West Bengal State Action Plan on Climate Change. As of October 2013, focus is on the current situation, concerns related to climate change, and strategies to address climate change concerns for the following sectors: water, agriculture, biodiversity and forests, human health, and energy efficiency, and renewable energy. However, the strategies for vulnerable regions, namely the Sundarbans and the hill region, were yet to be presented.

International negotiations on climate change open an opportunity to incentivize the protection and sustainable use of forests in the Sundarbans. A major focus of recent international negotiations on climate change has been the development of a mechanism to support climate change mitigation actions in the forest sector by reducing emissions from deforestation and degradation; conserving and augmenting forest carbon stocks; and enhancing sustainable forest management. These activities have been organized collectively under the program known as REDD-plus. The Conference of the Parties to UNFCCC, at its 16th session, listed the safeguards that should be promoted and supported when undertaking REDD-plus activities, including respect for the knowledge and rights of indigenous peoples and members of local communities; full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities; and ensuring that actions are consistent with the conservation of natural forests and biological diversity (UNFCCC 2011).

Carbon sequestered through REDD-plus projects could provide the basis for generating revenues for the Sundarbans. Wetlands and peatlands are estimated to store significantly more carbon per ha than other terrestrial ecosystems. In addition, global estimates indicate that avoided deforestation and avoided peatland destruction are among the most cost-effective climate change

<sup>5</sup>Deelstra et al. (2009) observe that rather than postponing decisions until negotiated alternatives have been elaborated and evaluated, the approach involves identifying and exploring strategic alternatives early on and then selecting one to be advanced on a fast track. See also Werners, van de Sandt, and Jaspers 2009.

<sup>6</sup>As part of the NLTA, a study tour was organized in 2010 for GoWB officials to visit the area affected by Hurricane Katrina in the United States; participants met in New Orleans with experts from the U.S. Army Corps of Engineers and other organizations engaged in post-Katrina follow-up work. Participants in the study tour learned about use of storm prediction systems and disaster management response methods, as well as measures to expand protection against hurricanes and associated floods. Participants found the tour informative. Some of the risk management systems that were discussed have been considered as potential candidates for future use in West Bengal.

<sup>7</sup>National Action Plan on Climate Change: <http://pmindia.nic.in/Pg01-52.pdf>.

mitigation options, with costs of US\$0.1–4 and US\$3–30 per abated ton of CO<sub>2</sub>, respectively. In comparison, equivalent reductions achieved through the increased use of biomass are estimated to cost US\$585–644, and those obtained through the use of nuclear and renewable energies have an estimated cost of US\$146 (Spracklen et al. 2008). Developed countries have already invested US\$4 billion in REDD-plus between 2010 and 2012.<sup>8</sup> GoI estimates that international funds could provide US\$3 billion for a national REDD-plus program over the next three decades (MoEF 2011). The Sundarbans region, being among the most important wetlands in India, is well positioned to benefit from REDD-plus.

To access REDD-plus funds, the Sundarbans must be identified as a priority in India's national strategy, and compliance with applicable safeguards ensured. The agreement achieved at the Conference of the Parties to the Climate Convention recommends that REDD-plus efforts begin with the development of a national REDD-plus strategy or plan, and that strategies be based on a national forest reference emission level and a robust and transparent national forest monitoring system, and a system for providing information on how safeguards are being respected (UNFCCC 2011). Thus, the Sundarbans as a region is unlikely to access REDD-plus markets unless it is part of GoI's national efforts. While voluntary carbon markets could also provide a stream of resources, they represent only around 1 percent of global regulated markets, with total transactions valued at US\$387.4 million in 2009 (Hamilton et al. 2010). Accessing the REDD-plus market will also require meeting safeguards for the protection of indigenous groups, local communities, and biodiversity. This is a significant issue as a strong debate ensued after the enactment of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, which gave rights to forest dwellers.<sup>9</sup> Institutional mechanisms for REDD-plus are still at a nascent stage, as GoI is in the process of creating a National Coordination Agency for REDD-plus. Specific arrangements will need to be developed at the national level to determine how REDD-plus benefits are distributed and safeguards respected. It is imperative to incorporate the Sundarbans into GoI's priorities for REDD-plus. At a more local level, careful planning and a long-term approach should be developed to ensure that efforts to obtain REDD-plus funding do not result in forced migration or loss of livelihood options for local communities, particularly minorities.

## Mainstreaming of Climate Change in Relevant Governmental Agencies

The impacts of climate change are highly local, and the effective means to adapt depend on local institutions in addressing climate change concerns. The typical rationale for local governments in helping regions adapt to climate change is as follows. Since environmental problems are typically felt locally, local governments are often in a better position to understand climate change concerns in their respective jurisdictions, and thus would achieve superior outcomes if given the freedom to choose the most appropriate policies and programs. However, adapting to climate change requires the participation of local populations, both in planning and implementation, as the majority of climatic events (sea level rise and storms) are mostly experienced by residents living in high exposure areas such as the Sundarbans.

Given that climate change is expected to cast a long shadow in the region, efforts to mainstream climate change considerations in all relevant institutions operating in the Sundarbans, as well as local governments, should be a priority over the medium term. Enhancing knowledge on climate change issues must be a continual process to eliminate the lack of relevant expertise in operating institutions, particularly at the local level. Currently, there are no formal mechanisms in place to identify priorities using analytical work and incorporate them in multi-year planning processes. Also missing are mechanisms to incorporate the concerns of groups (particularly women and children) most severely affected by climate change into local government and local institutions' planning processes.

The institutional capacity of the Nodal Agency for Climate Change located in MoEF should be strengthened to better address climate change impacts in the region.<sup>10</sup> The Climate Change Division of MoEF is India's nodal agency for climate change, dealing with climate change issues at both the domestic and global levels. It is also the nodal unit for coordinating the NAPCC.<sup>11</sup> The capacity of the agency should, therefore, be augmented by increasing the number of staff as well as their level of expertise on climate change. Furthermore, the West Bengal State Action Plan on Climate Change has a sectoral approach and its implementation could be hampered by the lack of cross-sectoral coordination discussed below. GoWB will prepare a specific strategy for the Sundarbans. This opens a window of opportunity to implement climate change responses through the coordinated

<sup>8</sup>See Climate Change Policy and Practice, "Oslo Meeting Reaches Agreement on Financing and Quick-Start Measures for REDD." <http://climate-lisid.org/news/oslo-meeting-reaches-agreement-on-financing-and-quick-start-measures-for-redd/>.

<sup>9</sup>NGOs and civil society have argued that the said act was in contravention of the Wildlife (Protection) Act of 1972, which requires critical tiger habitats to be kept "inviolable," including through removal of people from areas notified as tiger habitats. Identification of people living in forests, including those who depend on forest produce or are members of Scheduled Tribes, is supposed to be done through the Gram Sabha of the respective area, before an area is notified as a tiger habitat. However, there are allegations that authorities have used this tool to deny the rights of individuals and communities to access forests and their produce.

<sup>10</sup>Climate Change Division, MoEF, comments on draft NLTA Report, May 23, 2013.

<sup>11</sup><http://envfor.nic.in/public-information/climate-change>

efforts recommended by this report. Funding will also be needed to augment the agency's capacity to conduct analytic work related to climate change and to identify possible measures for climate change mitigation and adaptation in the Sundarbans. The Nodal Agency should undertake work on climate change in consultation with the Department of Environment, with both units collaborating with one another to develop the State Action Plan on Climate Change.<sup>12</sup>

### 13.3.4 Bilateral Cooperation with Bangladesh

Political boundaries hinder efforts to manage the Sundarbans as a single ecosystem. The Sundarbans stretches across the boundary between India and Bangladesh, and the potential for bilateral cooperation is significant, as both countries share interests in biodiversity protection, afforestation, and mangrove restoration, as well as the development of ecotourism, reduction of vulnerability to cyclones and other natural disasters, adaptation to climate change, and protection of local communities.

A Memorandum of Understanding<sup>13</sup> between the two countries was signed on September 6, 2011, in which both countries recognize that the Sundarbans represent “a single ecosystem divided between the two countries.” Specifically, both countries recognize the need to: (i) monitor and conserve the Sundarbans; (ii) adopt appropriate joint management and joint monitoring systems; (iii) explore the possibility of implementing conservation and protection efforts; (iv) develop a long-term strategy for ecotourism opportunities; (v) better understand the relationship between human settlements and the ecosystem; (vi) identify opportunities for livelihood generation that do not adversely affect the ecosystem; (vii) identify and catalog the diversity of flora and fauna; (viii) carry out research to develop a common understanding of the impacts of climate change and to determine appropriate climate change adaptation strategies; and (ix) sharing of relevant information and technical knowledge.

### 13.3.5 Key Organizations Working in the Sundarbans

Multiple organizations from the three levels of government (central, state, and local) are currently active or have a mandate to protect biodiversity and promote socioeconomic development in the Sundarbans. Central-level agencies are active in the region and oversee the implementation of conservation and development requirements in vulnerable areas. Their mandates range from the management of coastal areas to earmarking funding through centralized schemes for socioeconomic development.

GoI's MoEF is an organization with responsibilities and authorities that make it particularly relevant for the future

management of the Sundarbans. The ministry's mandate includes provision of policy directions for priority areas, such as the conservation and protection of the forest, wildlife, and coastal areas in India. Table A13.1 summarizes the main activities of MoEF and their relevance for the Sundarbans. While the ministry's functions are critical for the protection of the Sundarbans, its involvement in the region has been limited.

MoEF also plays an important role in the Sundarbans through its “power of the purse.” Though there is no specific unit within the ministry in charge of the region, and its involvement has been limited, the ministry provides the bulk of the resources invested to protect biodiversity and coastal areas in the Sundarbans. The total budget for West Bengal's Forest Department for all headquarter expenses, forest divisions, and reserves in West Bengal amounts to INR 351.14 million (US\$7.8 million). Roughly 39 percent (INR 135.42 million or US\$3 million) is allocated to the Sundarbans Tiger Reserve, with 87 percent provided by the central government and 13 percent originating from state resources. An analysis of the total budget for wildlife and habitat in the state of West Bengal indicates that around 71 percent of its resources are spent on nonplan expenses,<sup>14</sup> while 20 percent constitute centrally sponsored schemes and the remaining 9 percent is state plan expenses. Thus, by allocating a significant share of the resources available for conservation in the region and indicating how they might be spent, MoEF plays a key role in defining the priority areas for environmental management and biodiversity conservation in the Sundarbans.

The national Ministry of Agriculture also has an important mandate for the Sundarbans. A household survey<sup>15</sup> conducted under the World Bank's NLTA found that approximately 11 percent of households (on average) in the Sundarbans listed “fishing” as one of their occupations. In areas with easy access to rivers, the percentage was as high as 60–70. As is widely known, acquisition of land for embankment construction often causes people to resort to fishing in the various parts of the Sundarbans. Shrimp aquaculture, in spite of its negative effect on the ecology of coastal areas, has not been well regulated in India for a number of reasons, one of which (according to Menon et al. 2008) is the government's interest in safeguarding the interests of the industry. Having the mandate to oversee works in fisheries and aquaculture, the Ministry of Agriculture has the potential to play a key role in the Sundarbans.

At the state level, around 20 different GoWB agencies implement one or more programs or have a formal mandate to intervene in the Sundarbans (Table A13.2). Most of these agencies have a sectoral focus and implement statewide policies and programs that often fail to recognize the state's diverse ecological, social, and economic conditions, which results, for example, in similar efforts

<sup>12</sup>Climate Change Division, MoEF, Comments on Draft NLTA Report, May 23, 2013.

<sup>13</sup> The Memorandum of Understanding between India and Bangladesh on Conservation of Sundarbans, September 6, 2011, can be accessed at <http://www.hcidhaka.org/pdf/5.MOU%20between%20India%20and%20Bangladesh%20on%20Conservation%20of%20the%20Sundarban.pdf>

<sup>14</sup>“Nonplan expenses” comprise mostly salary and routine accounts, although some investment activities are also included.

<sup>15</sup>As part of this analytic work a survey of 2,188 households was completed by Gupta (2011).

**Table A13.1: Key Functions of the Ministry of Environment and Forests**

Function	Relevance for the Sundarbans
International negotiations on environmental topics	Bilateral cooperation with Bangladesh International negotiations on climate change and REDD-plus Convention on Biological Diversity Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) UNESCO Man and the Biosphere program
Formulation of acts, policies, and rules	Leads regulatory and policy issues in biodiversity and wildlife conservation, environment, and forests
Actions at state level through agencies	Departments of forests and environment Pollution Control Board
Central schemes to states	Project Tiger Conservation of the Sundarbans Biosphere Reserve Conservation of mangroves
Creating specific bodies to monitor special issues	Biodiversity Board Coastal Zone Management Authority

**Table A13.2: Role of State-level Agencies in the Sundarbans**

Name of Government Organization	Functions	Current Role in the Sundarbans
SAD (with SDB and Sundarban Infrastructure Development Corporation)	Implementation of Special Area Development Plan Coordination and integration of plans Performance assessment and monitoring	Responsible for socioeconomic development of the inhabited part of the Sundarbans. Greatly constrained in playing the role of the coordinator. Implements programs in several sectors, including rainwater harvesting, agriculture, and construction of tubewells, bridges, and jetties. SAD has four divisions: agriculture, fisheries, social forestry, and engineering, with deputed staff from the respective departments
Department of Forests	Enforces Indian Forest Act (1927), Forest (Conservation) Act (1980), and Wildlife (Protection) Act (1972), among other things Developmental role for soil conservation, nonsocial forestry, and timber yield	In charge of the National Park, Reserve Forest and sanctuaries, and wildlife. Oversees joint forest management initiatives and shares forest products with communities in a co-management framework
Department of Irrigation and Waterways	Flood control through protection of embankments in Sundarbans Drainage	Constructs embankments in the Sundarbans Also provides clearance for bridges
Department of Water Investigation and Development	Tubewells Licensing for groundwater extraction	Manages groundwater extraction in the Sundarbans. DSA implements boring of tubewells directly
Department of Environment	Enforcement of environmental regulations, mostly through State Pollution Control Board Lead agency for state's Biodiversity Strategy and Action Plan	Designs and implements Biodiversity Strategy and Action Plan for West Bengal



**Table A13.2 (continued): Role of State-level Agencies in the Sundarbans**

Name of Government Organization	Functions	Current Role in the Sundarbans
Department of Fisheries and Aquaculture	Responsible for conservation of fish species, creation of infrastructure for fishing activities (including jetties), surveying, undertaking programs of skill upgrading, and livelihoods	Fish farming technical support, prawn cultivation, distribution of fingerlings, etc. Apparent duplication in efforts in distribution of fingerlings
Department of Agriculture	Providing information on agriculture, schematic implementation at grassroots level, soil analysis, pest management, seed firms in districts and blocks, etc.	Rainwater harvesting, providing seedlings, and minikit supplies
Department of Panchayat and Rural Development	Social forestry Administering the three-tier local government at district, block, and village levels Supporting local governments with appropriate budget, technical support, and policies	Construction of boreholes for wells, obtaining land for school buildings, and all work at local levels are done through involvement of three-tier local government. Areas of work include agriculture, health, education, and other socioeconomic activities
Department of Animal Husbandry	Providing support, inputs, and guidance for improving livestock	Provides extensions services for improving livestock
Department of Nonconventional Energy	Awareness programs for nongrid power Implementation of nongrid power projects	Implementation of nongrid power projects
Department of Scheduled Castes and Scheduled Tribes	Development and improvement of sociocultural and livelihood aspects of Scheduled Caste and Scheduled Tribe populations Providing financial assistance and implementing employment generation schemes for Schedules Castes and Scheduled Tribes	Implementing employment generation schemes for Scheduled Castes and Scheduled Tribes
Department of Tourism	Promotion and development of tourism Administering conducted tours Developing properties for tourism purposes	Promotion and development of tourism
Department of Home (Police)	Implementation of law and order through upkeep of legal provisions of various departments	Works in collaboration with forest agencies, district administration, coastguard, navy
Department of Disaster Management	The State Disaster Management Authority is responsible for planning and implementation of disaster management schemes and coordinating relief and rehabilitation	Relief for disasters (e.g., Cyclone Aila) was routed to different departments through Department of Disaster Management. Also provides funds for cyclone shelters
Department of Health and Family Welfare	Protecting health of people through preventive and curative measures	Mobile ambulance scheme support
Department of Education (school, higher secondary, tertiary, and vocational)	All three departments of education are active across the state	Provides primary, secondary, tertiary education, and vocational training
Department of Self-Help Groups	Support to self-help groups at community level	Support to self-help groups at community level
Department of Public Health Engineering	Piped water supply Construction of tubewells Certifying quality of water Investigation for water sources	Design, construction, and management of water supply and sanitation systems
Public Works Department	Responsible for infrastructure and construction-related works through its own human resources	Building and maintenance of road infrastructure in the Sundarbans

being pursued in both the state's northern high hills and the Sundarbans. DSA is the only organization with a geographic approach that explicitly recognizes the region's terrain, poverty, and accessibility challenges. The presence of numerous governmental organizations with overlapping authorities and responsibilities often results in duplication of efforts.

DSA is the only organization with a special mandate to address the region's challenges. SDB, created under the Development and Planning Department of the state in 1973, was entrusted with "the planning and co-ordination of development activities in the backward region."<sup>16</sup> Sectoral departments worked in the Sundarbans, as in any other area of the state, but it was "only during 1973, [that] the extent of backwardness, the very fact of difficult, inhospitable and inaccessible terrain, the critical gap in developmental needs and the magnitude of the task confronting the development agencies prompted the state government to create a distinct and specific body for development in the region."<sup>17</sup> An independent DSA was created in 1994, led by a minister-in-charge and principal secretary. SDB was brought under DSA, and functions as a distinct development agency guided by the Board members. The Board includes elected representatives, district magistrates of North and South 24 Parganas districts (in which 19 blocks of the Sundarbans area falls), and representatives from NGOs and social groups.

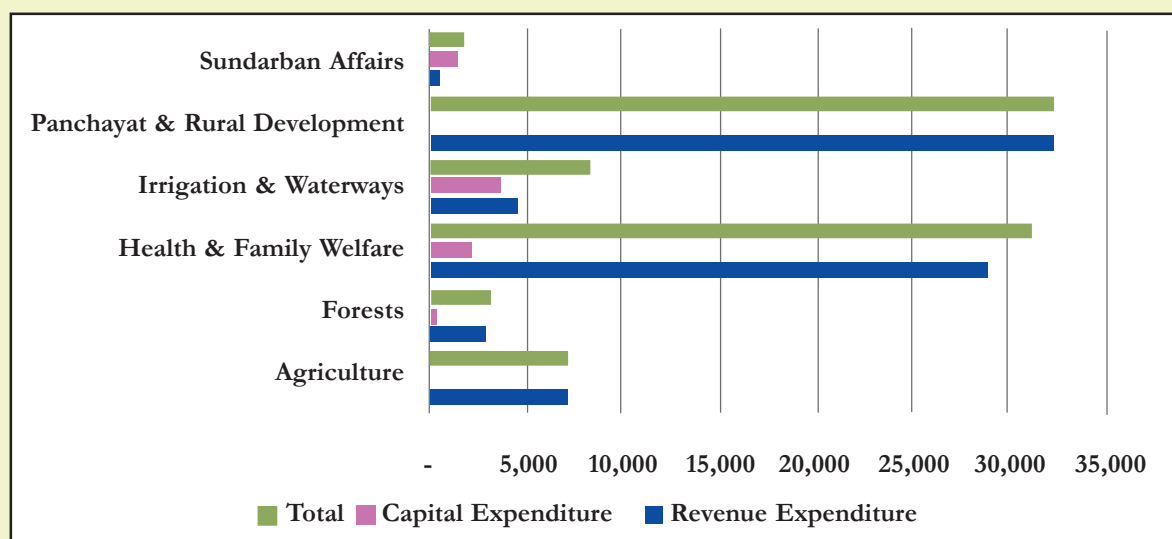
Even though DSA was created in response to a clear and specific need, its actions have been constrained by a number of factors, including the following:

- The scope of work of SDB and later DSA has been limited only to socioeconomic development of the inhabited parts in the Sundarbans. In addition, other relevant departments, such as those with responsibility for forests, irrigation and waterways,

health, and education, continued to plan and execute sectoral schemes in the Sundarbans independently, which defeated the purpose of creating DSA as a coordination agency;

- DSA has a formal mandate and structure to plan, monitor, and evaluate activities conducted by other agencies in the region. While these functions are carried out periodically, they have no clear influence on the allocation of resources or the improvement of schemes. For example, DSA publishes annual work plans, as well as yearly targets and achievements. However, there is no evidence of cross-sectoral coordination or alignment with a longer-term plan for the region. Thus, the schemes pursued are often at cross-purposes. Also, results are reported by sectoral divisions and independent impact evaluations are not carried out systematically;
- The power and influence of DSA is not significant compared to its larger counterparts for several reasons, including its limited budget compared to other departments (Figure A13.2); political economy issues related to decisions on investments or expenditures in the area; and a comparatively small spatial domain that is largely underdeveloped and vulnerable;
- SDB has four divisions – agriculture, engineering, fisheries, and social forestry – and it is staffed by officials deputed from the respective departments into DSA. The interests and incentives of such officials are more clearly aligned with their parent departments than with those of DSA; and
- Having a geographic and multisectoral mandate, DSA is required to look at complex and broad-ranging issues such as climate change, environment, forests, and agriculture. However, the staff with the technical capacity to oversee these areas is mostly located within line agencies working in those sectors.

**Figure A13.2: Actual Expenditure of State Departments in 2009–10 (INR Million)**



<sup>16</sup>Department of Sundarban Affairs website: <http://www.sadepartmentwb.org/>.

<sup>17</sup>Ibid.

In line with its mandate, DSA implements a number of socioeconomic development schemes, some of which are duplicated by sectoral departments. A few areas of duplication in work between DSA and other state departments are shown in Figure A13.3. Another review<sup>18</sup> of the institutional framework in the Sundarbans further highlights the duplication problem in the region. The review finds that SDB presently implements small-scale development projects such as construction of brick-paved roads, jetties, bridges, culverts and sinking of tubewells, which duplicates the activities of the Public Works Department and PHED.

Numerous examples exist: (a) aquaculture development undermines embankment stability; (b) complete bans on mangrove cutting reduce incentives for communities to manage them well and have, in fact, turned pursuit of some potentially sustainable uses into a crime; (c) ration cards intended to improve livelihood security keep people trapped in poverty by discouraging them from integrating themselves into areas of lower risk and greater economic opportunities; and (d) referral systems for health services ignore the reality that the “nearest” medical care center may, in fact, be impossible to reach because of difficult geographic terrain or lack of appropriate transport.

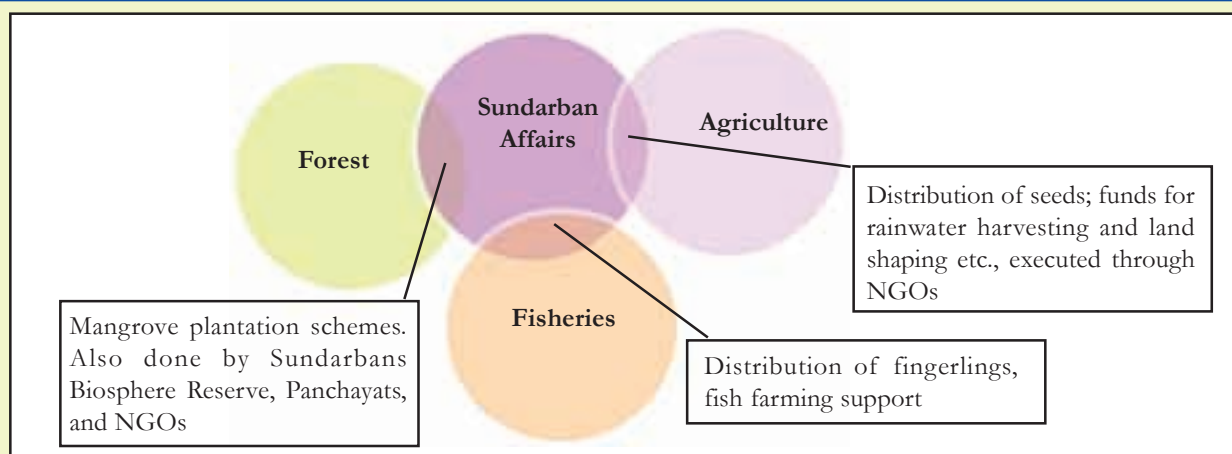
A different problem arising from lack of interagency coordination relates to the number of agencies whose de jure responsibilities are overlooked for compliance or safeguards. For instance, environmental impact assessments, which are supposed to be mandatory for significant projects anywhere in India, are not implemented for such projects in the Sundarbans. A similar situation occurs with regard to the rules on obtaining clearance for any construction activity within 500 m of tidal creeks. This applies to schemes funded through DSA, as well as for construction activities carried out by the departments concerned with forests, irrigation and waterways, and other relevant areas. Similarly, for sinking of deep tubewells, the West Bengal Groundwater Resources (Management, Control, and Regulation) Act (2005) stipulates that mandatory approval must be received from the appropriate state-

level authority or district-level authority. However, as most of the tubewell schemes are developed at village or block levels, it is unclear which agency should be responsible for providing such clearances. By default, the local government or Panchayat should be informed before such infrastructure schemes are undertaken, but no evidence of systematic coordination in this regard could be found during the preparation of this work.

Weak institutional capacity is another factor hampering the development of appropriate responses to development challenges in the Sundarbans. Even though there are numerous organizations with a formal mandate to address most of the challenges in the region, the capacity to actually carry out strategic interventions is inadequate. Existing institutions are frequently hobbled by lack of resources. The availability of adequately trained staff remains a constraint in many organizations: doctors, teachers, and other technical professionals have no incentives to work in an environment with risks as high as they are in the Sundarbans. Outdated technical approaches continue to be used, such as the promotion of monospecies forestry, overreliance on excessively restrictive and unenforceable conservation regulations, and lack of modernized systems to handle isolated communities in need of basic social services. Key institutional strengthening needs identified by the studies conducted under the NLTA include:

- In the transportation sector, investments are needed to build the capacity in agencies planning transport interventions in the region so that they can effectively gather data, manage information, and conduct analyses of transportation demand, and assessments of environmental and social impacts of proposed actions. The analytic work conducted as part of this NLTA determined that units planning transport systems in the area are lagging behind in terms of information management and various analysis methods and procedures. It is, therefore, recommended that appropriate investments be made in data collection, data management systems, and capacity building, and that interagency coordination related to transport systems be enhanced;

**Figure A13.3: Overlaps in Functioning between State Government Departments**



<sup>18</sup>Center for Science and Environment. 2012.

- In the short term, it is critical to place emphasis on preventive healthcare to reduce the incidence of diseases. Examples of preventive healthcare services include provision of health and hygiene education, physical examinations and screenings, immunizations, and vaccinations. Moreover, existing health initiatives<sup>19</sup> implemented by the Department of Health and Family Welfare need to be strengthened with the aim of: (a) improving and expanding these programs in hard-to-reach places, most of which are located in the high-risk area of the Sundarbans; and (b) placing additional emphasis on illnesses prevalent in the region. Wild animal attacks, as well as high diarrhea incidence linked to salinity intrusion,<sup>20</sup> are two examples of situations that are specific to the Sundarbans and require appropriate preventative and response interventions to reduce incidence and impacts; and
- In terms of energy services, the focus has traditionally been on providing grid power, but there should be an increased emphasis on appropriate local-scale alternatives. Many renewable alternatives have been identified, but capacity to manage these within a broader integrated network is still lacking. Additional training, especially in repair of systems through local or small-scale private businesses, could be facilitated by the Department of Power.

Another factor affecting development efforts in the Sundarbans is the heterogeneity of socioeconomic conditions in the region. Blocks within the Sundarbans region face more significant development challenges than other blocks that are also part of the North and South 24 Parganas districts. Figure A13.4 (A–D) illustrates the similarities between the blocks of North and South 24 Parganas that fall within the Sundarbans, according to various indicators. Furthermore, district human development reports for 2010 indicate that GoWB will face tremendous challenges to bring the socioeconomic and environmental indicators of these blocks on par with the best in West Bengal. In the future, blocks within the Sundarbans are likely to face similar challenges in terms of their vulnerability to geomorphological changes, sea level rise, and climate change.<sup>21</sup>

### 13.4. Recommendations to Strengthen the Institutional Framework of the Sundarbans

GoI and GoWB may consider a new approach for the planning, socioeconomic development, and management of the Sundarbans. The need for a new approach is not only supported by existing dismal social, economic, and environmental indicators, but also by the unsustainability of current trends. Other studies conducted under the World Bank's NLTA document the region's high population growth, erosion of the natural resource base, and problems with the current embankment system. There is no evidence indicating that traditional, BAU approaches can help to address these

problems and protect the Sundarbans' unique ecosystem. It is, therefore, recommended that institutional reforms be adopted to realign organizational mandates and resources with a long-term vision that recognizes both the challenges to socioeconomic development and the ecosystem's fragility.

The existing designation of different types of protected areas and reserve forests in the Sundarbans is complex and ignores changes that are taking place as a result of geomorphological shifts, sea level rise, and projected impacts of climate change. For example, several studies prepared under the World Bank's NLTA found that incremental salinity intrusion into the Sundarbans is pushing many of the freshwater species further northward, and exacerbating human–wildlife conflicts, most famously with the Royal Bengal tiger. Conservation of the rich ecosystem of the Sundarbans forms the cornerstone of the recommended long-term strategy to protect the many flagship species in this environment. And, as highlighted in the previous discussion of REDD-plus, ecosystem preservation could also provide a future revenue stream to improve socioeconomic development and lives of the region's residents.

Responding to the diverse and profound challenges of the Sundarbans will require a suite of reforms and institutional strengthening interventions that should result in bolstered capacity of sectoral agencies to implement programs that are tailored to the on-the-ground realities; strengthening of coordination and monitoring and evaluation mechanisms; and creation of a new spatially oriented organization that can set and act upon long-term priorities. The reform and realignment of existing organizations is not simple and, in many cases, will need to be accomplished using extensive participatory processes. Most of the recommended near-term interventions are urgently needed because ongoing and future degradation exposes large numbers of people in the transition zone to significant risks. Recommendations for actions that GoI and GoWB might consider to promote a new approach to conserving biodiversity, adapting to climate change, and enhancing socioeconomic development in the Sundarbans include:

- Currently, each of the several different types of specially designated reserve areas in the Sundarbans Biosphere Reserve has its own level of ecosystem protection and is managed according to a distinct set of rules, even though the spatial extent of these different types of areas sometimes overlap. It is recommended, therefore, that only one category of reserve be applied for a particular geographic area. Given the importance of the region's biodiversity, when there are overlaps, the category that has the strictest ecosystem protection levels should be applied;

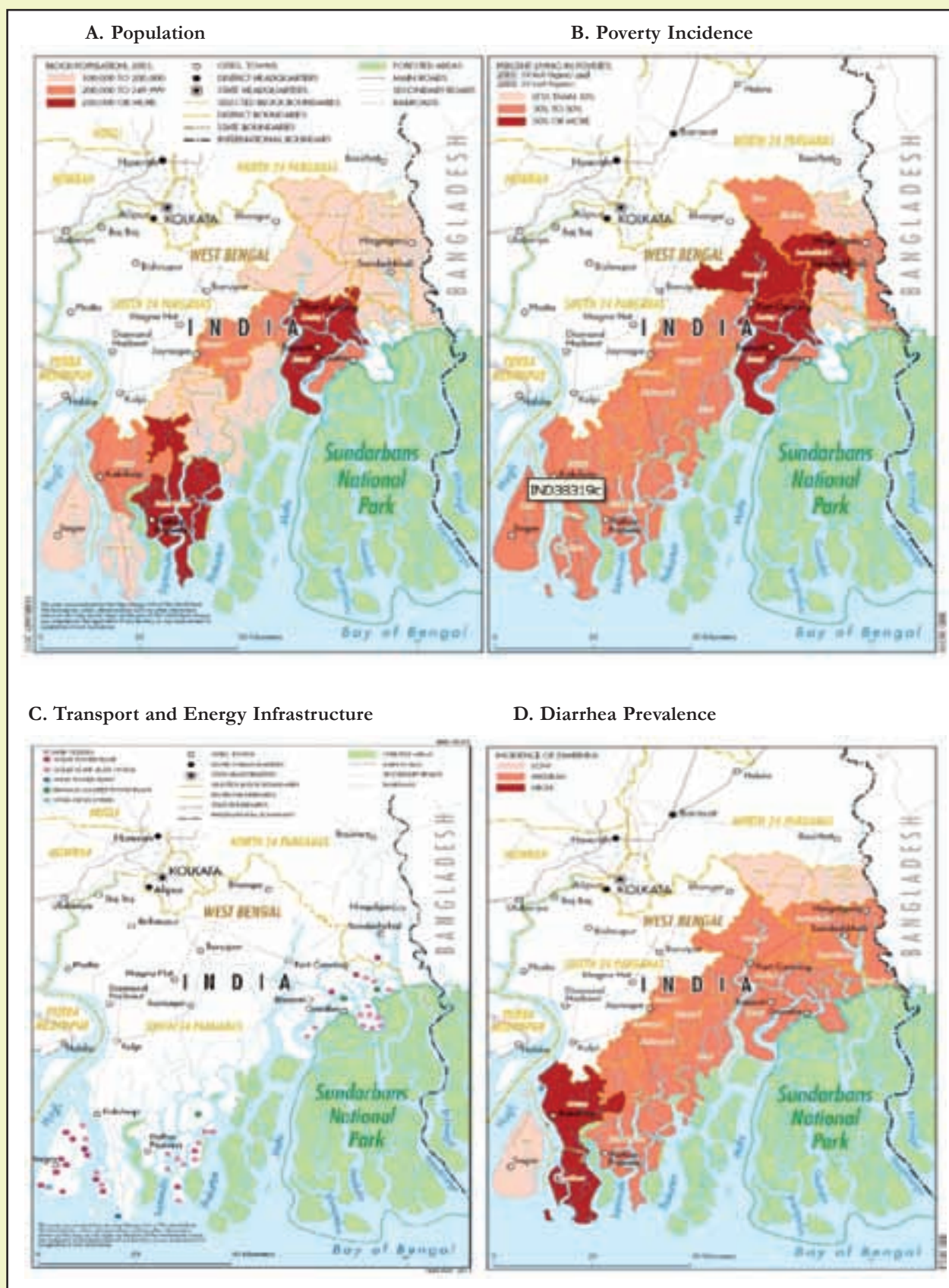
<sup>19</sup>These programs include the Reproductive and Child Health Program, Revised National Tuberculosis Program, and the National Anti-Malaria and HIV/AIDS Control Programs.

<sup>20</sup>Sea level rise could increase the incidence of diarrhea by decreasing the amount of available “sweet” groundwater, thereby reducing the supply of potentially potable water.

<sup>21</sup>Danda and Sriskanthan (2011) suggest that the blocks within the Sundarbans should be constituted as a single administrative unit, instead of being part of the two separate districts of South and North 24 Parganas.



Figure A13.4: Socioeconomic Indicators for North and South 24 Parganas and Sundarbans



- To continue to promote biodiversity conservation over time, and to minimize further risks to the population in this region, it is recommended that the status of existing reserve forests be upgraded to protected areas with conservation as a focus, and that the areas surrounding mangrove plantations be designated as reserve forests gradually (as those lands become government owned) over the next several generations;
- In order to manage the coastal area of the Sundarbans, the West Bengal Coastal Zone Management Authority should be made responsible for enforcing and overseeing the national regulations established through MoEF. This will require strengthening the Authority, considering that it was created only recently;
- GoWB should consider creating a Sundarbans Planning and Risk Management Authority as a spatially oriented government organization with a mandate to set regional priorities under a long-term vision, facilitate interagency cooperation, and coordinate implementation efforts. If created, the institution would be given responsibility for anticipatory planning and selection of effective and efficient interventions, along with a coordinating role that ensures various sectoral agencies are doing their part;
- GoWB should work with GoI to reassess the importance of the Sundarbans with regard to climate change. In particular, efforts should be made to gain an agreement to ensure that the Sundarbans is identified as a priority for climate change mitigation and adaptation efforts; such an agreement would be essential in enabling the region to benefit from REDD-plus funding;
- Given that the Sundarbans ecosystem lies within both India and Bangladesh, there would be mutual advantages in creating a mechanism for bilateral cooperation on Sundarbans biodiversity research. Bilateral cooperation is needed to address pressures on natural resources, particularly marine resources and migratory species, and assess the current condition of and threats to the region's biodiversity;
- The bilateral cooperation on the Sundarbans that has recently begun between India and Bangladesh should be expanded to include the co-management of a marine reserve area to protect the coastal and inland areas of the Sundarbans. Other areas where both countries might find it mutually advantageous to collaborate include research on the impacts of climate change, promotion of ecotourism, and protection of local communities from natural hazards;
- In order to promote the increased interagency coordination needed to implement the recommended development approach, the monitoring and evaluation role of DSA should be strengthened. Moreover, state agency funding allocations for work in the Sundarbans should be based on evaluation by DSA of the performance of the agencies that received prior funding allocations to meet specific goals in the region;
- Details regarding an approach to making funding allocations based on evaluation of state agencies' performance by DSA should be developed in a highly consultative and transparent manner, taking into account the concerns of local stakeholders, including communities, NGOs, and self-help groups. It is recommended that DSA strengthen its outreach to these constituencies as well as its communications and mediation capacities;
- Institutional strengthening programs should be implemented in the short term, comprising efforts to build the capacity of single institutions to carry out their sectoral mandate, including more effective interventions in the health, transport, and energy sectors, as discussed above;
- Additional institutional strengthening efforts should focus on enhancing cooperation between pairs of sectoral agencies, including: (a) irrigation and forestry, to encourage mangrove growth along areas that become available for restoration as a result of embankment retreat and realignment; (b) health and transport, to improve delivery of and access to health services, taking into account the difficult terrain and lack of resources in many health facilities in the Sundarbans; (c) irrigation and aquaculture, to ensure that aquaculture practices do not contribute to embankment failure and erosion; and (d) health and forestry, to handle emergency medical cases in the high-risk area occurring in the transition zone and the core zone, including medical emergencies (such as animal attacks); and
- The interventions carried out by these strengthened organizations should avoid creating perverse incentives that maintain or increase the number of people exposed to risks in the Sundarbans; instead, they should facilitate the voluntary and gradual migration out of the transition zone and into the densely populated stable zone. Infrastructure investments should focus on developing the stable zone of the Sundarbans in ways that make it an attractive place for possible migrants from the transition zone to seek improved livelihood opportunities. In particular, investments in energy supply, transportation infrastructure, water supply and sanitation, health, and education could create the enabling conditions for increased job generation and improved livelihood opportunities in the stable zone.

### 13.5. Conclusions

The implementation of the recommendations from the World Bank's NLTA will only be possible in an institutional environment that supports the overarching strategy of promoting biodiversity conservation, climate change adaptation, and socioeconomic development goals. To consolidate this supportive environment, a realignment of institutional arrangements is recommended. The institutional arrangements for planning, managing, and developing the Sundarbans were established during the late 19th and early 20th centuries, with multiple agencies and departments working primarily according to sectoral mandates. Given the challenging terrain of the Sundarbans and the many obstacles to development, it is recommended that institutional arrangements be restructured to embrace a spatial planning approach that better accounts for the unique features of the Sundarbans. As such, the interventions outlined in Table A13.3 are recommended.

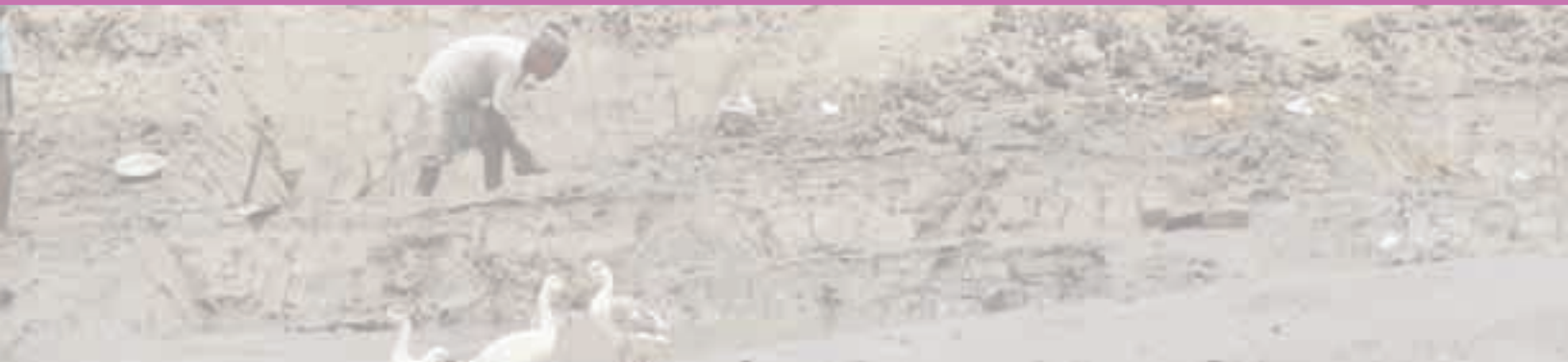
**Table A13.3: Recommendations for Restructuring of Institutional Arrangements**

Time Scale	Options for Action
Short term	Strengthen the capacity and effectiveness of single institutions to better address problems in the Sundarbans (for example, Department of Health and Family Welfare to focus on preventing and treating illnesses prevalent in the region)  Initiate paired cooperation and coordination efforts among lead institutions, particularly those in the following sectors: irrigation and forestry; health and transport; irrigation and aquaculture; and health and forestry
Medium term	Task DSA to monitor and evaluate sectoral agency activities; GoWB's Finance Department would allocate the budget that can be spent in the Sundarbans during the next cycle based, in part, on DSA's evaluations of performance, with increased funding directed to agencies that achieved solid results and decreased funding for agencies that performed poorly  Task the West Bengal Coastal Zone Management Authority to enforce and oversee national coastal zone management requirements in the Sundarbans
Long term	Create a new institutional authority called the Sundarbans Steering Committee to set implementation priorities and facilitate coordination efforts

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# GLOSSARY

**Accretion.** Gradual accumulation of sediments through deposition on a landmass.

**Acute lower respiratory infection.** Acute health conditions that occur in the lower respiratory tract. The lower respiratory tract covers the airways from the trachea and bronchi to the bronchioles and alveoli. Pneumonia and bronchitis are examples of acute lower respiratory infection.

**Amancrop.** A crop that is grown during the rainy (monsoon) season.

**Annual parasitic incidence.** Number of blood smears found positive for the malaria parasite in a year per 1,000 population.

**Below the poverty line.** Subsistence below the economic benchmark and poverty threshold used by the Government of India to identify individuals and households in need of government aid.

**Block.** The administrative unit of local government below the district level in India, also more completely referred to as community development block. The area is administered by a block development officer and covers several Gram Panchayats (GP), which are the local administrative units at the village level.

**Block primary health center.** The hub for primary health care activities within a block; such centers are part of the public health service system in the Sundarbans.

**Business as usual approach.** An approach whereby current policies and programs are allowed to continue their course. For the Sundarbans, this base case scenario incorporates the existing government plans and programs for all key sectors (education, health, energy, and so on) and represents the most likely path of development in the absence of major new interventions to improve the livelihood and welfare of local populations.

**By-catch.** Aquatic species that are caught unintentionally in fishing gear. Unlike target species (species specifically targeted for capture), by-catch is unwanted and often discarded back into the water.

**Climate Investment Funds.** A pair of funds to help developing countries pilot low-emission, climate-resilient development. With Climate Investment Fund support, 45 developing countries are currently piloting programs in clean technology, sustainable management of forests, increased energy access through renewable energy, and climate-resilient development.

**Community delivery center.** Focal point for delivery of institutional health services provided by a nongovernmental organization. Such centers either stand alone or are integrated with primary health care centers.

**Core zone.** In the context of this report, the “core zone” comprises all the legally protected areas of the Sundarbans – the National Park, wildlife sanctuaries, and the Reserve Forest – not just the National

Park and Tiger Reserve. Roughly 40 percent of the Reserve Forest area has been brought under protected area status.

**Cropping intensity.** The number of crops that are harvested in a year from a given piece of land, calculated as the ratio of gross cropped area to net cropped area, and expressed as a percentage. The higher the cropping intensity, the higher the gross returns.

**Decentralized distributed generation.** Energy distribution using small, modular, decentralized, off-grid energy systems located in or near the place where energy is used.

**Declared supply voltage.** The level of voltage required for a reliable power supply. Indian Electricity Rules 1956 (as amended to date) stipulate 230 volts, with a permissible variation of 6 percent.

**Department of Sundarban Affairs.** The Department of Sundarban Affairs (DSA) is the only organization with a geographic focus and a special mandate to address the region’s challenges. It executes its activities through the Sundarban Development Board (SDB), established in 1974, and later institutionalized as part of the DSA.

**Disability-adjusted life year (DALY).** A measure of the overall disease burden, expressed as the number of years lost due to disability, illnesses, or premature death.

**Enhanced rural development approach.** An approach entailing implementation of new policies, programs, and interventions across all key sectors in a concentrated effort to increase living standards and economic development in rural areas. The enhanced rural development approach involves the development of schools, public health centers (including hospitals), and infrastructure (for example, roads and railways), and implementing measures to attract firms to set up in rural areas.

**Enteric fever.** A bacterial infection characterized by diarrhea and a rash, most commonly caused by the bacteria *Salmonella enterica*, which spreads through contaminated food and water.

**Environmentally sustainable ecotourism.** Tourism that focuses on maintaining the natural, biological, and cultural integrity of the environment so that environmental degradation does not occur.

**Environmental damage costs.** This includes costs arising from environmental degradation, ecosystem degradation and biodiversity loss, damage from cyclones, and cost of health effects of inadequate water supply, sanitation, and hygiene, and household air pollution, among others.

**Erosion.** The process by which rocks, soil, and other materials are removed from the land surface by natural forces, principally water.

**Eustatic sea level rise.** A global rise in sea level, for example, due to changes in the volume of water in the world’s oceans.

**Feeder line.** A branch line of a grid electrical network system.

**Forest Department.** The Forest Department is the agency

responsible for the protection and conservation of flora and fauna in the Sundarbans Biosphere Reserve. The Sundarbans Biosphere Reserve wing, located within the Forest Department, is responsible for managing the reserve forest areas, managing the tiger habitat and the wildlife sanctuaries at Sajnekhali and Lothian, facilitating the development of joint forest management committees in areas of mixed forest use, and developing an overall conservation plan for the Sundarbans Biosphere Reserve.

**Gram Panchayat.** Local self-government unit operating at the village level in India.

**Headwater area.** The area where a river or stream begins; the source location of a river or stream.

**High-risk zone.** The area that overlaps with both the core area and the transition zone in the Sundarbans. The high-risk zone includes all legally protected areas, the Reserve Forest, and the fringe area, that is, the belt on the periphery of the forest and the inhabited area.

**Irrigation intensity.** The ratio of net irrigated area to net sown area, expressed as a percentage. The higher the irrigation intensity, the higher the cropping intensity and yield, and thereby the higher the gross returns.

**Isostatic sea level rise.** A sea level change that is localized, such as the change in relative sea level caused by deltaic subsidence.

**Kala-azar.** Also known as visceral leishmaniasis, kala-azar is a chronic and potentially fatal parasitic disease of the viscera (the internal organs, particularly the liver, spleen, bone marrow, and lymph nodes) due to infection by the parasite *Leishmaniadonovani*.

**Land shaping and rainwater harvesting.** In the context of the Sundarbans, this technology involves digging on-farm rainwater harvesting ponds on 20 percent of the total plot of a farm to capture and store rainwater. The soil from the excavation is then spread over the rest of the plot to create two or three tiers of land of various heights. This combination of tiered land and a rainwater harvesting pond can alleviate problems caused by stagnating water during the kharif season and lack of water during the rabi season. By creating land tiers of different heights, it allows for crops other than paddy to be grown during kharif.

**Long-lasting insecticide-impregnated net.** Mosquito nets treated with insecticides, which repel or kill mosquitoes that cause malaria. They are designed to be effective for the life of the net (and therefore do not need retreatment).

**Long-term vulnerability reduction approach.** In the context of the Sundarbans, along-term and gradual integration of the population into urban areas. This strategy reduces human vulnerability by educating residents of the dangers of living in the transition zone and aims first to improve health and educational standards so that in the longer term Sundarbans residents can successfully integrate themselves into cities away from the Sundarbans Reserve Forest.

**Main workers.** Persons working in a gainful activity for more than four hours a day for at least 183 days during a year.

**Occasional migration.** Migration that takes place for a period of less than 90 days per year.

**Payment for ecosystem services.** The practice of offering financial compensation to landowners who adopt sound management practices that deliver ecosystem services. Specific services that have been recognized by programs include climate change mitigation, catchment area services (such as decreasing sedimentation and preventing floods and landslides), and biodiversity conservation.

**Primary health center.** Functioning at the lower level of the health delivery system, the primary health center provides primarily outpatient treatment and, in some cases, inpatient facilities.

**Rabicrop.** A crop that are sown during the winter season.

**Rajiv Gandhi Grameen Vidyutikaran Yojana.** The Ministry of Power, Government of India, launched the Rajiv Gandhi Grameen Vidyutikaran Yojana as a flagship program in March 2005 with the objective of electrifying over 100,000 unelectrified villages and providing free electricity connections to 23.4 million rural households below the poverty line. Under the program, electricity distribution infrastructure is envisaged to establish the rural electricity distribution backbone with 33/11 kilovolt substations, village electrification infrastructure with at least a distribution transformer in a village or hamlet, and stand-alone grids with generation where grid supply is not feasible.

**Ration card.** A card issued by the government that allows the holder (generally poor) to buy certain essential commodities at a subsidized rate.

**REDD-plus.** The enhanced version of the reducing emissions from deforestation and forest degradation program (REDD), which is a mechanism to support climate change mitigation actions in the forest sector by reducing emissions from deforestation and degradation, conserving and enhancing forest carbon stocks, and promoting sustainable forest management. In brief, REDD-plus is a climate change mitigation solution that many initiatives, including the UN-REDD Programme, are currently developing and supporting. Other multilateral REDD-plus initiatives include the Forest Carbon Partnership Facility (FCPF) and Forest Investment Program (FIP), hosted by The World Bank.

**Resilience.** A concept applied in complex systems science to describe the capacity of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient system can withstand shocks and rebuild itself when necessary. Resilience has the following defining characteristics: (a) the amount of change the system can undergo and still retain the same controls on function and structure; (b) the degree to which the system is capable of self-organization; and (c) the ability to build and increase the capacity for learning and adaptation. Reduced resilience increases the vulnerability of a system to smaller disturbances that it could previously cope with. Even in the absence of disturbance, gradually changing conditions can surpass threshold levels, triggering an abrupt system response (see <http://www.resalliance.org/index.php/resilience>).

**Sea level rise.** Change in the relative value of mean sea level to a fixed local point, conceptually measured from the earth's centre. Sea level rise can thus occur from local decrease in land level from

compaction or deltaic sinking, as is the case in the Sundarbans; this is *isostatic* sea level rise. It can also occur from global changes in the volume of water in the oceans and seas; this *eustatic* sea level rise is that usually referenced in discussions of climate change, in which the main contributors are ice melt (contributing to increases in the mass of water in the oceans) and increases in global and sea temperature (contributing to a volumetric increase because of thermal expansion).

**Seasonal migration.** Migration that takes place during a particular time of year, for example, the work season.

**Short-term migration approach.** An approach centered on an out-migration process in which residents leave the Sundarbans in order to find safer places to live. The approach also has the effect of protecting biodiversity. To encourage outward migration (and even involuntary resettlement), residents would be educated about the dangers of living in the area and economic incentives for relocating them would be provided. The strategy would also restrict in-migration.

**Stable zone.** In the context of this report, it is the densely populated areas far from the Sundarbans Reserve Forest. Further, this is the zone where the delta is relatively stable and further away from the mouths and tidal river courses. Any ongoing geomorphological processes are mainly involved with sedimentation and accretion (as opposed to erosion), enhancing the stable nature of the zone. Most of this land is attached to the mainland and contains the peri- and semi-urban environments closer (and relatively well connected) to Kolkata. The stable zone contains established settlements, such as Bakkhali, Canning, Jaynagar-Majilpur, Kakdwip, Minakhan, Namkhana, Sagar Island, and Tengrabichi.

**Sundarban Development Board.** The Sundarban Development Board implements the works of the Department of Sundarban Affairs. As the main decision-making body of the Department, the Board has primary discretion over how funding under different schemes is distributed among the different blocks in the Sundarbans.

**Sundarbans Biosphere Reserve.** The Sundarbans Biosphere Reserve comprises the entire 9,630 square kilometers of the Sundarbans. The geographic area considered as the “core zone” of the Sundarbans region by the World Bank’s Non-Lending Technical Assistance comprises roughly 40 percent of the Reserve. The remaining 60 percent consists of the “transition zone,” where economic activities take place and urban settlements are found.

**Sundarbans National Park.** With an area of 1,330 square kilometers, the Sundarbans National Park is located within the core area of the Sundarbans Biosphere Reserve.

**Sundarbans Reserve Forest.** The Sundarbans Reserve Forest is spread over 19 administrative blocks. Administratively, it comprises 13 of 29 subdivisions of South 24 Parganas district and six of 22 subdivisions of North 24 Parganas district of West Bengal. Blocks in South 24 Parganas are Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Canning I&II, Basanti, Gosaba, Mathurapur I&II, and Jaynagar I&II. The blocks in North 24 Parganas are Haroa, Sandeshkhali I&II, Hingalganj, Hasnabad, and Minakhan. The area

of the Reserve Forest is roughly 4,200 square kilometers. About 40 percent of the Reserve Forest has been declared a protected area, under the categories of national park or wildlife sanctuary.

**Sundarbans Tiger Reserve.** Established in 1973 as part of Project Tiger to maintain, conserve, and restore the tiger population and its habitats, the reserve has a total area of 2,585 square kilometers, comprising 1,600 square kilometers of land and 985 square kilometers of water bodies. Both the Sundarbans National Park and the Sajnekhali Wildlife Sanctuary are located within the Tiger Reserve.

**Sundarbans wildlife sanctuaries.** Three sanctuaries are located within the core area of the Sundarbans Biosphere Reserve, covering a total area of 406 square kilometers: Sajnekhali Wildlife Sanctuary (362 square kilometers), Lothian Island Wildlife Sanctuary (38 square kilometers), and Haliday Island Wildlife Sanctuary (6 square kilometers). Wildlife sanctuaries typically consist of an area of ecological, faunal, floral, geomorphological, natural, or zoological significance, and are established for the purpose of protecting, propagating, or developing wildlife and its environment.

**Tidal prism.** The volume of water that flows into and out of a channel during a complete tidal cycle (excluding upland freshwater discharges). If the tidal prism is made larger – for example, by extending the reach of tidal flows so that upstream fishponds are recharged with estuarine waters – the velocity of tidal flow increases. In contrast, if upper portions of a channel are cut off from an estuary to create reservoirs of fresh water, the tidal prism is made smaller and tidal velocity is reduced.

**Total Sanitation Campaign (Nirmal Bharat Abhiyan).** A program implemented at the district level to improve sanitation facilities in rural areas with a broader goal to eradicate the practice of open defecation. Under this approach, a nominal subsidy is given to rural poor households for construction of toilets. The total sanitation campaign emphasizes the following elements: information, education and communication, capacity building, and hygiene education to effect behavior change.

**Transformer.** Device that steps up or down the voltage level.

**Transition zone.** In the context of this report, it is the area in the Sundarbans surrounding the forest and consisting primarily of rural communities with limited infrastructure and high levels of poverty. This area is sandwiched between the core and stable zones (in the context of this report) and comprises areas that are along major tidal rivers.

**Voluntourism.** Travel that focuses on volunteer work. Voluntourism is a growing international phenomenon and a key market segment for emerging destinations, such as the Sundarbans Tiger Reserve and National Park.

**Workforce participation rate.** The percentage of main plus marginal workers as a proportion of the total population.

**Years of life lost.** The component of the DALY that measures years of life lost due to premature death. Years of life lost are estimated according to the World Health Organization’s calculation of DALYs, using age weighting and a discount rate of 3 percent.









