Enhancing Coastal Community's Disaster and Climate Resilience in the Mangrove Rich Indian Sundarban

2016

RAJARSHI DASGUPTA

Enhancing Coastal Community's Disaster and Climate Resilience in the Mangrove Rich Indian Sundarban

A Thesis Submitted for the Fulfillment of PhD

2016

RAJARSHI DASGUPTA
Graduate School of Global Environmental Studies
Kyoto University, Japan

Acknowledgements

This thesis would not have seen the light of the day without the active support of a number of individuals, institutes and organizations. I would like to express my sincerest thanks and gratitude to each one of them for their constant support, suggestions, advice and guidance at various stages of this study. Although, it is probably impossible to name each one of them, I shall try my best to list the names of people, institutes and organizations who have helped to complete this long journey.

Firstly, I would like to express my earnest gratitude to my current supervisor Professor Shigeo Fujii. This thesis would never be possible without his guidance, constructive comments and strong administrative supports - especially during the final days of my research. I am also deeply indebted to Professor Rajib Shaw, under whom I joined Kyoto University and conducted majority part of this research. Not only he inspired me to work in the Indian Sundarban delta, but also, his keen interest in my research, insightful comments and moral support has been the main driving force for accomplishment of the current work.

Secondly, I am deeply grateful to Professor Kenji Okazaki and Assoc. Professor Izuru Saizen of Graduate School of Global Environmental Studies, Kyoto University for being the reviewers of my thesis. Their critical comments, advice and suggestions helped me a lot to improve the current contents as well as to make the thesis more comprehensive.

Thirdly, I would also like to thank Dr. Koichi Shiwaku, Researcher, Graduate School of Global Environmental Studies, Kyoto University for his immense support for the preparation of the necessary official documents in Japanese. In this regard, I humbly acknowledge the supportive role of Ms. Sachiko Terasawa, Ms. A. Shiozaki, Ms. Yumiko Hamada and Ms. Kuri Sakamoto for their respective roles in various phases of my stay in Kyoto. I would also like to appreciate the help and support of the office staffs of the Graduate School of Global Environmental Studies of Kyoto University.

I am extremely grateful to a number of institutes and organizations who made this research possible. I am especially thankful to the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan for financially supporting my study and my stay in Japan. My research was also supported by various organizations from time to time. In particular, I am thankful to the Global COE Program on ‘Sustainability / Survivability Science for a Resilient Society Adaptable to Extreme Weather Conditions’ (GCOE-ARS Program), ‘Connectivity of Hills, Human and Ocean (CoHHO)’ program of Kyoto University and the Kyoto University Foundation (KUF) for sponsoring my research trips to Sundarban and other places.

Back home in India, there is also a long list of people - without whom, it was impossible to conduct this research. I am deeply indebted to Mr. Santanu Basu, IAS, Mr. Anurag Srivastava, IAS, Dr. Kishor S. Mankar, IFS and Ms. Lipika Roy, IFS for their strong administrative support, necessary permissions and logistic help. I am immensely thankful to the other administrative officers of Sundarban region, especially the District Disaster Management Authority (DDMA) of South 24 Parganas and the Block Development Officers (BDOs) of the 19 Blocks. In addition, I express my sincerest thanks to all the project officials of Aila

Embankment Reconstruction Project from the Irrigation and Waterways Department (I & W) of the Government of West Bengal. In this regard, I would like to extend my deep appreciation for Prof. Santosh Sarkar from the University of Calcutta and Prof. Kalyan Rudra, Chairman, West Bengal Pollution Control Board for their scientific explanation on the current problems of the Sundarban delta which immensely helped me to better understand the research problems. I also duly acknowledge the role of my field volunteers, especially Mr. Gopal and Mr. Amit, and many other villagers for their strong local support. The research results and key findings have already been shared with the concerned district authorities and other stakeholders through a consultative workshop and policy summary report during 2014. In addition, a good number of academic papers and chapters have been published based on the current research work. I shall be more than happy if it serves any of the future planning purposes for the disaster risk reduction of the local communities.

My four years stay in Kyoto became more than memorable because of my Japanese and non-Japanese friends and laboratory mates. I would like to thank all my laboratory members and close friends for their words of encouragement and support. In particular, I am especially thankful to Dr. Nitin Srivastava, Dr. Glenn Fernandez, Dr. Sukanya Mishra, Dr. Anwarul Abedin, Dr. Uma Habiba, Dr. Farah Mulyasari and Dr. Noralene Uy and all the ex-laboratory members of the International Environment and Disaster Management (IEDM) Laboratory. I also remain indebted to Mr. Indranil Mukherjee, Mr. Ranit Chatterjee, Mr. Kensuke Otsuyama, Mr. Genta Nakano, Mr. Masashi Sakamoto, Ms. Neha Sahoo, Ms. Thinn Hlaing Oo and Ms.Yumika Yoshinaga. I shall always treasure and cherish your company for the rest of my life.

Lastly, this list of acknowledgement would always remain incomplete without the mention of my wife and family members. I extend my sincerest thanks and appreciation to Mrs. Mrittika Basu (DasGupta), my loving wife, who has been a source of strong moral support during my testing times. It is because of her, I decided to go for a doctoral research leaving a stable job in India. I would remain ever indebted to my parents, Dr. Gautam DasGupta and Dr. (Mrs.) Niyati DasGupta and my loving brother Mr. Saptarshi DasGupta for their continuous encouragement and unconditional support. I am also equally grateful to my parents-in-law, Mr. Sadhan Basu and Mrs. Indra Basu for their trust bestowed upon me.

The completion of this thesis comes at a time when I and my wife are expecting our first child. At times, I feel guilty for not doing enough as a husband and a 'would be' father. While both I and my wife are very excited to welcome the baby, I also extend a vote of thanks to the baby and duly apologize for not giving enough time. I promise that I will make a good husband and better father afterwards!

Above all, I am thankful to God, the almighty, and strongly believe that I am nothing more than a mere implementer.

Place: Kyoto, Japan
Dated: 17th of February, 2016

Table of Content

Chapter 4: Participatory Action Planning for Coastal Resilience

Chapter 5: Enhancing Livelihood Resileince

Chapter 6: Enhancing Participatory Mangrove Management for Coastal Resilience

Chapter 7: Strategies and Actions for Embankment Protection

Chapter 8: Toward a 'No Regret' Approach for Disaster Risk Reduction in Indian Sundarban

Chapter 9: Conclusion

Annexures

List of Tables

List of Figures

List of Boxes

Abbreviations

BDO-Block Development Office/Officer

CAP-Community Action Planning

CBDRR-Community based Disaster Risk Reduction

CBMM-Community based Mangrove Management

CDB-Community Development Block

CZM-Coastal Zone Management

DRR-Disaster Risk Reduction

Eco-DRR-Ecosystem based Disaster Risk Reduction

EDC-Eco-Development Committee

FGD-Focus Group Discussion

FPC-Forest Protection Committee

FSI-Forest Survey of India

GBM-Ganges-Brahmaputra-Meghna Delta

HFA-Hyogo Framework for Action

I & W-Department of Irrigation and Waterways, Government of West Bengal

ICZM-Integrated Coastal Zone Management

IMD- Indian Meteorological Department

INR-Indian Rupees (approx.1 US $=62 INR as of April, 2015)

IPCC-Intergovernmental Panel on Climate Change

JFM-Joint Forest Management

JFMC-Joint Forest Management Committee

LECZ- Low Elevated Coastal Zone

MGNREGA-Mahatma Gandhi National Rural Employment Guarantee Act

MoEF-Ministry of Environment and Forests, Government of India

PCFA- Per Capita Forest Availability

PWD- Public Works Department

SFD-State Forest Department

SFDRR-Sendai Framework for Disaster Risk Reduction

SFM-Sustainable Forest Management

STR-Sundarban Tiger Reserve

UNCED-United Nation Conference on Environment and Development

UNESCO-United Nations Educational, Scientific and Cultural Organization

UNISDR-United Nation International Strategy for Disaster Reduction

USD-The United States of America Dollars

Executive Summary

Background of the Dissertation

Being exposed to nearly 7% of the world's deadly tropical storms and associated surges, disaster and climate vulnerability of the Indian Sundarban delta is well known. Especially, the rampage caused by Cyclone 'Aila' in 2009 left an indelible memory to the affected communities living in the small, isolated deltaic islands of the region. Further, with the rapid onset of climate change and depleting mangrove ecosystem services, researchers from all around the world as well as several international developmental agencies predict that the prevailing risks of coastal disasters in the delta are most likely to intensify in these extremely low-lying deltaic islands. This includes more intensified tropical storms and surges, an escalated sea level rise, severe coastal erosion and wide array of hydro-morphological changes that are expected to massively disrupt community's lives and well-being in this eco-fragile delta. In fact, it is not probably an overstatement that the very survival of the delta remains at a critical juncture and it is imperative to formulate an ameliorative disaster and climate risk reduction strategy in order to improve community's resilience against the prevailing and expected adversities.

Under this backdrop, this particular action research, mainly conducted between 2012-2014, principally attempts to provide research-driven appropriate policy guidelines to the related stakeholders, with an intention to improve the coastal community's disaster and climate resilience through participatory socio-ecological planning, collection and analysis of primary data and methodical screening of wide array of secondary data. The research, conducted against the backdrop of cyclone Aila, primarily used the devastation caused by the storm as the principal reference point for all the participatory exercises and further, hypothesized that the probability of such events or even a stronger storm (along with coastal flooding) remains much likely in the near future. Thereafter, this research characteristically aims to identify the key attributing factors that resulted in massive social and economic disruption of the communities' aftermath the 'Aila', through a bottom-up intensive assessment (both indicator and perception based) - especially focusing at the local government (block level) and the community level. Hence, the term 'resilience', as have been used in this research, principally depict the capacities of the local communities to adapt and/or embrace the adverse impacts of future disasters.

Research Concepts, Objectives and Questions

As have been hypothesized over the last decade, resilience of the coastal communities is inextricably linked with their surrounding environment. This coupled system of human and nature, often referred as ‘socio-ecological’ system, serves as the theoretical basis of the current study. In particular, the study recognizes coastal areas as typical examples of highly dynamic ‘socio-ecological systems’ bounded by its human and environmental limits, and resilience of such systems depend on multitude of complexly interlinked social, economic and ecological factors. Needless to say, the performance of coastal ecosystems such as mangroves remains seeming important to enhance community’s resilience against coastal hazards. In addition, the study also recognizes various other aspects such as societal structure, resource-dependency and governance as impounding factors of community resilience in coastal areas, and thereby, envisages on correlative management of both the social and ecological systems in order to foster community resilience.

Being the largest mangrove habitat in the country and hosting nearly 4.37 million resource dependent coastal communities, the complexity of the Indian Sundarban Delta is unmatched. Additionally, dire poverty and isolation are the impeding factors that continues to exert tremendous pressure on the existing mangrove resources leading to this high complexity and erosion of resilience in the observed socio-ecological system. Given such complexities, this particular action research aims to achieve four objectives as mentioned below:

- <u>Quantification of Community Resilience</u>, i.e. to develop an integrated framework and indicators and to assess coastal community’s disaster resilience in the backdrop of the study area.
- <u>To identify and prioritize specific indicators, relevant tasks and corrective actions</u> capable for enhancing communities’ resilience against hydro-meteorological hazards and/or climate change.
- <u>To develop community led sectorial plans on the prioritized indicators.</u>
- To recommend <u>an ameliorative disaster, climate and ecological risk reduction strategy</u> for the Indian Sundarban Delta in order to enhance community resilience.

Specifically, the study targets to answer the following research questions

- To what extent are the communities resilient to coastal hazards and/or the possible impacts of climate change?
- Which are the key attributing factors that are impeding communities’ resilience?

- Which are the precise tasks and actions required to enhance the disaster and climate resilience of the communities?
- What would be the appropriate risk reduction model against the current and future ecological, disaster and climate risk of the delta?

Research Methodology and Steps

The present study deploys a variety of qualitative and quantitative Participatory Rural Appraisal (PRA) tools across diverse stakeholders ranging from the local government units (Community Development Blocks) to the household and individuals. In order to achieve the above mentioned objectives, the study adopts the following research steps-

- In response to the first research question, the study aimed to develop an appropriate community resilience assessment framework and a composite resilience index against coastal disasters and climate change with special reference to the coastal rural communities. Consequently, based on extensive literature review, a questionnaire was developed from the above mentioned framework that consisted of 125 variables under 25 relevant indicators and 5 dimensions. In the present research, 'community resilience' of 19 coastal administrative blocks (Community Development Blocks or CDBs) of Indian Sundarban delta were assessed through an institutional questionnaire survey at the Block Development Offices. The administrative head of the blocks, i.e. the Block Development Officers were the primary respondents of the questionnaire. However, the collection of the data was also supported by other relevant Block officials such as Block Disaster Management Officer (BDMO), Agricultural extension officers etc. Resilience scores were calculated based on the specific inputs received in a pre-defined Five point Likert scale and a weightage average was taken to compute the final scores for each indicator and dimension. Classification and spatial mapping were conducted through an 'Equal-interval classification method' using ARCGIS^{TM} 10.2.
- In order to attain the second and third research objectives, the research deployed the tool of 'Participatory Action Planning' or 'Community Action Planning' which includes collection of subjective feedbacks and prioritization of specific issues identified by the 'Cyclone Aila' affected communities. The four distinct locations were chosen based on the results obtained from the above indexing exercises, proximity to the mangroves and recommendations made by the respective block development officers. The research essentially relied on four intensive Focus group discussions (FGDs) with Cyclone Aila affected communities. The results of the FGDs were summarized in 18 relevant 'Tasks' (corresponding to 25 main

indicators used earlier) and 54 corrective actions based on a directed content and problem-tree analysis of the proceedings. The identified 'Tasks' and actions thereunder, were later subjected to a prioritization survey in the worst affected villages in the same four blocks (*n=268*). Based on the ranking, three of the community prioritized tasks (i.e. Improve livelihood resilience, enhancing the participatory mangrove conservation and embankment protection) were later taken up for the detailed investigation and planning.

- In order to advance and risk proofing the current livelihood scenario, the research principally aimed to conduct participatory adaptation planning for the coastal agriculture and estuarine fishing communities. This study was specifically designed against the backdrop of reported crop damage (especially loss of agricultural land in Cyclone Aila) and high residual soil salinity aftermath the 'Cyclone Aila' that led to massive loss of livelihood in the delta. A total of twelve FGDs were conducted with farmers and estuarine fishermen in order to identify their perceived threats and adaptation/coping options associated with their existing livelihood. In a follow up process, individual survey, aimed at three groups of farmers, i.e. small, marginal and agricultural labor was conducted to understand the nature of crop damage, yield loss and intended adaptation/coping options (*n=126*). The similar research methodology was also followed for the estuarine fishers *(n=46).*
- With respect to the second component (mangrove conservation), the research typically examined the existing incentive design and extent of community participation in the prevailing participatory mangrove management (Joint Forest Management). The research steps include (a) interviews with forest officials (enquiry on incentive design, forest production trends etc.), (b) focus group discussions with 10 Joint Forest Management Committees (JFMCs) (enquiry related to their respective roles in the distribution and delivery mechanism of the incentives) and (c) semi-structured interviews with 119 forest beneficiaries (enquiries on perceived benefits and threats from the JFM arrangements). In order to identify the existing incentives under the JFM arrangements, the interview reports with forest officials were subjected to summative content analysis. The transcript of the FGDs and semi-structured interviews with 119 forest beneficiaries were subjected to directed content analysis and identification of potential issues were done with coding and frequency count method.
- In relevance with the third prioritized component (embankment protection), the study primarily examined the ongoing 'Sundarban Embankment Reconstruction Project' through the lens of a 'socio-technical framework' for long term embankment sustainability. The

study was conducted by interviewing the concerned government officials from the Irrigation and Waterways Department. Specific enquires were made on the design parameters, construction methods, fund availability, operation and maintenance etc. A wide array of design data, including the engineering drawings of the proposed embankments were also collected. The information obtained from the interviews were later validated in terms of their long-term sustainability through interview of local experts, including persons from hydrogeological, social and administrative background with extensive working experience in the delta.

- In order to satisfy the last objective, the research findings obtained from the above exercises were shared with the relevant stakeholders in a stakeholder's interface workshop held in Kolkata on 5th December, 2014. The workshop was held in association with South 24 Parganas District Authority with participation of the BDOs from the Sundarban Region, academia and researchers from local universities, community representative and members from local NGOs. The 'Research Summary' report was published encompassing the key research findings and recommendations (Can be downloaded from http://www.filedropper.com/sundarbanresileincestakeholderbriefing). Feedbacks were gathered on the specific research findings and observation, suggestion, and recommendations from all the stakeholders were carefully noted. In the later stage, these recommendations were further refined and were translated to a 'No-regret' risk reduction strategy for the study area.

Key Finding of the Research

- The index based composite scores of community resilience in the Indian Sundarban delta were found to <u>vary between 2.51 and 3.63 in a five-point Likert scale</u>. Out of the existing 19 coastal blocks, only <u>one could be classified as 'high' resilient block (Mathurapur I) and the rest were found to be in the 'low' and 'moderate' resilience categories</u>. In general, majority of the extreme coastal blocks, that are situated against the open sea, were found to be poorly resilient. Nevertheless, this is not only a result of their 'high exposure' (i.e. poor natural resilience), but also the lack of other essential capacities such as poor socio-economic conditions, infrastructural deficits and improper and ineffective management of coastal resources. In particular, the study observes high correlation between the composite resilience scores with institutional resilience (r=0.80) leading to the realization of the importance of local institutions (*block offices and village panchayats*) to foster disaster and climate resilient communities. Nevertheless, the study also observed an unprecedented human and physical developmental deficits such as primitive communication, lack of livelihood options, high resource dependency, lack of access to water and sanitation etc. In summary, this index based resilience assessment provided a decent starting point to methodically delineate the study area according to its existing resilience profile.

- The results obtained from the indicator based assessment of coastal community's resilience through the five dimensional 'Coastal Community Resilience Assessment Framework' provided an overall impression of the existing lacunas, especially in-terms of its socio-economic, physical, institutional, ecological and disaster risk management capacities. However, this assessment was based on the survey inputs received from the block officials, therefore, scores and specific weightage assigned to each indicator is mostly the reflection of the local institutions rather than the community in question. Additionally, some of the demographic and geographical data such as land use were significantly outdated. Considering the above, 'Participatory Action Planning' was conducted with the 'Aila' affected communities to identify the specific indicators, tasks and corrective actions.

Based on the extensive PRA exercises, the study could identify some commonly prioritized tasks across the four surveyed blocks, i.e. 'Enhancing Livelihood resilience', 'Enhancing safe mobility' (Transportation), 'Develop improved source of drinking water', 'strengthen the embankment network' and 'Conservation, Protection and Restoration of Mangroves'. Although, the study observed significant variation among the prioritized tasks and actions, and argues that <u>disaster and climate resilience is essentially a property of place</u>, the above mentioned tasks remains important irrespective of locations. In general, these prioritized tasks indicate the high developmental deficits that remain as the signature characteristics of the delta. On the other hand, the survey results also suggest that the communities, in general, are highly aware of the benefits of the mangrove forests. This was widely reflected from their affiliation to mangrove based corrective actions such as barrier plantation in front of embankments, mangrove plantation for flood risk reduction and erosion control in open areas. <u>In addition, the study observed a close nexus between livelihood, embankment and mangrove conservation in the backdrop of the devastation caused by the cyclone Aila.</u> This nexus arises from the failure of the unprotected earthen embankments and consequently saline water flooding of low-lying agricultural lands. As have been revealed by the communities, massive disruption of coastal agriculture for consecutive years led to significant stress on the mangrove ecosystems since communities were impelled to violate forest laws and penetrate the restricted areas. This, in turn, results in further degradation of the mangroves, limiting its role in embankment protection, flood control and livelihood sustainability. Hence, considering this close nexus, these three indicators were further chosen for detailed action planning.

- With respect to the livelihood sustainability of the coastal communities, FGDs with the local farmers identified a total of eleven adaptive/coping methods that can be applicable against the current and projected agricultural adversities. These were grouped as <u>three behavioral adaptation measures, seven technical adaptation measures and one institutional adaptation option.</u> Among these adaptive/coping options, the follow up questionnaire survey indicated that the intentions and ability to adapt varies at individual level. Hypothesis testing through χ^2 test and Freeman Halton Extension of Fisher Exact Test reveals a statistically significant ($p<0.05$) difference among three farming groups in intention to adapt (in case of 8 out of the 11 potential adaptation/coping options). The result from the survey also suggests that <u>small farmers largely wished to cultivate salinity resilient rice varieties, construction of irrigation facilities and dual use of agricultural lands. Similarly, marginal farmers also mentioned about construction of irrigation facilities and salinity tolerant rice varieties, however, put additional priority on dual use of agricultural land. On the other hand, most of the agricultural labors prioritized cultivation of salt tolerant species, dual use of agricultural land and migration to different places as their potential adaptation options.</u> Nevertheless, the study also observes the lack of physical infrastructures, technical and financial capacity as the major constraint for infusing these adaptive options in the existing agricultural practices. With respect to inland and estuarine fishermen, similar participatory exercises revealed six potential corrective (adaptive) actions; of which, <u>cultivation of fresh water aquaculture</u> (e.g. *Telapia sp. etc.)* <u>and diversification to non-fisheries based livelihood such as goatery etc</u>. have been found to have major applicability in ensuring the livelihood sustainability of the fishers. Similar to the farmers, fishermen also mentioned about their technical and financial inability to incorporate the adaptive measures.

- Investigation over the existing ecosystem based incentives and extent of community participation reveled a precariously safety-margin based incentive design approach which largely restricts the overall goals and objectives of JFM. The study observes, although the existing restrictive policies are in line with the overall conservation goals of the government, it severely impairs effective participation from the communities. <u>In general, the study observes that the forest dependent communities are bifurcated into supporters (e.g.</u>

agricultural communities, forest product collectors, tourist operators) and criticizers (e.g. Fishermen, prawn seed collectors), and the division has strong correlation with the share of household income derived out of forest benefits. In particular, perception generally tends to be negative (anti-institutional) with greater degree of dependence on mangroves. For example, more than 70% of the household income of the fishermen and 100% of the household income of prawn seed collectors are derived from the mangrove waters. In addition, multitude of other factors, such as lack of market and poor pricing of forest products, territorial rights are identified to play a significant role in shaping user perception. Given the existing complexity of the stakeholder's interests where collective consensus is barely reached, the study argues that the long term sustainability of the existing JFM arrangement is questionable. The study recommends the need of more competitive incentives through calculation of maximum sustainable yields of fish and other products and a bottom-up, need based incentive design. Alternatively, non-forestry based provisions such as direct monetary provisions or developmental incentives (e.g. construction of sluice gates, ponds, rural infrastructure, small scale jobs, alternative livelihood etc.) can be used to complement the mangrove based incentives in order to achieve better community participation in the existing JFM arrangements.

- The evaluation of 'Sundarban Embankment Reconstruction Project' through the lens of the proposed 'socio-technical' framework reveled that the reconstruction of the earthen embankments mostly fulfills the minimum desired technical requirements. For example, safety factors/aspects considered for construction material, embankment height, width and wind speed durability, barrier plantation is within the range of 'moderate' to 'good'. However, in terms of institutional and social factors, monitoring and maintenance of these extensive earthen embankment network, emergency land acquisition and livelihood interests remain the key attributing factors for the long term sustainability of these extensive earthen embankments. In order to overcome these challenges, the study recommends to establish a participatory embankment monitoring mechanism (such as village embankment committee), formulating an appropriate land acquisition law, rerouting cargo ships and establishment of a reliable funding mechanism for the sustainable management of these extensive coastal infrastructures. In addition, it also remains imperative to extend the current embankment reconstruction program beyond the damaged embankments (778 km) in the cyclone Aila.

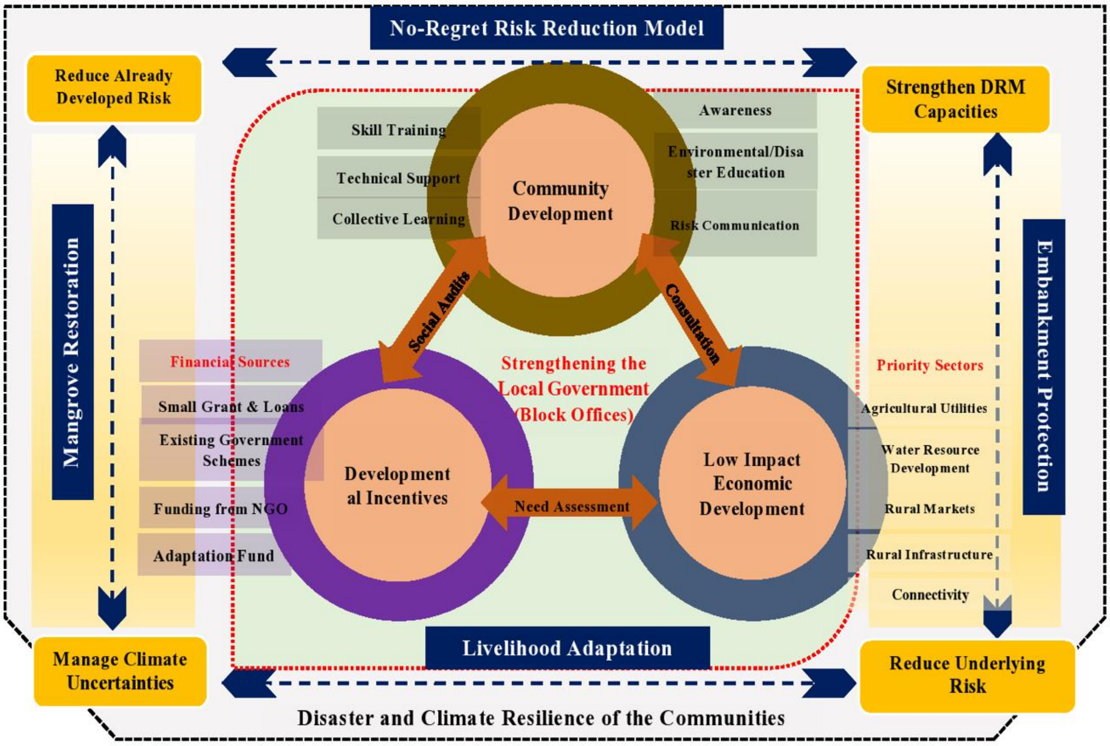


Figure E.1. 'No-Regret' Model for Disaster and Climate Risk Reduction Strategy in the Indian Sundarban Delta

- They study principally realizes that the observed poor resilience of the communities is the result of extensive human and physical developmental deficits that not only increases the susceptibility to coastal hazards and results in poor recovery from the impacts of Aila, but also exerts significant stress on the biotic and abiotic resources of the delta. In order to overcome these deficits (factors related to basic vulnerability of the communities) and to enhance community's coping capacities (capacities to minimize the impacts of future disasters), the study, essentially proposes a 'No-regret' risk reduction model for the Indian Sundarban delta. As have been hypothesized in the 'No-regret' doctrine, these model essentially rely on minimal capital investments and refrains from the major alteration of societal structures and livelihood profile. On the contrary, this model essentially advocates for implementing a risk sensitive, low impact economic development strategy which depends on combining social and ecological engineering for fulfilling the current developmental deficits as well as to minimize the existing and future risks (including ecological, disaster and climate risks). The above figure outlines a schematic flow of the suggested 'no-regret model'. Although, this model is conceptualized based on the key research findings, the study argues, that the suggested risk reduction strategy needs to be customized at the local government level, especially at the block level in order to produce most effective results. A brief narrative of this 'no-regret' risk reduction model is provided in the following paragraphs.

- As depicted in the figure E.1., the model is comprised of four essential risk reduction components based on the recommendation furnished in the recently concluded Sendai Framework for Disaster Risk Reduction (SFDRR), i.e. **(a)** ***Reduce already Developed Risks-*** which is mostly the current human and infrastructural developmental deficit (i.e. factors leading to poor recovery from 'Aila'), for example, reduction of poverty and improving economic alternatives and secondly, mangrove restoration in the reclaimed and degraded areas ***(b) Strengthen the Disaster Risk Management (DRM) components***, particularly the monitoring and maintenance of the the embankments and develop a culture of preparedness through appropriate community development ***(c) Reduce the underlying risk factors***, i.e. mostly controlling the risk of future embankment failure and restricting further degradation of mangrove ecosystem services and lastly, (***d) Managing the future uncertainties***, mainly focusing on implementation of planned adaptation process for sustainable livelihood, long-term management of earthen embankment systems etc. In order to implement this model, the study proposes a theoretical implementation strategy which is essentially divided into three components, i.e. **Low Impact Economic Development (LIED), Developmental Incentives and Community Development.** LIED is known to be an alternative economic development approach that is intended to reduce the adverse ecological impacts and utilize the ecosystems or environmental services for the betterment of the communities. The superiority of LIED over the conventional high investment based development approach can be broadly summarized in its low capital investments and '*building with nature'* principles. In addition, LIED, in general, has greater social acceptability, since, it does not aim to alter any massive changes in the social structures, community profile and livelihood etc. In addition, the implementation mechanism is mostly participatory and envisages active community participation. Based on the research findings, the study identifies the key sectors where small capital investment can bring about the desired changes. These sectors are (a) Strategic investments in agricultural utilities (mostly to facilitate planned adaptation process) (b) Water harvesting structures (to solve the acute water shortage for agriculture and other uses) (c) Connecting rural producers to urban markets (to enhance profitability) (d) Improvement of rural connectivity and (e) betterment of existing rural infrastructure. The second part of the model, i.e. 'Developmental Incentives' is the backbone of this model and the study argues, that the proposed LIED should not only rely on capital investments, but also make necessary arrangement for providing developmental incentives to the community. The incentives should aim at individual or community groups in recognition to their participation in mangrove conservation, embankment protection and plethora of participatory social development projects. A social business approach may be high imperative. The incentive may include monetary and non-monetary support in form of (a) Small grants and Loans (b) Proper utilization of government schemes (c) Funding support from the NGOs (d) funding through a dedicated adaptation fund to enhance community livelihood and economic gains. The last component of this model is essentially aimed to 'community development'. This can be done through imparting environment and disaster awareness, skill training for the development of alternative livelihood, technical support for promoting research-led adaptation programs and lastly, by establishing community based risk communication and collective learning platforms. As have been mentioned, the intended implementation of this model is aimed at the local government, especially at the block level. Therefore, empowering and strengthening the local government (especially block offices and panchayats) remains highly imperative in the backdrop of the current study.

- **Research Implications and Way Forward**

The study took a participatory approach to enhance community's disaster and climate resilience in Indian Sundarban Delta, assuming that the communities are the best judge of their risks and are capable of managing their risks, given sufficient knowledge and resources are provided to them. Contrary to a hierarchical risk reduction approaches, the research steps used for this present study essentially relies on community perception and intended actions, thereby, attempts to utilize the 'no-regret' doctrine of disaster/climate risk reduction for designing a local level risk reduction strategy. In general, the research implication can be summarized as the development of an ameliorative resilience assessment framework capable for measuring coastal community's resilience, community based identification of potential tasks and corrective actions, development of a planned adaptation strategy for coastal farmers and fishermen, strategies for improving the existing participatory mangrove management mechanism and rudimentary action plan for strengthening the extensive earthen embankment network. Although, the current research finding are site specific, the research results have several implications in Indian Sundarban and beyond. In particular, the study can be used as a baseline and reference for several other vulnerable mega-deltas in Asia or across the world.

The research outcome has also highlighted a number of information gaps and potential areas for future research. For example, on the scientific front, future research should identify the possible changes of mangrove ecosystem services and its impacts on the community. Additionally, there is also a requirement to better quantify the current sea level rise and it potential impacts on the delta. On the other hand, apart from the geo-morphological changes, research should also focus on developing locally applicable high yielding, salinity tolerant rice varieties, sustainable prawn cultivation methods etc. In the policy research domain, one important aspect of future research would be assessing the effectiveness of local conservation policies including the utility and effectiveness of vast protected area network, management policies for controlling upstream pollution, developing strategies to control migration from across the international border etc. Above all, the thrust area of the policy research should remain on meaningful engagement of local communities in regional development process.

***

CHAPTER 1: Introduction

'There's an awful temptation to just keep on researching. There comes a point where you just have to stop, and start writing.'- David McCullough, US Historian

CHAPTER 1: Introduction

This chapter is introductory in nature and provides a brief description of the overall research framework. It illustrates the backdrop of the current research through a detailed account of exceptionally high disaster and climate vulnerability of the Asian Mega Deltas. Thereafter, the chapter provides the justification for choosing the Indian Sundarban delta as the research location and delivers an in depth review of existing scientific knowledge of disaster and climate risks of the Indian Sundarban Delta. The chapter also narrates the research objectives and questions along with a brief description of the adopted research methodology and structure of this thesis.

Outline of the Chapter 1

1.1. Background and Problem Statement

Our world is essentially a coastal planet with nearly 1,634,701 km long coastline that marks the boundary between the land and the sea (Burke et al. 2001, Martínez et al. 2007). As civilization blossomed in the fertile coastal plains, for over thousands of years, coastal areas across the world have served as economic turbine of human societies and continues to do so. The thriving economic opportunities have lured communities to migrate coastward. No wonder, the world is extremely crowded along its coasts, accommodating nearly 41% of the global population (Martínez et al. 2007). Over the past three decades, world's coastal populations have increased globally from 1.6 billion to over 2.5 billion (Barbier 2015). It is further expected to rise up to 3.1 billion by the end of 2025; an increase of nearly 34% from its earlier assessment in 2000 (Duxbury and Dickinson 2007). As a matter of fact, 12 of the world's 16 megacities (with populations more than 10 million) are located within 100 km from the coast. Despite of such tremendous and diverse economic opportunities, coastal settlements, irrespective of their location in developing or developed countries, continue to struggle against series of seaward hazards that often disrupt human societies jeopardizing economic development and human sustainability. Needless to say, being at the juncture of the land and sea, constantly shaped and reshaped by the powerful tides and winds, coastal areas have certain intrinsic vulnerability that the communities are compelled to live with.

1.1.1. Coastal Disasters and Human Sustainability

Since the last three decades, statistical evidences indicated an escalating rise of natural disasters across the globe. As shown in the **Figure 1.1.**, hydro-meteorological disasters such as flooding and storms constituted the largest share of the natural disasters over the previous years. Helmer 2006 mentioned that hydro-meteorological disasters, such as floods, storms and wet mass movements accounted for nearly 90% of the disasters encountered in the last decades. Much of the impacts of these disasters are concentrated along the coasts. Although, the blessings of advanced technology and early warning systems have largely restricted the loss of precious human lives in recent years, economic damage to natural disasters still continues to escalate. Coastal areas also remain at the forefront of economic damage caused by natural disasters. Rough estimation shows that nearly 60% of the economic damage triggered by natural disasters have been localized in the coastal zones (Helmer 2006). For example, the two costliest disasters in the recent years i.e. Hurricane Katrina (2005) and East Japan Earthquake & Tsunami (2011) had strong coastal connection.

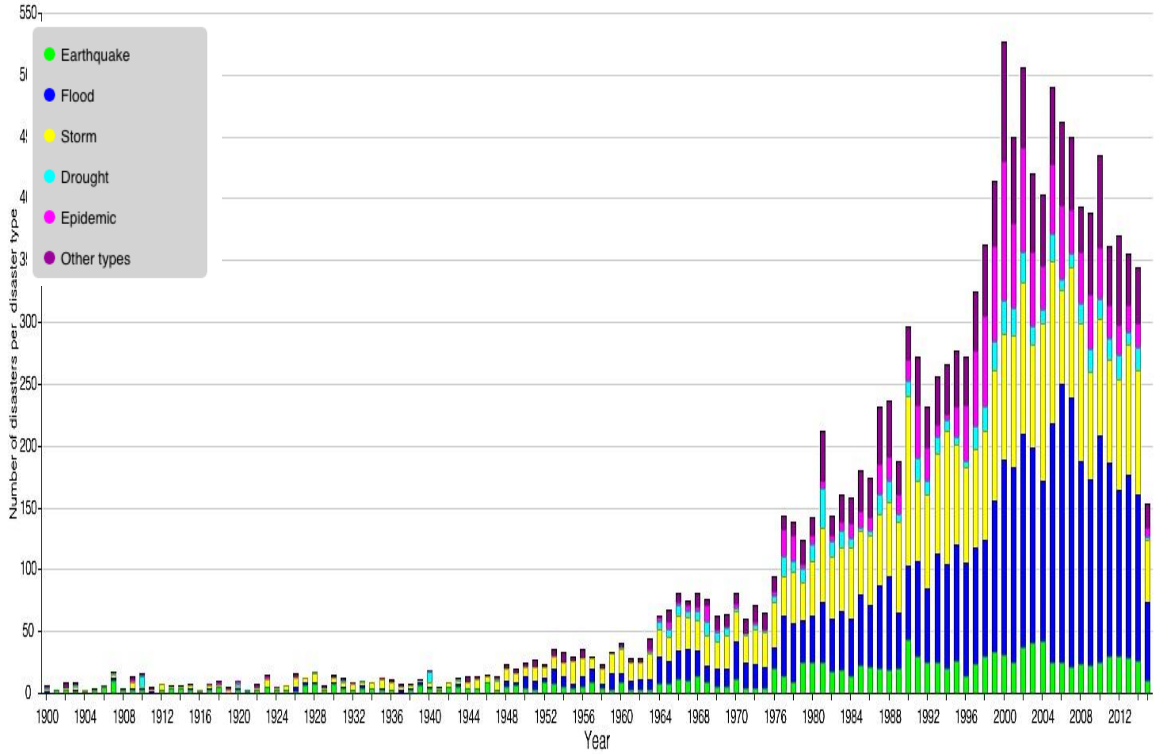


Figure 1.1. Trend of Natural Disasters from 1900-2014, *Source: EM-DAT Global Database*

While the world's coast continues to become crowded as more and more people migrate towards the coast, human sustainability in coastal areas remain at a critical juncture as the threats of seaward hazards continue to rise under the influence of global climate change. Nevertheless, this is being escalated not only by the global sea level rise and associated environmental changes, but also from unplanned and rapid coastal development, diminishing the natural ecosystem services in the coastal areas. It is imperative to mention that, no other place in the world has changed so much as it's coasts because of thriving economic development. Despite of the fact that there exists large amount of uncertainties in absence of precise and accurate predictions, climate change is most likely to compound the existing scenario of coastal disasters- mostly in a negative way, impounding human lives and development. For example, the mean maximum speeds of tropical cyclones are predicted to increase by 2 to 11 % by the next century; rainfalls are likely to intensify by 20% within 100 km of the tropical cyclone centers (Knutson et al. 2010). Additionally, scientists estimated an accelerated rise (3.3 ± 0.4 mm/year) in global sea level since 1993 compared to their earlier estimation (1.7 ± 0.3 mm/year). Despite of some suspicions, it is believed that global sea level will continue to rise and may increase by 30 to 180 cm by the end of 2100 (Nicholls and Cazenave 2010). Needless to say, the predicted impacts will bring awful consequences for millions of people living besides the sea, and particularly for those who live in Low Elevated

Coastal Zones (LECZ) or small islands, irrespective of their location in the tropics or at higher latitudes (Mimura et al. 2007).

LECZ denotes specific areas up to 10 m elevation in coastal areas (McGranahan et al. 2007, Vafeidis et al. 2011) and constitutes 2% of the world's land area. Yet, LECZ hosts nearly 10% of the world's population including some of the world's largest mega cities (McGranahan et al. 2007). Much of the classified LECZ are confined in the large river deltas which are traditionally prone to coastal disasters such as flood, cyclone and storm surges. Syvitski et al., 2009, based on their comprehensive study conducted over 33 deltas across the world, mentioned that 85% of the existing deltas had experienced severe flooding in the past decade, causing temporary submergence of nearly 260,000 km^2 coastal areas (Syvitski et al. 2009). They further mentioned that the vulnerability of coastal flooding in these deltas is most likely to increase by 50% under the projected sea level rise scenario for 2100 - putting the delta dwellers, particularly in Asia, at an unparalleled risk of coastal flooding. In lieu with this, deltas have been traditionally prone to tropical storms and surges and there are also growing evidences for a future shift in the average global intensity of tropical cyclones towards stronger storms (Woodruff et al. 2013).

1.1.2. Disasters in Asian Mega delta

Out of a global population of 634 million people living in the LECZs, an estimated population of 466 million live in the LECZ of Asia. The LECZ in Asia predominantly includes heavily populated large river deltas located at the confluence of the mighty Asian rivers and the sea. As per the existing literature, there are nine deltas that has been classified as mega-deltas within the geographical territory of Asia. These heavily populated delta plains are located at the mouths of the large rivers such as Indus, Ganges-Brahamputra-Meghna (GBM), Irrawaddy, Chao Phraya, Mekong, Red (Song Hong), Pearl (Zhujiang), Chiangjiang (Yangtze) and Huanghe (Yellow) Rivers (Woodroffe 2010). Most of Asian coastal mega-cities (those with a population in excess of 10 million people) are located in these deltas and the entire urban population of these nine mega deltas are estimated as 354 million (Chan et al. 2012). India and Bangladesh are the two countries having the largest populations living within the designated low-elevation coastal zone, predominantly in the large river deltas. In India, approximately 63 million people (nearly 6% of the total population) lives in LECZ, while in Bangladesh nearly 62 million people (46% of the entire population) lives in the same. However, what is significant to mention is that, in contrast to deltas in the other continents, the Asian Mega deltas consists

Table 1.1. Population Density and Relative Vulnerability of Asian Mega Deltas

Mega Delta	Location and standing water body	Country	Area in sq. Km	Major Settlement Type	Population in 2000	Population in 2015	Population Density (Annual Growth Rate)	Vulnerability to Climate Change According to IPCC AR 4
Indus	Arabian Sea	Pakistan	19,800	Semi urban/Rural	3058500	4,425,100	223/sq.km (3%)	Medium
Ganges-Brahmaputra-Meghna	Bay of Bengal	India, Bangladesh	115,600	Rural	12931100	166,217,000	1438/sq.km (2%)	Extreme
Irrawaddy	Andaman Sea	Myanmar	31,500	Rural	10591700	12,163,600	386/sq.km (1%)	Not mentioned
Chao Phraya	Gulf of Thailand	Thailand	11,600	Urban/Semi-Urban	11485600	16,487,900	1421/sq.km (3%)	Medium
Mekong	South China Sea	Vietnam	37,900	Rural	15754200	19,039,800	502/sq.km (1.5%)	Extreme
Red (Song Hong)	Gulf of Tokin	Vietnam	9,900	Urban/Semi-Urban	13293900	16,063,400	1622/sq.km (1.5%)	Medium
Pearl (Zhujiang)	South China Sea	China	5,900	Urban	9846400	27,166,900	4605/sq.km (11.7%)	Not mentioned
Chiangjiang (Yangtze)	East China Sea	China	15,600	Urban	25945700	33,147,500	2124/sq.km (2%)	High
Huang he (Yellow River)	East China Sea	China	25,100	Urban	14060400	16,614,100	661/sq.km (-1.5%)	Not mentioned

Source: Compiled from Ericson et al. 2006, Chan et al. 2012, IPCC AR 4 a large amount of rural population and extensive farmlands for agriculture. Table **1.1.** lists the current status of these nine Asian Mega deltas with population density and predominant type of settlement. Mega-deltas like GBM delta, Irrawaddy, Mekong were historically reclaimed to promote coastal agricultural by deforesting huge tract of mangroves, and over the years, these areas were predominantly occupied by large farming communities. In particular, the GBM delta, Irrawaddy and Mekong are traditionally known for its productive agricultural land and rural resource dependent communities. However, these deltas have also been historically prone to coastal disasters, particularly from storms and associated surges, coastal flooding and tidal inundation during the monsoons. In particular, deltas surrounding the North Indian Ocean is well known for their traditional vulnerability against tropical cyclones. For example, nearly 7% of the world's deadly storms have originated from the Bay of Bengal (Alam et al. 2003). In fact, the history of cyclone devastation in the river deltas surrounding the Bay of Bengal can be traced back as early as eighteen centuries (e.g. The Great Calcutta Cyclone in 1737 which resulted in loss of 30,000 lives). In addition, a rough compilation of the number of casualties against the tropical storms shows an exceptional high loss of life in India and Bangladesh over the years. For example, Bangladesh lost nearly 930,000 lives due to cyclones from 1822-1991, while, India lost over 800,000 lives due to storms over the last two centuries.

Historical data retrieved from Indian Meteorological Department (IMD) reveals that during the period of 1890 to 1989, there have been 236 cyclonic storms originated from the North Indian Ocean, while nearly 80% of the storms were formed over the Bay of Bengal. More recent data, i.e. from 1990-2015 (*after the introduction of IMD Tropical Cyclone Intensity Scale*) shows an escalated figure of 98 cyclonic storms, 55 severe cyclones, 35 very severe cyclones and 4 super cyclones in a span of 25 years. Much of the impacts of these cyclones have been concentrated in these low-lying deltas. Here it is important to mention that, nearly 80% of the damage caused by the cyclones have been actually caused by the storm surge inundation, to which these deltas are typically prone. **Table 1.2.** provides an account of some of the deadly cyclones of recent years originated from the Bay of Bengal which unanimously establish the exceptional vulnerability of deltas in the North Indian Ocean. Further, Syvitski et al., 2009 argued that the vulnerability of the deltas surrounding the North Indian Ocean have increased drastically in recent years due to lesser accumulation of sediments and an overwhelming rate of relative sea level rise. This has been the result of premature land reclamation and restricting fresh water flows by large dams and reservoirs, and as a consequence, communities living in the extreme coastal areas of these delta now live with unprecedented risk of seaward hazards.

Table1.2. Major Tropical Storms originated from the Bay of Bengal in last Two Decades

Cyclonic Storms	Category/Maximum Sustained Wind speed (in km/h)	Surge Height	Area of Landfall	Casualties	Economic Damage (Approximate in USD)
1990 Machilipatnam Cyclone	Super Cyclone 235 km/h	Not Known	Edurumandi Islands in Krishna Delta of Andhra Pradesh in India	967 people died	$600 million
1991 Bangladesh cyclone	Super Cyclone 250 km/h	6 meters	Chittagong Division, worst hit Swandip Islands of Bangladesh (Estuary of Meghna River)	138,000 (Dead), Over 10 million homeless	$1.5 billion
1999 Orissa Cyclone	Super Cyclone 260 km/h	8 meters	Paradip Coast in Orissa, India	9,803 (Dead), 1.67 million people affected.	$4.5 billion
2007 Cyclone Sidr	Super Cyclone 260 km/h	4 meters	Sundarban in Bangladesh and several coastal districts of GBM Delta	3,447 dead	$3.1 billion
2008 Cyclone Nargis	Extremely Severe Cyclone 165 km/h	3 meters	Irrawaddy Delta in Myanmar, especially Labutta Township	>138,000 dead	$10 billion
2009 Cyclone Aila	Severe Cyclonic Storms 110 km/h	5 meters	Sundarban Delta in both India and Bangladesh	345 dead, 4 million affected	$618 million
2014 Cyclone Phailin	Extremely Severe Cyclone 215 km/h	1 meter	Orissa and Andhra Pradesh in India	46 dead	$1.5 billion

1.1.3. Disaster and Climate Vulnerability of the GBM Delta

Densely populated deltas such as the Indus Delta, Ganges-Brahmaputra-Meghna (GBM) delta, Mekong, Chao Phraya, Irrawaddy, Huanghe (Yellow), Changjiang (Yangtze), Zhujiang (Pearl) and Song Hong (Red) are key societal hotspots of coastal vulnerability and receives high exposure from seaward hazards. All these deltas are vulnerable to frequent storms and floods which will most probably intensify with global climate change. Yet, despite of the fact that striking similarities exist among these Asian deltas, the GBM Delta stands out far in terms of relative vulnerability. The IPCC Fourth Assessment Report put the GBM delta as 'extremely' vulnerable comparable to other Asian mega-deltas against the impacts of climate induced global sea level rise and possibility of large scale displacement (***see*** **Table 1.1**.). This has been time and again highlighted by different researchers and international developmental agencies, and, in particular, the high vulnerability of the Sundarbans in Bangladesh is well documented compared to the Indian side. Nevertheless, the following factors can be held responsible for high disaster and climate vulnerability of the GBM delta.

- Firstly, the GBM Delta consists of nearly 100 million people, of which, approximately 80% of the population are predominantly rural resource dependent communities. Leaving aside the mega cities such as Kolkata (Calcutta) and Dhaka, the rural population density within the GBM Delta (both in India and Bangladesh) is unprecedented and the measured population density is well over 1000 person/sq. km. In addition, majority of these communities live with dire poverty. More so, extreme remoteness associated with their existence make them typically vulnerable to coastal hazards.

- Secondly, the delta is undergoing rapid subsidence, much faster than the other mega-deltas in this region. Despite of wide uncertainties and absence of reliable data, Syvitski et al. 2009 and Brown & Nicholls 2015 mentioned the GBM Delta is probably subsiding at the rate close to 5-8mm/year. This also implies faster inundation under the rising sea which is measured around 5 mm/year, significantly high compared to an overall 2 mm/year sea level rise in the North Indian Ocean.
- Accelerated compaction of the GBM Delta, as highlighted by Syvitski et al. 2009, is also another factor that makes the GBM Delta exceptionally prone to disasters. The average elevation of this delta is 2 to 5 meters, while extreme coastal areas in the southern tip of the delta has already went under the high tide level. At present, tidal inundation is restricted by extensive earthen embankment or polder network, however, these systems are not very reliable to protect the delta against storms or heavy tidal surges.
- Large deltas survive on the heavy sediment loads carried out by the rivers from the upstream. However, huge reduction in freshwater flow into the GBM Delta has been referred as a serious factor behind the high rate of coastal erosion and changes in hydrological and salinity regime. In particular, many researchers from Bangladesh have highlighted dramatic reduction of fresh water flow due to the construction of Farakka Barrage in the upstream of the Ganges.

1.2. Research Location and Its Significance

The present research is conducted in the southern extension of the tidally active GBM Delta, popularly known as the Sundarban Delta. It spreads across 25,000 sq. km. and is disproportionately shared between India (38%) and Bangladesh (62%) (**Figure 1.2**). The present research, however, is conducted over the Indian counterpart, which consists of 102 low-lying deltaic islands in the south western fringe of the Ganges Brahmaputra Meghna (GBM) delta (as shown in **Figure 1.2**). The Indian Sundarban spreads across nearly 10,000 sq. km and is confined between 21°32′ to 22°40′ Northern Latitude and 88°05′ to 89°00′ Eastern Longitude. The boundary is roughly demarcated by the river Hooghly on the west, the Bay of Bengal on the south, the Ichamati-Kalindi-Raimongal Rivers on the east and by an imaginary line (Dampier & Hodge Line) drafted by Mr. Dampier and Lt. Hodge during 1829 to 1830 to separate the rich mangrove forest inhibited islands (Banerjee 1998). Historically, the entire extent of Indian Sundarban used to be under dense mangrove forests, however, over the years, 54 islands were reclaimed for agriculture, and as a result, human settlements and farmland replaced its historical landscapes (see Chapter 6 for historical extent of mangrove forests and the history of land reclamation).

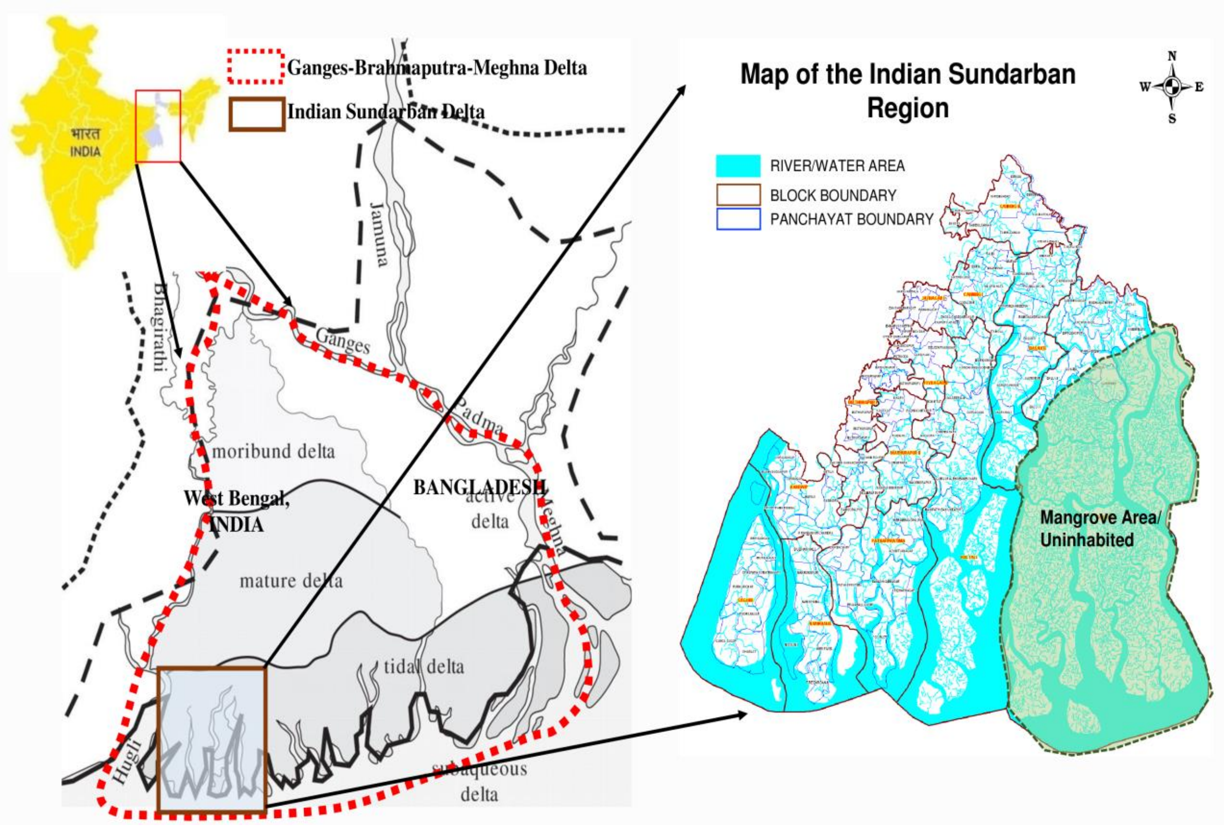


Figure 1.2. Location Map of the Study Area: Indian Sundarban Delta

1.2.1. Administrative, Demographic and Social Scenario

In an administrative hierarchy, Indian Sundarban is further categorized into 19 Coastal Developmental Blocks (smallest administrative units in India); of which 13 are in the district of South 24 Parganas and 6 are in the district of North 24 Parganas in the eastern Indian province of West Bengal. All of these coastal blocks are the parts of the active tidal delta which were prematurely reclaimed nearly two centuries ago and still undergoes natural erosion and accretion under the influence of innumerous tidal creeks and channels. A network of nearly 3500 km long earthen embankments protects the reclaimed areas from the diurnal tides. On a socio-economic perspective, Indian Sundarban hosts a predominate rural population of 4.37 million people with a staggering density of 957 persons/sq.km (as per the latest census of 2011).

Although historically these areas were occupied and deforested for agriculture, such a high density of rural population can be attributed to sudden influx of population, mainly due to cross border migration after the independence and partition of the British India (1947) as well as during the Bangladesh’s war of independence (1971). Nearly 36.5% of the existing population belongs to Scheduled Tribes and Scheduled Castes (SC & ST), significantly higher compared to the provincial average of 25.61%. In terms of livelihood, 90% of the population, directly or indirectly survives on mono-crop rice cultivation. However, within this community, a significant population is additionally involved in estuarine and deep sea fishing, forest product collection, tourism (especially boat driver and operators) etc. Despite agriculture being the primary livelihood of the delta, nearly 54% of the communities are landless. The vulnerable socio-economic scenario can be further justified as 43.5% of the population living in the region are earmarked below the nationally designated poverty line (BPL or Below Poverty Level Population). No wonder, the entire region has been officially earmarked as ‘Backward region’ and the ‘backwardness’ can be attributed to the following social and economic factors.

(a) Despite of recent outward migration, the region suffered from uncontrolled population growth with low income level. For example, population increased from 0.29 million in 1872 to 4.37 million in 2011 (the latest census) with almost an exponential growth rate as shown in **Figure 1.3.** Although, initially the area was reclaimed to increase government revenue under the British India, as depicted in Figure 1.3., a number of geo-political incidence resulted in huge inward migration during different periods of history. Further, inheritance of agriculture lands through generations led to fragmentation of productive lands and to massive poverty of the successors.

(b) The region also suffers from heavy infrastructural deficits. Lack of major industries, electricity and large scale employment opportunities impels the communities to live on natural resources in its crudest forms. Despite of large protected mangrove forests in the eastern part of the Indian Sundarban Delta, people continue to exploit mangrove resources. In addition, lack of irrigation facility essentially compels the communities to survive on rain-fed, mono-crop agriculture.

(c) Out of the 4400 sq.km. of inhabited areas, there is only 42 km. of railway line and about 300 km. of metal roads. In addition, communication between the islands is through the primitive water-transports which is not only poorly organized, but also lacks public safety and security. Hence, scope for outside employment opportunities is heavily restricted.

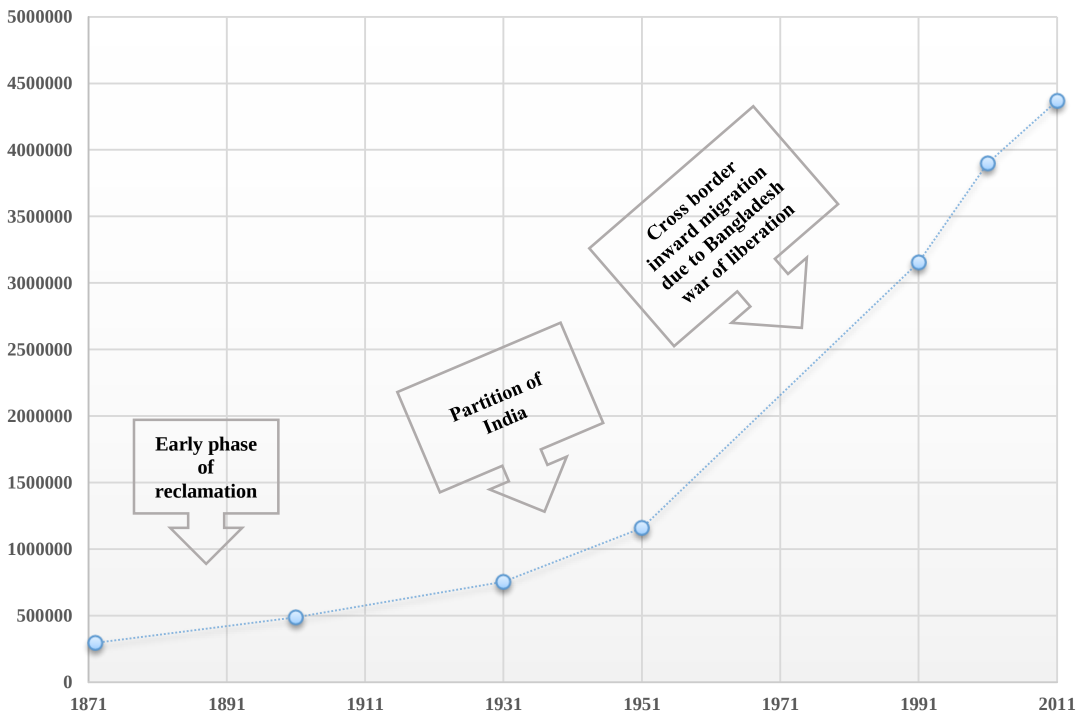


Figure 1.3. Population Growth in Indian Sundarban Delta: Compiled from Various Government Sources

(d) The region is open to the sea, and therefore remain highly prone to cyclones and storm surges. Occasional disasters often lead to temporary flooding, breaching of embankments and salinization of coastal agricultural land. The recent Cyclone Aila, which has been discussed in the following sections, had disastrous consequences on the delta.

(e) The Indian Sundarban delta also remain at the crucial juncture of developmental dilemma, because of its highly fragile mangrove ecosystems. In the past, any large scale developmental program of the Indian Sundarban delta has been powerfully rejected by the Ministry of Environment and Forests (MoEF) considering the fragility of the delta. Although, it can be argued, whether or not, the industrial development is real fit for the delta, this has negatively impacted the infrastructural growth of the delta.

1.2.2. Climate of the Indian Sundarban Delta

The Indian Sundarban Delta experiences a tropical monsoon climate; however, due to its proximity to the sea, relative humidity (>80%) is high almost throughout the year (Banerjee 1998). The summer season usually arrives from middle of March and continues up to the second week of June. Although the average summer temperature remains close to 30°C, yet, the excess humidity makes the summer extremely uncomfortable. Summer season is also characterized by thunderstorm in the afternoon locally known as '*Kalbaishaki'* which results in heavy pre-monsoon rain and significant lowering of air temperature. On the other hand, monsoon starts from middle of June and continues up to the end of September. The economic sustainability of the agro-based societies living in the delta strongly depend on a good monsoon since the majority of rainfall required for rice cultivation occurs within this period. The average annual rainfall in the Indian Sundarban is estimated as 1661.6 mm (Gopal & Chauhan 2006). During the post monsoon season (mid October to mid November), tropical cyclones are very common. The winter exists mostly from December to February and can be characterized by bright sunny days and calm and quiet rivers. A synoptic analysis of the monthly average of maximum and minimum temperate, maximum and minimum relative humidity and rainfall for the past 25 years (1989-2013) is furnished in **Figure 1.4.**

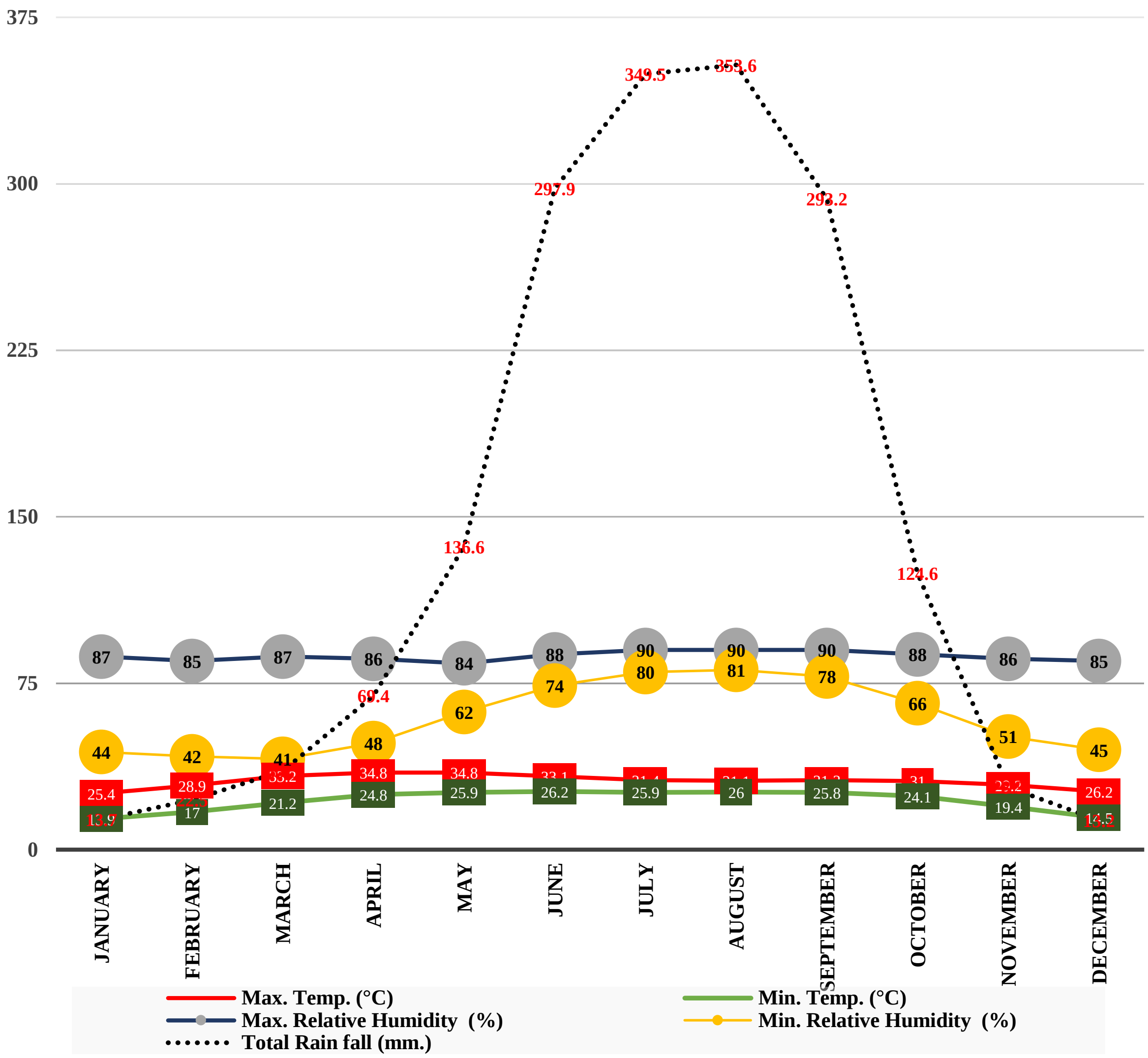
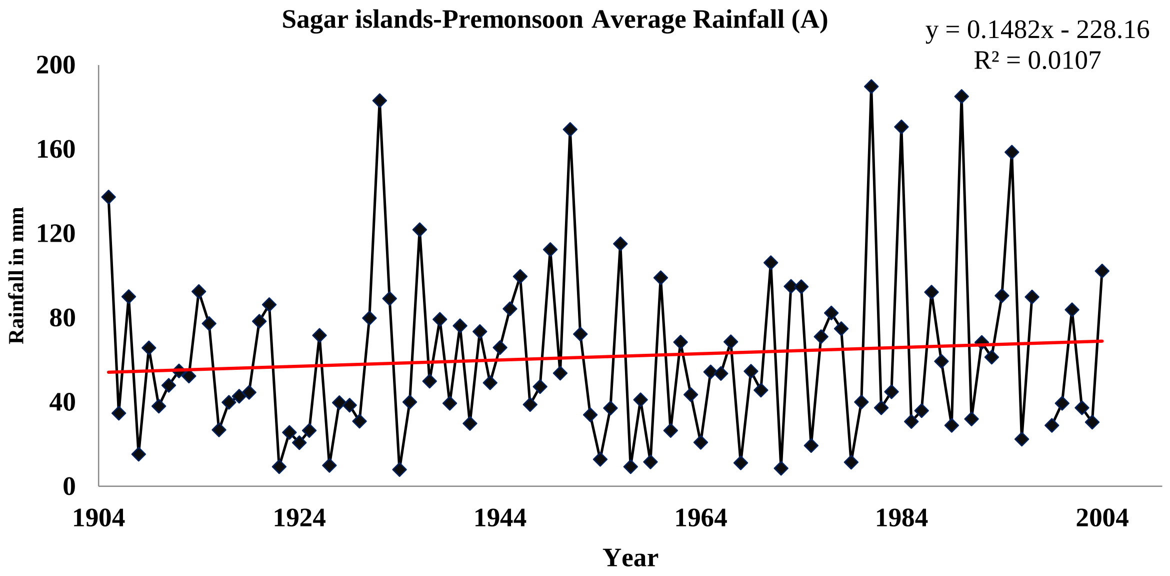
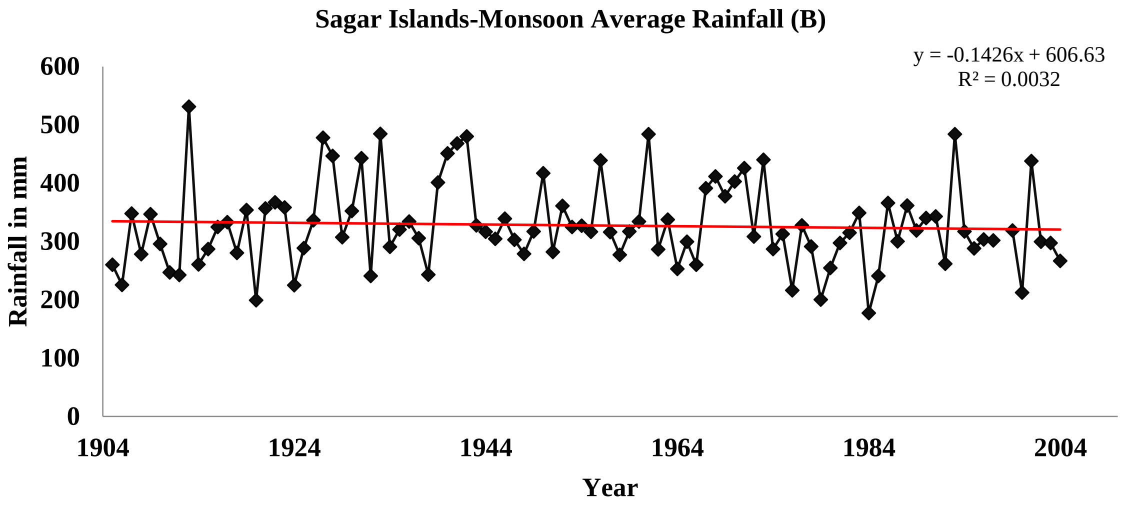
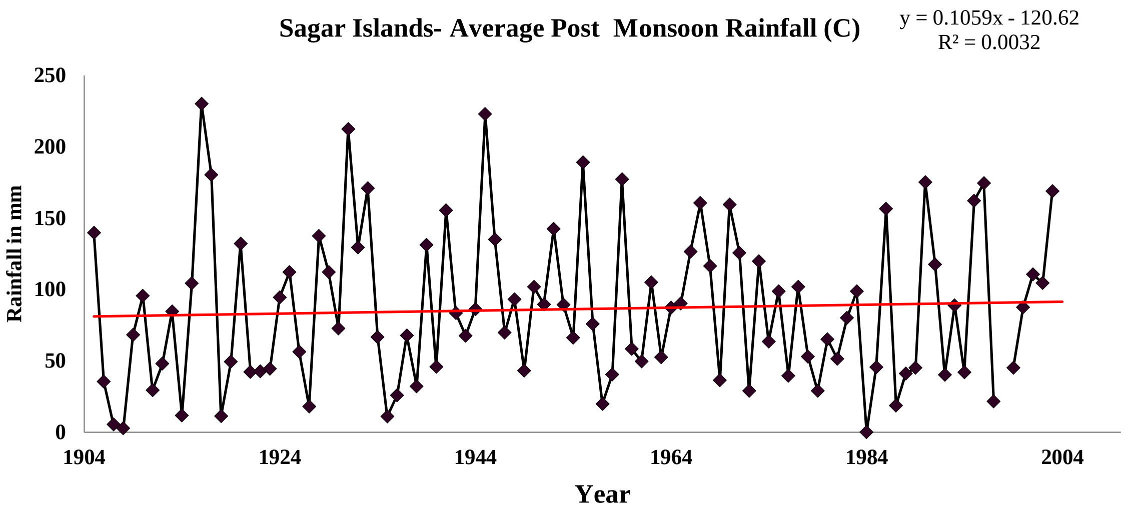


Figure 1.4. Monthly Average Weather Profile of the Indian Sundarban Delta for Past 25 Years (1989-2013), Analyzed from Raw Data Provided by District Authorities, South 24 Parganas

Although the Figure 1.4. is not indicative of any trend, this draws the overall weather profile of the delta. In order to examine the trend of weather, historical data were also collected from the three IMD weather stations in the Indian Sundarban Delta. These stations are located in Canning, Diamond Harbor and Sagar Islands. However, data obtained from IMD for the above stations contained significant bias due to several missing data. Particulalry, the stations located in Canning and Diamond Harbor have been long discontinued, therefore, data obtained from this was not considered as relevant. For the Sagar Island weather station, only rainfall data from 1904-2004 could be recovered. Since rainfall is an important weather parameter considering the agricultural sustainability of the delta, these data were categorized into four seasons (*as per the classification of IMD*) and were carefully analyzed. The seasonal rainfall varriation is furnished in **Figure 1.5. (A-D).** Despite of the fact that the observed trend is statistically insignificant to conlcude any likely changes of seasonal rainfall, a slightly decreasing trend of monsoon average rainfall were observed. However, pre and post monsoon rainfall seems to be mostly unchanged. The same data series, when observed on the monthly basis, shows a slight delay of arrival of monsoon, particulalry lack of rainfall in the month of June and slightly high rainfall in the month of Spetmeber. Despite of this, no statistically significant changes in rainfall pattern have been observed over the 100 years rainfall data.







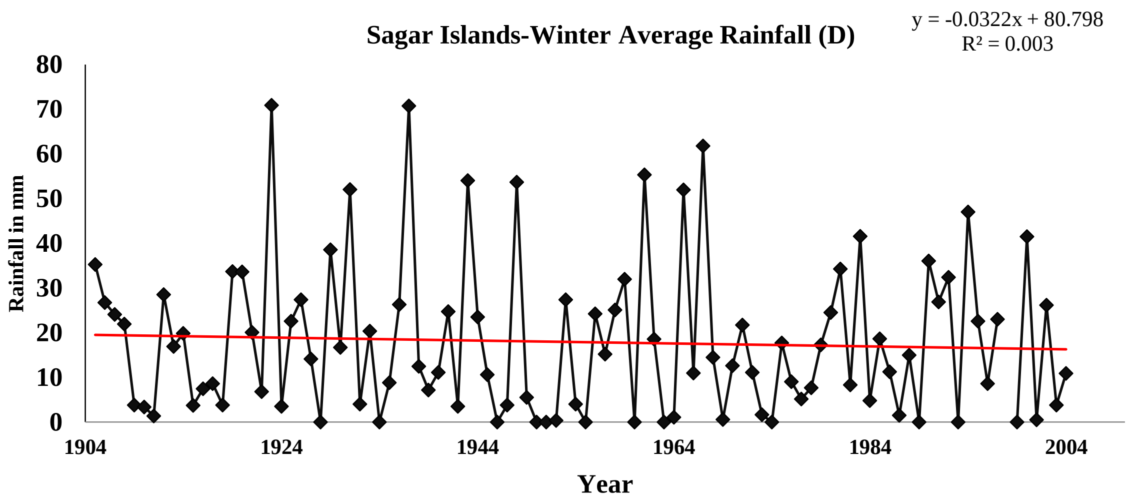


Figure 1.5 (A-D). Seasonal Rainfall Variation in Sagar Islands from 1904-2004. Analyzed from raw data provided by IMD, Kolkata

1.2.3. Observed trend of Natural Disasters and Climate Change

The region of Indian Sundarban, as mentioned, has been historically prone to natural disasters. The region, over the documented period of history, had undergone several tropical cyclones, flooding, drought and earthquakes. However, due to improper documentation, comprehensive history of natural disasters in the Indian Sundarban delta can not be retrieved accurately. This is mostly due to the partition of the delta, and any data prior to 1947 represents the disaster profile of the entire lower Gangetic Delta, including the Bangladeshi Sundarban. The following section documents the current scientific knowledge of disaster risks in the Indian Sundarban delta.

(a) Tropical Cyclones and Storm Surges

Although several researchers (e.g. Banerjee 1998; Gopinath & Seralathan 2005) referred to the total numbers of cyclonic storms formed in the Bay of Bengal (314 cyclonic storms and 100 severe cyclonic storms between 1831-1960 and 39 Cyclonic storms and 41 super cyclonic storms during 1937-2006) to highlight the region's age-old vulnerability against tropical cyclones, historically the Indian Sundarban had survived majority of those because of the eastward trajectory. Therefore, while the Bangladesh counterpart of Sundarban have been devastated time and again, Indian Sundarban mostly enjoyed its fair share of luck. Some recent examples are Cyclone 'Sidr' in 2007, Cyclone 'Rashmi' in 2008 which actually hit the Bangladesh counterpart, and escaped the Indian part by little margins. However, under the current context, a preliminary calculation from government sources reveal that the total number of Severe Cyclones that actually hit the Indian Sundarban Delta in the last century (1900-2010) is 11; while reported cyclonic storms is approximately 39 during the mentioned period. Of which, Cyclone 'Aila' in 2009, Cyclone in May 1995, Super Cyclone in Oct, 1942 are notorious for their catastrophic impacts. Therefore, all the extreme coastal blocks remain highly prone to the cyclonic impacts, especially from May to November, the IMD designated cyclone seasons. Here it is important to mention that, the cyclones generally mark its landfall with strong surge waves, hence majority of them lead to breaching of earthen embankments and temporary flooding of the delta. Average surge heights varies from 3 to 5 meters depending on the tide situation. Bandyopadhyay 1997 estimated that the Sundarban have an average return period of Severe Tropical Cyclone, Cyclonic Storms and Deep Depression in about every 3.3, 2.9 and 0.6 years respectively. Recent trend suggests that annual frequency of tropical cyclones in the Bay of Bengal has decreased by 15% per hundred years, although the intensity has risen by 20% per hundred years for the month of May & November (Singh et al. 2000).

(b) Sea Level Rise and Coastal Erosion

Assessment of the extent of relative sea level rise in Indian Sundarban is contradicted by number of literatures. Recent reports such as CSE 2012 refer that annual average sea level rise of the delta is about + 5.14 mm/y while it also refers to earlier measurement made for Sagar island (+ 3.14 mm/y) based on a specific five-year data studied by Hazra et al. 2002. The official report of INCAA, 2010 supports the claim of 5mm/year sea level rise in the Diamond Harbor gauge station. However, historical tidal gauge observation from PSMSL (Permanent Service for Mean Sea Level) data shows annual sea level rise of -3.82mm/y and +4.85mm/y in Sagar & Diamond Harbor respectively (Nandy & Bandhopadhyay, 2011), which is in complete contradiction with the former. The absence of reliable baseline and proper scientific measurement methodology are key barriers to obtain trustworthy scientific information of sea level rise in the Indian Sundarban Delta. Nevertheless, an overwhelming majority of literature cite the ongoing physical evidences of rapid erosion in small western islands as a possible consequence of sea level rise. In particular, the disappearance of a small deltaic island in 2006, named Lohachara, received widespread international attention. Parts of Sagar Islands, the largest of all deltaic islands in Indian Sundarban is also undergoing rapid erosions (**Figure 1.6**). Yet, it would be gross generalization to put the entire blame on the global sea level rise since several geomorphological factors are also responsible behind this. Principally, two factors are responsible for the observed physical variation of sea-level rise.

Firstly, as mentioned earlier, eastern tilt of the Bengal basin since 18th century has lead to gradual subsidence of the delta which is also an apparent cause of relative sea level rise (Stanley & Hait 2000; Gopal & Chauhan 2006), while, Syvitski, 2009 argued poor accretion due to lack of sediment accumulation in the GBM Delta is another triggering factor of the relative sea level rise.

Secondly, thermal expansion of sea water in the India Sundarban delta has also been considered as another important factor. For example, Mtira et al. 2009 reported that water surface temperature in the Indian Sundarban has risen by 0.5°C per decade, therefore, wide spread erosion phenomena can well be attributed to both of the above causes.

In addition, annihilation of mangroves from the western blocks is further aggravating the risk of coastal erosion. In absence of mangroves, virtually no sediment accretion process in going on the prematurely reclaimed western islands, dumping all the sediment loads at the bottom of the tidal rivers and creeks.

Figure 1.6. (Top) Recent Satellite Images of the Lighthouse in Sagar Islands, gradually being swollen by the rising sea. The latest images (2013 and 2014) also show the existence of newly constructed sea-dyke to prevent further inundation. (Bottom)The photograph depicting the same, the old remains of the lighthouse is visible through the sea. Source: Google Earth (Top) and Author, 2013

(c) Salinity

Salinity in the Indian Sundarban delta is one of the critical component that are associated with number of interlinked factors, such as agriculture, fisheries and most importantly mangrove conservation and its diversity. For example, *Sonneraita caseolarsis,* a mangrove species which were earlier found in abundance, now have become almost extinct due to lack of regeneration in highly polluted saline zones of Indian Sundarban (Mandal et al. 2010; DasGupta & Shaw 2013). In addition, major discontinuation of coastal agriculture (*see chapter 5 for more details*) have been directly linked with renormalized high soil and inland water salinity in the agricultural lands of the delta. Although the trend of salinity is inconsistent and primarily depend on seasonal factors, Mitra et al. 2009 observed a decrease (1.67 psu/decade) in salinity in the western part of the delta whereas reported an increase by 2 psu/decade in the eastern part. The decrease is, however, referred to adequate freshwater availability in the River Ganges. On the contrary, high rate of sedimentation of the eastern river systems and severe environmental pollution (waste water discharge of Kolkata municipality) are cited as major cause behind the observed varriation. Following the cyclone Aila in 2009, Mitra et al. 2011, based on the analysis of several spot samples, reported a high increment (>20%) in inland water salinity due to the surge flooding caused by Cyclone Aila.

(d) Earthquake and Tsunami

It is believed that the Indian Sundarban experienced a devastating earthquake in 1737, however, there is no documentary evidence exists in support of that (Bandyopadhyay, 1997). Since the last two centuries, there was no significant incidents of earthquake or a Tsunami in the Indian Sundarban. However, recent predictions by Cummins 2007 underline the possibilities of a gigantic earthquake and Tsunami along the Myanmar coast, undoubtedly this would also adversely impact the Indian Sundarban. Nevertheless, possibilities of such events remain contested in the academia.

(e) Arsenic Contamination

The Bengal basin is notoriously known for ground water arsenic contamination, particularly in the water from shallow aquifers. This has been considered as a 'silent disaster' as WHO mentioned the phenomenon as worst incident of mass poisoning in human history. Despite of being in the zone of acute risk for ground water Arsenic contamination, fortunately, majority of Indian Sundarban delta is void of such contamination. This is probably due to lack of dependence on shallow ground water aquifers. However, although not very significant, arsenic contamination has been found over small patches in the Indian Sundarban delta. As per the District official reports, some tube wells samples in Hasnabad and Hingolganj block in the eastern fringe of Indian Sundarban have been found to be contaminated with arsenic.

1.2.4. Rampage of Cyclone 'Aila' in 2009

A powerful Severe Cyclonic Storm named as 'Cyclone Aila' (IMD designation: BOB 02, JTWC Designation: 02B) hit the delta of Indian Sundarban on 26th May, 2009. The storm sustained a maximum wind speed of approximately 110 km/hour and overlapped with the morning retreating tide, generating a combined surge of 5 to 7 meters. In the documented history of Indian Sundarban, this has been one of the high impact natural disasters with wide spread social, economic and environmental consequences. Unfortunately, communities living in the delta could not show any sort of resistance to the furry of the cyclone. Part of which can be attributed to lack of physical infrastructures (such as cyclone shelters), while lack of preparedness was also among the key factors that triggered massive disruption of lives and properties. Despite of an early detection and warning, 169 people died in the delta, while many other went missing. The storm resulted in breeching of nearly 400 km long earthen embankments and flooded large areas of the low lying deltaic islands. In the post Aila period, water remained stagnant for nearly two months as thousands of farmers lost their livelihood due to high soil salinity (see Chapter 5 for more details). The cyclone led to massive outward migration (over 60,000) of the communities in search of livelihood. On the other hand, it also incurred extensive damage to the existing rural infrastructures such as fresh water ponds, agricultural land, embankments, roads and jetties impairing the life and livelihood of the communities. Despite of significant efforts from the provincial and national governments, the delta still suffers from the scars of the cyclone Aila and requires an urgent attention to prevent such awful consequences from similar event in future.

1.3. Research Objectives

As have been mentioned, the possibility of a disasters like Cyclone 'Aila' or even a stronger storm is very much likely for the Indian Sundarban Delta. Moreover, with the rapid onset of global climate change, the entire delta remains at the forefront of disaster risks, be it more intense tropical cyclones, stronger surges or flooding. Further, with the gradual depletion of mangrove ecosystem services, increasing population pressure and loss of traditional livelihood, the existing capacity of the communities to respond to such adverse consequences is extremely limited.

Given such adversities, the prime objective of this present research is to study and identify the key attributing factors that can enhance community's resilience against hydro-meteorological disasters, and thereby, develop an integrated risk reduction strategy. The research primarily hypothesizes that communities are the best judge of their risks, and in order to enhance their resilience to the ongoing and future coastal hazards, it remain imperative to develop a risk reduction strategy which essentially is participatory in nature. In order to attain the the above mentioned objectives, the research aims to accomplish the following secondary objectives.

(a) To develop an integrated framework and indicators to assess community's disaster and climate resilience.

(b) To identify and prioritize specific indicators, relevant tasks and corrective actions capable for enhancing communities' resilience against hydro-meteorological hazards and/or climate change.

(c) To develop community led sectorial plans on the prioritized indicators.

(d)To recommend an ameliorative, community-based disaster, climate and ecological risk reduction strategy for the Indian Sundarban Delta.

1.4. Research Questions

Based on the understanding of the existing risk profile of the Indian Sundarban delta, the study attempts to investigate the following research questions that are aligned with the above mentioned research objectives.

(a) To what extent are the communities resilient to coastal hazards and/or the possible impacts of climate change?

(b) Which are the key attributing factors that are impeding communities' resilience?

(c) Which are the precise tasks and actions required to enhance the disaster and climate resilience of the communities?

(d) What would be the appropriate risk reduction model against the current and future ecological, disaster and climate risk of the delta?

1.5. Research Methodology and Thesis Structure

In order to achieve the above mentioned research objectives and to answer the key research questions, several qualitative and quantitative research tools were utilized throughout the study. The following section mentions the specific tools that have used to accomplish several thematic components of this study.

(a) Qualitative Research Tools

The research has extensively used qualitative Participatory Rural Appraisal (PRA) tools such as Focus Group Discussions (FGDs), structured interviews, semi-structured interviews and stakeholder workshop in almost all phases of the study. Especially, FGDs were used to formulate specific tasks and actions for disaster resilience (Chapter 4), problem identification and screening of adaptive measures in agriculture and the estuarine fishing activities (Chapter 5) and during an institutional survey of the Joint Forest Management Committees (JFMCs) (Chapter 6). Similarly, structured and semi-structured interviews were used for wide range of data collection ranging from understanding the perception of forest officials about the existing participatory arrangement, identifying user's satisfaction over the derived incentives (Chapter 6), identification of embankment design parameters (Chapter 7) etc. Lastly, stakeholder workshop was conducted for dissemination of the research results and the feedbacks were used to formulate the participatory risk reduction strategy for the delta.

(b) Quantitative Research Tools

The research has also party used questionnaire surveys to quantify and prioritize specific actions. For example, an institutional questionnaire survey was conducted to assess community resilience in the 19 coastal blocks of the Indian Sundarban (Chapter 3). In addition, household level questionnaire survey was conducted to prioritize tasks and actions required for enhancing community resilience (Chapter 4), identification of preferred adaptive actions in agriculture and inland fishing (Chapter 5). Data obtained from the above mentioned tools were analyzed using Microsoft excel and SPSS. In some cases, ARCGIS^{TM} version 10.2 was used for spatial visualization.

In general, the research can be classified into four steps, i.e. Problem Understanding, Assessment, Planning and Implementation Strategy. Purpose of each step is discussed in brief in the following section and have been synoptically presented in **Figure 1.7.**

Problem Understanding – This initial step includes an extensive literature review for problem identification and understanding of key pertaining issues with community resilience in coastal areas. Desktop review was conducted for mainly three purposes, firstly, in order to identify study area specific social, economic, ecological and other environmental issues. This is partly furnished in this chapter and partly in the introduction section of chapter 5, 6 and 7. Secondly, the study area being a part of the largest contiguous mangrove forests, the study opted for a thorough review of the concepts of ecosystem based disaster risk reduction (as well as other non-engineered risk reduction approaches) with special emphasis on mangroves and its role in disaster risk reduction. In addition, the study characteristically focused on the current status and management of mangroves in South and Southeast Asia and described in details about the opportunities and challenges for mangrove conservation on a regional perspective. In particular, special emphasis was provided on the Indian mangroves. The entire **Chapter 2** has been dedicated to literature review which typically attempts to provide a conceptual summary of scope, opportunities and challenges in ecosystem based disaster risk reduction approaches. Thirdly, the research also conducted extensive review on the concepts of 'resilience'. This has been mostly discussed in the backdrop of the development of the resilience assessment framework and furnished in details in the beginning of the Chapter 3.

Assessment- This particular phase of the research aligns to an indicator based assessment of coastal community's resilience against hydro-meteorological disasters and climate change. Assessment of coastal communities' disaster and climate resilience was conducted through

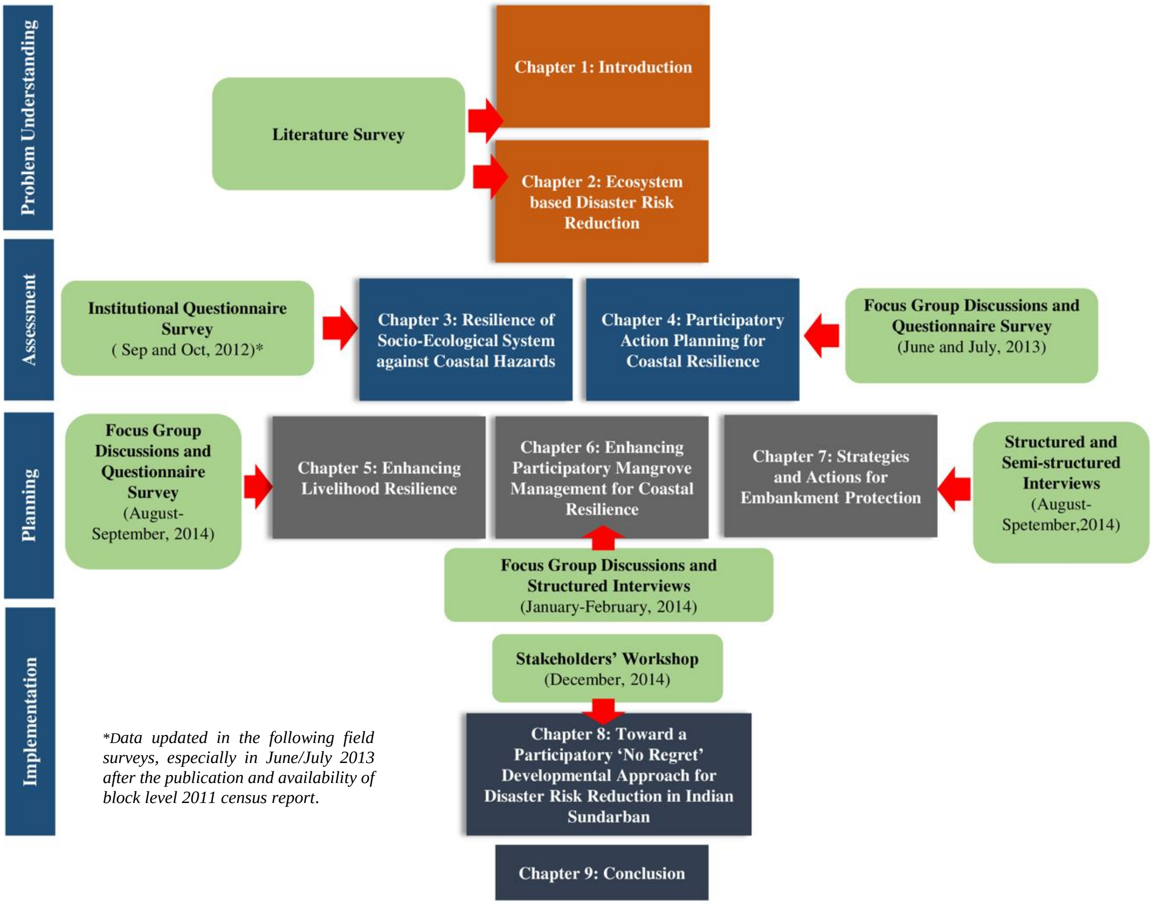


Figure 1.7. Research Methodology and Thesis Structure

institutional questionnaire survey of all the 19 blocks of Indian Sundarban. Detailed methodology, results and key findings of this assessment is furnished in **chapter 3.** Further, in order to identify the relevant indicators and required actions from the community's perspective, four intensive focus group discussions and 268 household survey were conducted with the Cyclone Aila affected communities. **Chapter 4** describes the results and major findings of these participatory rural appraisals.

Planning- Planning phase of this research includes detailed action planning of three prioritized indicators, i.e. 'community livelihood', 'mangrove conservation' and 'protection of embankments'. In case of livelihood, Focus Group Discussions and questionnaire surveys were conducted with farmers and fishermen in order to develop a livelihood adaptation strategy. Detailed methodology, results and major recommendation are furnished in **chapter 5.** In case of mangroves, the research principally examined the existing incentive design and sustainability of participatory mangrove management under the JFM arrangements through structured interviews and Focus Group Discussions with forest officials, JFMCs and mangrove dependent communities. **Chapter 6** describes in details the research methodology and outcome of this study. In the last planning phase, the study made an evaluation of the existing Sundarban Embankment Reconstruction Project through a proposed 'Socio-technical' framework for embankment sustainability. The qualitative evaluation was conducted by interview surveys with project officials and validating key parameters through expert interviews. The research finds and recommendations are made in **Chapter 7.**

Implementation – This is the concluding phase of the research where the key findings of this thesis, especially from Chapter 5, 6 and 7 were shared with the local government, NGO and academia in a stakeholders' workshop. The workshop particularly aimed to scrutinize the specific research findings in order to build a bottom-up and participatory risk reduction model to enhance the local communities' resilience against climate related disasters. **Chapter 8,** which presents the conclusive arguments of this research, describe a conceptual a 'no-regret', risk reduction model that can be adopted for enhancing community's disaster and climate resilience. On the other hand, **chapter 9** provides the exclusive summary of the research findings and implication of this research against the Indian Sundarban delta and beyond.

References

Alam, M., Hossain, M., & Shafee, S. (2003). Frequency of Bay of Bengal cyclonic storms and depressions crossing different coastal zones. *International journal of climatology*, 23(9), 1119-1125.

Bandyopadhyay, S. (1997). Natural environmental hazards and their management: a case study of Sagar Island, India. *Singapore Journal of Tropical Geography*, 18(1), 20-45.

Banerjee A. (1998). Environmental Population and Human Settlements of Sundarban Delta (pp 31), Concept Publishing Company, New Delhi

Barbier, E. B. (2015). Climate change impacts on rural poverty in low-elevation coastal zones. *Estuarine, Coastal and Shelf Science*, 165, A1-A13.

Brown, S., & Nicholls, R. J. (2015). Subsidence and human influences in mega deltas: The case of the Ganges–Brahmaputra–Meghna. *Science of The Total Environment*, 527, 362-374.

Burke, L., Kura, Y., Kasem, K., Revenga, C., Spalding, M., McAllister, D., (2001). Coastal Ecosystems. Washington DC World Resources Institute.

Chan, F. K. S., Mitchell, G., Adekola, O., & McDonald, A. (2012). Flood risk in Asia's urban mega-deltas drivers, impacts and response. *Environment and Urbanization* Asia, 3(1), 41-61.

CSE (2012): Living with Climate Change: Impact, vulnerability and adaptation challenges in Indian Sundarbans.

Duxbury, J., and Dickinson, S. (2007). Principles for sustainable governance of the coastal zone: in the context of coastal disasters. *Ecological Economics*, 63(2), 319-330.

Ericson, J. P., Vörösmarty, C. J., Dingman, S. L., Ward, L. G., & Meybeck, M. (2006). Effective sea-level rise and deltas: causes of change and human dimension implications. *Global and Planetary Change*, 50(1), 63-82.

Gopal, B., & Chauhan, M. (2006): Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, 68(3), 338-354.

Helmer M. (2006): Natural disasters and climate change. *Disasters* 2006; 30, 1-4

INCCA, (2010). Climate Change and India; A 4 x 4 Assessment, Ministry of Environment and Forests, Government of India.

Knutson T.R., Mcbride J.L., Chan J., Emanuel K., Holland G., Landsea C., Held I, Kossin J.P., Srivastava A.K. and Sugi M. (2010): Tropical Cyclones and Climate Change, *Nature Geoscience*, 3, 157-163

Martínez, M. L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., and Landgrave, R. (2007). The coasts of our world: Ecological, economic and social importance. *Ecological Economics*, 63(2), 254-272.

McGranahan, G., Balk, D., & Anderson, B. (2007): The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19(1), 17-37.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem, (2007): Small islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687-71.

Mitra, A., Gangopadhyay, A., Dube, A., Schmidt, A. C., & Banerjee, K. (2009): Observed changes in water mass properties in the Indian Sundarbans (northwestern Bay of Bengal) during 1980–2007. *Curr Sci*, 97(10), 1445-1452.

Mitra A, Mondal K, Banerjee K (2011) Spatial and tidal variations of physico–chemical parameters in the lower Gangetic Delta Region, West Bengal, India. *J Spatial Hydrol*, American Spatial Hydrology Union Spring 11(1):52–69

Nandy S & Banyopadhyay S.(2011): Trend of Sea Level change in the Hugli estuary, India, *Indian Journal of Geo-Marine Sciences*, Vol. 40(6), 802-812

Nicholls R.J. and Cazenave A. (2010): Sea-Level Rise and Its Impact on Coastal Zones, *Science* 328, 1517-1520

Singh, O. P., Khan, T. M. A., & Rahman, M. S. (2001): Has the frequency of intense tropical cyclones increased in the north Indian Ocean? *Current Science*, 80(4), 575-580.

Syvitski, J.P.M., A.J. Kettner, I. Overeem, E.W.H. Hutton, M.T. Hannon, G.R. Brakenridge, J. Day, C. Vörösmarty, Y. Saito, L. Giosan, and R.J. Nicholls, (2009): Sinking deltas due to human activities. *Nature Geoscience*, 2, 681-686.

Vafeidis, A.T., R.J. Nicholls, L. McFadden, R.S.J. Tol, J. Hinkel, T. Spencer, P.S. Grashoff, G. Boot, and R.J.T. Klein, 2008: A new global coastal database for impact and vulnerability analysis to sea-level rise. *Journal of Coastal Research*, 24(4), 917-924

Wong, P.P., I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, and A. Sallenger, (2014): Coastal systems and low-lying areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on

Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361-409.

Woodroffe, C.D. (2010) Assessing the vulnerability of Asian megadeltas to climate change using GIS. In Green, D.R. (ed) Coastal and Marine Geospatial Technologies, Springer, pp. 379-391.

Woodruff, J. D., Irish, J. L., & Camargo, S. J. (2013). Coastal flooding by tropical cyclones and sea-level rise. *Nature*, 504(7478), 44-52.

CHAPTER 2: Ecosystem based Disaster Risk Reduction

'A good decision is based on knowledge and not on numbers'
Plato, Greek Philosopher

CHAPTER 2: Ecosystem based Disaster Risk Reduction

This chapter narrates the principal concepts and approaches of disaster risk reduction, with a special focus on the eco-system based disaster risk reduction or Eco-DRR approaches. In addition, the chapter provides a detailed analysis of the utility and application of the Eco-DRR approaches in the backdrop of densely populated coastal areas in South and Southeast Asia. Focusing especially on mangroves, the chapter provides a detailed review of the role of mangroves in disaster risk reduction, the problem of mangrove degradation in the region and the consequent escalation of disaster risks in the low lying coastal areas. Focusing on the conventional and contemporary management approaches of mangrove ecosystems in the South and Southeast Asia, the chapter concludes with the Indian experience of mangrove management over the last century and highlights the scopes of participatory mangrove management as an ameleorative and alternative approach for effective conservation and management of mangrove forests .

Outline of Chapter 2

2.1. Introduction

From the ancient civilizations to the modern 'technology-driven' societies, human history has been constantly reshaped by large-scale natural disasters. Great civilizations perished following mega-disasters and countless cities and human settlements annihilated throughout the course of time. For example, one of the several hypotheses behind the collapse of the great Indus Valley Civilization during the 1800-1700 BC indicates to a series of droughts following an eastward shift of the monsoon. Likewise, according to Historian Eric Cline at George Washington University, a series of natural disasters between 1225 BC and 1177 BC led to downfall of ancient societies, including the great Egyptian civilizations, heralding the beginning of the 'dark age' (Cline 2014). Throughout the history, examples of how human survivability has been relentlessly challenged by natural disasters are plenty, and in fact, it is possible that a natural disaster will eventually cause the end of the world, whenever that inevitably happens. Nevertheless, as the world continues to struggle against a plethora of natural disasters, it also learns and realizes. Over the past several hundred years, the collective experience gained by humanity largely indicates, that, at least to some extent, the adverse consequences of natural disasters can be avoided if we plan carefully and timely; and that, the solution lies in either by aiming to contain the forces of nature, or by altering human own behavior. This has led to the continuous transformation of our traditionally acquired knowledge to theoretical notions, and as a result, the theory of 'Disaster Risk Reduction' (DRR) emerged and received recognition. Nevertheless, this was not a meteoric transformation, but an incessant process of evolution that is not only worth investigating, but also remain imperative to have comprehensive understanding of 'Disaster Risk Reduction'.

2.2. The Evolution of Disaster Risk Reduction Concepts

In official terminology provided by UNISDR, 'Disaster' is defined as '*a serious of disruption of the functioning of a community or society that results in wide spread damage and losses that exceeds the ability of the affected community or society to cope using its own resources'* (UNISDR, 2009). However, unless this particular definition was acknowledged as a common, globally accepted definition, many researchers have postulated different definition of 'disaster' as the concepts of Disaster Risk Reduction was evolving over the last three decades. A short discussion of this evolution process remains imperative to understand the evolution of the central concept of disaster risk reduction, and how this is applicable in the real world. Nevertheless, to start with, it is imperative to look at the origin and use of the word 'disaster' purely from a linguistic perspective. According to the Oxford Advance Learners Dictionary, the word ‘disaster’ can be traced to its origin from a 16th century Italian term ‘*disastro*’ which generally refer to 'ill-starred event' [dis- (expressing negation) + astro 'star' (from Latin astrum)]. The word is retained in the English vocabulary ever since, and has been used to denote wide sense of purposes ranging from the occurrences of large natural calamities (such as earthquakes, typhoons etc.), undesirable physical events (e.g. power cut, disease outbreak etc.) to social and political blunders. Traditionally, the sense of the word ‘disaster’ closely contested with ‘accident’. By definition, ‘accident’ is an ‘unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury. A disaster, on the other hand, was described as a ‘calamitous event, especially one occurring suddenly and causing great loss of life, physical damage or hardship’. Needless to say, these two definitions are quite close and not distinctive. The thin line of differences, however, later broadened by number of scholars. For example, a definition posed by International Labor Party and cited in Rutherford and Boer (1983) described disasters as ‘destructive event which, relative to the resources available, causes many casualties, usually occurring within a short period of time’. It is important to note here is that, as the definition was taking its explicit shape, three boundary concepts were imbued, i.e. ‘resource availability’, ‘many casualties’ and ‘short period of time’. The idea and notion behind using this definition of disaster was to look at the capability of ‘locally available resources’ to overcome sudden shocks. Boer 1990, later justified that if the sudden shock can be managed utilizing the own resources and minimizing causalities, this can be referred as ‘accidents’ rather than ‘disaster’; while, on the contrary, if it attracts external resources and include high casualties, this can be termed as ‘Disaster’. The idea of ‘locally available resources’, be it human, economical or technical, possibly gave birth to the concept of ‘vulnerability’ and ‘capacity’, which, according to Boer, is the largest determinants of the impact of an external catastrophic event.

As argued by Wisner et al. 2004 and Shaw et al.2013, eighties were the decades, when the ‘vulnerability’ approach to disasters gained momentum by rejecting the assumption that disasters are caused by external natural events, and that, there is nothing to do with its surrounding social environment at the point of impact. During this time, it was hypothesized that even with the high probability of catastrophic events, which later was defined as ‘hazards’, not all communities remain equally prone to damage. In the contemporary texts, the ideas were summarized in a more concrete definition, and ‘disasters’ were mentioned as ‘events that overwhelm the capacity of local communities to cope, are the result of one or more hazard striking vulnerable human populations, physical structures, economic assets or sensitive environments' (Carter, 1991; Cuny, 1993; Ward 1994; Shook, 1997). What is important to note here is the inclusion of the the key concepts of 'hazards' and 'vulnerability'. Hazard is defined as 'dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage' (UNISDR, 2009). The fundamental arguments which evolved during this time is that, 'Hazard' cannot produce a disaster unless it interacts with humans and infrastructures (Cannon 2008; McEntire, 2012). One excellent argument suggested by Kelman & Glantz 2015 is that, if we consider only the event of an earthquake from the Great East Japan Earthquake & Tsunami (2011), it cannot be probably referred as a 'disaster' in the true sense of the term. The reason being, thanks to the country's excellence in earthquake engineering, that, despite of a 9.0 Mw earthquake, loss of human life and physical damage were extremely limited. Therefore, metaphorically, it can be argued that all hazards are not disasters, but all disasters are the outcome of hazards. As the above example suggests, neither all human societies are equally prone to impacts, since it also remains a function of various physical, social, economic, and environmental factors, collectively known as their potential 'vulnerability'. For example, 'vulnerability' may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management (UNISDR, 2009).

Consequently, it was identified, that Disaster are functions of 'Hazard' and 'Vulnerability' (Eqn. 2.1.), and in particular, since 'Hazards' are generally considered sudden shock events, it is imperative to manage the 'vulnerability' component, which is relative and inclusive of several dynamic variables.

$$\textit{Disaster Risk (R) = Hazard (H) x Vulnerability (V)} \ldots\ldots\ldots\ldots\ldots\ldots \textit{Eqn. 2.1.}$$

In the recent disaster literature, the above relationship is further modified with the incorporation of two major terms, 'coping capacity' and 'exposure', both borrowed from the the ongoing climate change adaptation domain which largely focuses on the 'uncertainties' of the events. As argued by many, climate change would more likely to complex the current 'hazard scenario' (e.g. World Risk Report 2011; UNISDR 2012), therefore, the incorporation of these two dimensions are characteristically justified. In the core sense of hazard research, 'exposure' is largely defined by the entities exposed and prone to be affected by a hazard event. In particular, it is defined mostly in temporal and spatial terms, for example, according to the World Risk Report 2011, exposure is related to the potential average number of individuals who are exposed each year to earthquakes, storms, droughts and floods (World Risk Report 2011). On the contrary, the origin of the concept 'coping capacity' can be broadly interlinked with similar concept of 'adaptive capacity 'in the existing Climate Change Adaptation (CCA) research. 'Coping Capacity', as defined by UNISDR, 2009, is 'the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters'. Much like adaptation itself, 'coping capacity' requires continuing awareness, resources and good management, both in existing and future perspectives, typically aiming at reducing the impact of hazards. Therefore, according to the latest conceptual amendments, Disaster Risk has been redefined as-

$$\textit{Disaster Risk (R)} = \textit{Hazard (H)} \times \frac{\textit{Exposure (E)} \times \textit{Vulnerability (V)}}{\textit{Coping Capacity (C)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textit{Eqn. 2.2}$$

Considering the above equation as the basis of assessing disaster risks, many researchers, particularly over the last decade, have attempted to further clarify this equation. In particular, it became imperative to look further into the variables of Vulnerability (V), Exposure (E) and Coping Capacity (C), so that, something can be done to reduce vulnerability and exposure, and increase coping capacity. A host of theoretical research have been conducted to identify the key factors that affect these three components. For example, Blaikie et al. 2014 categorized the component vulnerability into root causes (such as limited access to power and resources, poverty, health, education etc.) [the same has been identified as basic vulnerability [(Vb) e.g. World Risk Report 2011; ADB 2013], Dynamic pressure (lack of local institutions, adaptive capacity, population growth etc.) and unsafe conditions (dangerous physical environment). In short, vulnerability has been characteristically divided into two ways, i.e. Basic Vulnerability (mainly defined as access to resources and through indicators of human development) and secondly the other vulnerability component that arises from the surrounding physical environment, e.g. irrespective of the social-economic status of the communities, all the coastal communities are vulnerable to sea-ward hazards, although their exposure might be different. On the other hand, significant research has also been conducted in order to suggest measures for 'reducing exposure' to disasters. For example, risk sensitive spatial planning, beneficial utilizations of natural ecosystem services, land-use planning are some of the suggested measures to minimize physical exposure to hazards (UNISDR 2012; Renaud et al. 2013). It is imperative to mention that the term 'exposure' can also be thematic. For example, apart from physical exposure, researchers also consider this terminology especially from the perspective of economic and psycho-social stresses that may ascend from the possibilities of a disaster. Similarly, it has been also hypothesized that given the stature of a particular community, the maximum possible 'coping capacity' is constant. This, in practice, means that all the communities do not have equal capacity to cope, and there remains a potential maximum coping capacity with respect to a defined community.

Summing up these recent conceptual adjustments, Disaster Risk Index, an indicator of assessing the risk from flood and water related disasters, has been proposed in the draft report of AWDO. This equation can be conceptually represented as,

$$\textit{Disaster Risk } (R) = H \times E \times V_b \times (1 - C/C_{max}) \quad \ldots\ldots\ldots\ldots\ldots \text{ Eqn. 2.3.}$$

Where, R: Disaster Risk, H: Hazard, E: Exposure, V_b: Basic Vulnerability, C: Community Coping Capacity, C_{max}: Potential Maximum Coping Capacity.

The above equation provides an overall idea of scopes and opportunities for reducing disaster risks, and it is imperative that policy planners and practitioners should target to alter at least one of the three discussed components, if not all, to reduce the risk of disasters. For example, with respect to a particular community, Disaster Risks can be reduced by (a) Controlling exposures, both physical, economic and social (b) Reducing the basic vulnerabilities, i.e. improving the basic HDI (Human Development Indicators) and (c) Lastly, by increasing coping capacities such as early warning, evacuation centers etc. Ideally, as the above equation suggests, if we achieve the potentially maximum coping capacity (C_{max}), the entire risk can be nullified. However, this theoretical idea hardly exists in reality. Nevertheless, the potential risk is certainly minimized if we increase the 'coping capacities', which perhaps is a continuous developmental process.

2.3. Institutionalization of 'Disaster Risk Reduction'

The above discussion can be thoughtfully summarized as, the risk of natural disasters can be reduced through appropriate interventions in controlling the exposure, enhancing coping capacities and certainly, by diminishing the existing vulnerabilities (or increasing the resilience[1]) of a particular community. However, even with this theoretical conceptualization,

[1]Here it is important to mention that vulnerability and resilience are two competing concepts that are considered mostly inversely proportional, although there exist some semantic differences. See chapter 3 for more details.

many, including the local and national governments, considered disasters as event to be waited for and only after the disaster strikes, would remedial action be taken to ensure a speedy return to normality (Van Niekerk 2008). Although the issues of disaster risks always received priority just after the disasters, virtually, national governments were stuck with the relief centric approaches to manage disaster risks. The thematic identity of disaster risk reduction, however, got it desired attention when the United Nations declared the1990s as the 'International Decade for Natural Disaster Reduction' (IDNDR). Consequently, 'Yokohama Strategy and Plan for Action' were adopted at the first United Nation World Conference on Disaster Risk Reduction (WCDR) in 1994. As Shaw et al. 2015 mentioned, this could be considered as the first blue print on Disaster Risk Reduction (DRR) policy guidelines focusing on institutional and governance reform.

The concept of Disaster Risk Reduction is, therefore, relatively new and just over 25 years old. In particular, comparative to other contemporary developmental agendas such as poverty reduction, sustainable development and environmental conservation, which largely came into existence as the outcome of the United Nations Conference on the Human Environment held in Stockholm, Sweden in 1972 and the follow-up Rio Earth Summit in 1992, the institutionalization of DRR is arguably still in nascent stages. Yet, within its short span of propagation, it received wide recognition from academia to policy planners, developmental agencies to international donors and most importantly from the national governments. On the termination of IDNDR, United Nation General Assembly established the secretariat of the United Nations International Strategy for Disaster Risk Reduction (UNISDR) in order to facilitate the implementation of the International Strategy for Disaster Reduction, a successor mechanism of the IDNDR (Shaw et al. 2015). The second WCDR held in Kobe, Japan in 2005, was attended by 168 member countries with greater political commitments and the outcome of 'Hyogo Framework for Actions (HFA), 2005-2015: Building the Resilience of Nations and Communities to Disasters' is the first milestone of Institutionalization of DRR and considered as monumental shift in DRR. Through the five set of priorities, the concept of DRR as put forth in the HFA reflects a stronger focus on risk preparedness and prevention, as compared to the response and recovery (UNISDR 2005; Shaw et al. 2015; de la Poterie, & Baudoin 2015). As mentioned, the year 2015 marked the end of HFA, and looking back to the specific achievements it made throughout the world, and in particular in the Asia and Pacific, it can be summarized as that the **Priority Area 1** of the HFA i.e. "Ensure that DRR is a national and local priority with a strong institutional basis for implementation" and **Priority Area 5** "Strengthen disaster preparedness for effective response at all levels" have made **considerable**

progress, while there has been **less progress** in **Priority Area 2** “Identify, assess and monitor disaster risks and enhance early warning”. **Priority Area 3** “Use knowledge, innovation and education to build a culture of safety and resilience at all levels”, and **Priority Area 4** “Reduce the underlying risk factors” have seen the least progress (UNISDR 2014). Understandably, the HFA resulted some policy alteration at the national government level, with many countries coming up with Disaster Management Acts, policies, long-term risk reduction plan etc. Yet, despite of significant mobilization of resources and establishments of new capacities for DRR at the national government level, the HFA review, as cited by Shaw 2015 and Poterie & Baudoin 2015, largely indicated the exclusion of local governments and communities in local level DRR policy framing and implementation. In addition, as identified in the HFA review, little have been done to reduce the underlying risks which characteristically reinforce that we are living with the same vulnerabilities and probably more exposed to natural hazards.

The HFA framework was eventually replaced by the Sendai Framework for Disaster Risk Reduction (SFDRR), which was put into place following the third WCDR held in Sendai City, Japan. The SFDRR have an operational period of 15 years (2015-2030) and outlines its goals in four priorities, i.e. understanding disaster risk (Priority 1), Strengthening Disaster Risk Governance (Priority 2), Investing in the Disaster Risk Reduction for Resilience (Priority 3), and Enhancing disaster preparedness for effective response, and to build back better in recovery, rehabilitation and reconstruction (Priority 4) and also comes with seven time bound quantitative tasks. Although this is too early to find the utility of the SFDRR, many argues about the absence of baselines, lack of distinctive responsibilities, local level involvement, lack of quantitative targets etc. as the the major drawbacks of the SFDRR (Chatterjee et al. 2015; Cutter & Gall 2015).

2.4. Contemporary approaches for Disaster Risk Reduction

UNISDR, 2009 defined DRR as ‘*the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events’*. Yet, despite of significant research, international protocols and extensive negotiations, disasters continue to happen. For example, by the time this research was conducted (2012-2015), a total of 1222 disasters took place all over the world, taking a toll of 69079 lives with physical damage ranging over billions of dollars (assessed from EM-DAT). However, it is unwise to say that nothing has happened during the previous years. On the contrary, the last two decades witnessed several theoretical evolutions of specific DRR approaches that have been applied, or at least justified, against variety of natural hazard and social scenarios. What is interesting to note, that, compared to the hard engineering based risk reduction approaches, which, at a point of time, was considered the only way to reduce the exposure of communities from specific hazards, several alternative approaches evolved to meet the objectives of controlling exposure, reducing vulnerability and enhancing coping capacities. Some of the well researched approach that were postulated during the previous years includes Community based Disaster Risk Reduction (CBDRR), Ecosystem based Disaster Risk Reduction (Eco-DRR), Restrictive Planning etc. Collectively known as 'Soft-approaches or No-regret for Disaster Risk Reduction', these are especially aimed to capitalize the existing human and natural resources for pro-active risk reduction. Needless to say, these approaches are complimentary and not essentially contradicting to traditional hard engineering based DRR approaches, and often, based on the hazard profile and the capacity of the community, these approaches can be combined for effective results. It is, however, imperative to understand the potential scopes and opportunities of these specific approaches. **Table 2.1.** outlines a summary of the contemporary approaches of DRR with its specific contribution in reducing vulnerability, exposure and increasing coping capacities. The following sections describe in short the specific applicability of these different approaches.

Community based Disaster Risk Reduction or CBDRR is defined as a process in which the affected communities are put to the central of risk reduction. Much often, it is referred as participatory, bottom-up solutions that are coming from the community itself and not in the form of a request/order from higher authorities. The principal arguments of this approach lies in the understanding of the fact, that, communities are the best judge of their own risk, and are capable of managing the risk. In particular, CBDRR attempts to reduce the risk of disasters within a community, by focusing on the root causes of risks and address it through local knowledge and available expertise. On the other hand, one of the much referred international policy document of the last decade was the Millennium Ecosystem Assessment (2005), which reemphasized the need of harvesting the unbounded relations between the human and nature, especially by promoting the concepts of 'Ecosystem Services'. Although traditionally human societies lived in close harmony with their surrounding ecosystems, which not only provided a variety of provisioning, supporting and cultural services, but also, served as a natural defense to external hazards. However, with poor environmental practices, much of the world's ecosystems remain critically degraded. This, in turn, increases the risk, not only by increasing

Table 2.1. Approaches for Disaster Risk Reduction

DRR Approaches	Reducing Exposure	Reducing Vulnerability	Enhancing Coping Capacity	Applicability and Utility
Engineering approaches based Disaster Risk Reduction	**(Major Role)** For example, Sea dykes, Earthquake resilient buildings, Dams and reservoirs	**Semi-Major Role** Mainly reducing Physical vulnerability	**(Major Role)** Advanced Early warning, Scientific Modeling of Risks	• Adequate financial capacity of the national and local government • In-depth understanding of Hazards. • Reliability
Community-based disaster risk reduction (CBDRR)	**Minor Role** Not directly related, however, better community understanding of risks lead to reduction of exposure; such as not settling by the sea etc.	**(Major Role)** Creating local assets and mutual understanding, Enhances Social capital	**(Major Role)** High disaster awareness, Efficient evacuation, culture of preparedness	• Existence of week local governments. • Applicable in Local Risk Management. • Net social benefits.
Ecosystem based Disaster Risk Reduction (Eco-DRR)	**(Major Role)** For example, Strom surge attenuation, Soil accumulation, Erosion Control Etc.	**(Major Role)** Asset creation in terms of Livelihood and physical resources	**Minor Role** Creating Environmental awareness for sustainable ecosystem management	• Low cost adaptive approach. • Generates net environmental benefits
Restrictive Planning	**(Major Role)** For example, planned retreat, coastal regulation zones	**Semi-Major Role** Mainly reducing Physical vulnerability, however, may increase high social vulnerability	No role	• High relative cost • Requires proper legislations and policy reforms • May lack social acceptability

community's exposure to natural hazards, but also enhancing the potential vulnerability, in terms of livelihood and access to resources. For example, many poor people across the LDCs or the developing world directly dependent on ecosystem services for their livelihood activities, and, therefore, remain particularly vulnerable to changes in environmental conditions (Thomalla 2006; Renaud 2013). Efficient management of ecosystems, that aims to revitalize or enhance the ecosystem services, are, thus, remain a cognitive approach for disaster risk reduction. For example, the HFA recognized environmental degradation as a major contributing factor in disaster risks, mainly through HFA Priority 4 (Doswald & Estrella, 2015). As argued by Shaw 2006 and Renanud 2013, the synergies between sound ecosystem management and disaster risk reduction received wide recognition since the Indian Ocean

Tsunami, as various reports and case studies of the storm surge attenuation capabilities of mangroves were referred after the catastrophic event (e.g. Kathiresan & Rajendran 2005; Danielsen et al. 2005; EJF 2006). This, in particular, renewed the interests in ecosystems and its services in disaster risk reduction, giving arise to a new concept of Ecosystem based Disaster Risk Reduction or Eco-DRR. In addition, the 'Eco-DRR' concept has received wide recognition since the UNEP adopted the concept as their doctrine for ecosystem conservation. In particular, these approaches are hypothesized as low cost, futuristic risk reduction approaches that are aim to generate net social and ecological benefits as well as a cognitive approach for dealing with future uncertainties.

In addition, there was another approach for DRR which largely revolves surrounding the principles of restrictive planning. Evolved mostly in the early nineties, it largely attempts to reduce disaster risks through reducing direct physical exposures, such as zonation, planned retreats etc. As argued by Abel et al.2011, planned retreats provide a reasoning approach where building hard engineering structures are beyond the capacity of the governments. In addition, it also provides the space for ecological succession that is imperative to further reduce the exposure to disasters. Needless to say, all these approaches, individually and collectively, remain imperative from the perspective of minimizing the risks from disasters. As mentioned earlier, governments and policy planners can choose one or a combination of approaches based on their understanding of risks, social, economic and technical capacity of the communities concerned.

2.5. Ecosystem approaches for Disaster Risk Reduction in Coastal Areas

The traditional approaches for coastal disaster risk reduction has been, by and large, the hard engineering approaches, which, to a significant extent, were successful to reduce the risk of sea ward hazards. For example, the extensive dyke network of the Netherlands serves as the most prominent illustrations of this. This system of robust dykes with extensive mechanization has been tremendously effective to mitigate storms and surges, and are being constantly upgraded to match the changing exposures. The capacities of this heavy engineered structures are currently stretched to mitigate hazard events that may occur once in ten thousand years. In case of Japan, out of its coastline of approximately 35000 km, nearly 9600 km of the coast line is protected by sea dykes that are designed to protect human habitation from the Level-1 Tsunami [According to *Kaigan hou (Japanese Sea-Coastal Law of 1953. Amended 1999),* Level -1 Tsunami are the events that may occur once in hundred years]. Needless to say, these hard engineering risk reduction measures demands major capital investments and recurring maintenance costs. Yet, these hard and strong coastal defense mechanism are not always as productive as planned, since the sea dykes only provided a false sense of security during the East Japan Earthquake and Tsunami, 2011. In addition, sea dykes are also considered to have negative environmental impacts, such as disruption of natural shoreline processes and destruction of shoreline habitats such as wetlands and intertidal beaches.

As argued by Harada and Imamura 2005, there has been a growing demand in recent years to integrate environment and resource utilization in coastal management, which limits the further consideration for the sea dykes, since it relies on the modification of coastal environment and inhibits resource utilization. In addition, these hard engineering based approaches mostly remain beyond the capacities of the local governments in the developing world. Consequently, as an alternative, a growing body of literature essentially advocates for ecosystem based approaches such as barrier plantation and coastal defense forests as an alterative to engineered structures (Hiraishi & Harada 2003; Harada and Imamura 2005; Danielsen et al. 2005). For example, Hiraishi & Harada 2003, based on a theoretical study, suggested that a costal forest of 30 trees per 100 sq. meter in a 100-m wide belt may reduce the maximum tsunami flow pressure by more than 90%. Although, this observation can be contested since wave attenuation ability of coastal forests largely remain a complex factor of wave heights, density of forests, root diameters, duration of impact etc., nevertheless, empirical evidences from the aftermath of mega disasters, in particular the Indian Ocean Tsunami, essentially suggests the protective roles of coastal vegetation in tsunami wave attenuation (e.g. Kathiresan & Rajendran 2005; Danielsen et al. 2005; EJF 2006). On the other hand, based on the extensive review of empirical studies, Kunkel et al., 2006 indicated that coral reefs also provide an effective buffer against tsunamis and further mentioned that a barrier reef within a meter or two of the surface which is separated from an island by at least a few hundred meters, can play an important role in reducing tsunami impact. In lieu with the above direct protective role, coastal ecosystems such as mangroves, coral reefs etc. provide a plethora of ecosystem services that are essential to strengthen community livelihood and economic resilience to coastal hazards. Unfortunately, degradation and loss of coastal ecosystems over the past two to three decades (e.g. 35% of the mangroves and 30% of coral reefs have been lost since last three decades) has largely restricted the scope of ecosystem based risk reduction in coastal areas (Millennium Ecosystem Assessment 2005; Barbier et al. 2008; DasGupta et al. 2015). Therefore, significant effort is required to promote such approaches. Another important component of coastal disaster risk reduction is to increase community assets which particularly remains pivotal against the economically deprived coastal communities across the developing nations. As have been identified by MEA, 2005, ecosystem degradation has multiple consequences in community livelihood, especially to the rural resource dependent communities.

2.5.1. Role of Mangroves in Disaster Risk Reduction

Within the current knowledge of ecosystem based DRR approaches, mangrove occupies the center theme of attention[2] (e.g. Barbier et al. 2008; Mitra 2013; Renaud, 2013; DasGupta et al. 2015). In general, three factors can be attributed to such overwhelming attention on mangroves. Firstly, approximately 41% of the world mangrove occupies the tropical and sub-tropical coasts of South and Southeast Asia, along the densely populated and highly exposed coasts of several disaster prone developing countries such as India, Bangladesh, Sri Lanka, Myanmar, Malaysia, Indonesia, Vietnam etc. (DasGupta & Shaw 2013a). Secondly, community dependence on mangroves are exceptionally high in the above mentioned countries, and with highest exposure to sea ward hazards, mangrove ecosystem services remain imperative for inclusive risk reduction. Thirdly, mangroves remain one of the critically vulnerable ecosystems in South and Southeast Asia, where the risk of sea ward hazards are hypothesized to be the maximum. For example, it is estimated that since 1980, the region actually marked nearly 25% decrease to its original mangrove cover and suffered a net loss of of 1.9 million hectares (FAO 2007). Hence, many researchers have hypothesized the need for mangrove based DRR approaches in the region, especially focusing of the low-lying coastal areas and Asian mega-deltas (Danielsen et al., 2005; EJF 2006; Shaw, 2006; Barbier et al. 2008; Mitra 2013; Renaud, 2013). However, before the scopes and limitations for mangrove based disaster risk reduction is discussed within the regional context, it is imperative to understand the specific role of mangroves ecosystem services with special emphasis to disaster risk reduction in coastal areas.

(a) Role of Mangroves in Reducing Direct Exposure

As have been documented so far, mangroves provide nearly 70 valued ecosystem services that are fundamental to human wellbeing, and many of such services are pivotal for disaster risk reduction in coastal areas (Dixon 1989; Kathiresan 2012). In general, ecosystem services of mangroves have been broadly classified as **provisioning services** (e.g., timber, fuel wood, wax, honey, charcoal etc.), **regulating services** (e.g., flood, storm and erosion control, prevention of salt water intrusion**), habitat services** (e.g., breeding, spawning and nursery ground for fishes, biodiversity), and **cultural services** (e.g., recreation, aesthetic) (Vo et al. 2012). Among

[2]*Here the term mangroves are inclusive of nearly 69 true species of mangroves and hundreds of mangrove associates that grow along the intertidal region where freshwater mixes with seawater.*

these four types of services, majority of the existing literature and case studies characteristically highlight the regulating services of mangroves and its role in reducing the exposure of coastal hazards, in particular its ability to wind and wave energy attenuation. However, it is imperative to mention that the attenuating ability of mangroves remain a complex function of water height, wind thresholds and the host of other factors such as forest density, width of the forests, root diameter etc. and, so far, there has been no empirical generalization of factors. As mentioned earlier, following the Indian Ocean Tsunami, 2004, several studies highlighted the protective role of mangroves across the affected countries (e.g. Kathiresan & Rajendran 2005; Danielsen et al. 2005; EJF 2006). For example, in case of Indonesia, amidst widespread damage, Simeuleu Islands, which is merely 41 km away from the epicenter, was partially saved due to mangroves (UNEP, 2005). Another empirical case study from Kapuhenwala, a small coastal hamlet in Sri Lanka, suggested that the village suffered only two casualties due to the existence of protective mangrove forests, where the 6-meter tsunami waves were virtually reduced to 40 cm by a combination of sand dunes, mangroves, coconut plantation and homestead gardening (EJF 2006). In the state of Tamil Nadu, India, mangroves also proved to be effective in safeguarding the lives and properties of the coastal hamlets. Kathiresan and Rajendran 2005 reported, based on an empirical study conducted over tsunami affected villages, that the loss of human lives had significant positive correlation with the absence of mangrove forests. Further, Danielsen et al. 2005 mentioned that in Cuddalore district in Tamil Nadu, they observed strong physical evidences that coastal hamlets protected by mangroves characteristically suffered lesser damage. Nevertheless, it has also been criticized these reported findings are over simplistic, incomplete and overexertion of facts; as researchers in the following years identified various other attributing factors such as topography, wave height, distance from the shore, canopy density as the potential auxiliary factors behind such observations (Dahdouh-Guebas et al. 2006; Vermaat & Thampanya 2006; Wolanski, 2007). Theoretical case studies based on laboratory simulations following the Tsunami event, however, provided some more specific clues. For example, Yanagisawa et al. 2009 reported, based on a simulation and reconstruction of the Tsunami event in Thailand, that a mangrove forest of *Rhizophora sp.* with a density of 0.2 tree/ sq. meter and a stem diameter of 15 cm in a 400 m wide area has the capacity to reduce the tsunami inundation depth by 30%, when the incident wave is assumed to have a 3.0 m inundation depth and a wave period of 30 min at the shoreline. Consequently, from this above mentioned case study, in can be concluded that in areas with the maximum tsunami intensity, mangroves probably can not provide much shielding, however, it certainly makes a differences in other areas, resulting in lesser damage and loss of human lives; although it is perhaps difficult to represent it in a direct, linear relationship. Needless to say, a knowledge gap still exists to characteristically identify the factors and other variables that can be attributed (or managed) in order to use mangroves as potential bio-shields against Tsunamis.

While Tsunami is a 'High intensity, low frequency' event, mangrove forest also plays an important role in wind and wave energy attenuation, especially from the 'high frequency' events such as cyclone, typhoons and associated surges. Theoretical and empirical evidences cited by a number of researchers have indicated that mangroves provide an effective barrier between the land and sea by arresting the wind energy (e.g. Das 1999; Zhang et al. 2012; Das, & Vincentm 2009; Mitra, 2013). For example, Das 1999 and Das & Vincentm 2009 cited the protective roles of mangroves during the Orissa Super Cyclone in 1999. They concluded that villages with wider mangroves between them and the coast experienced significantly fewer deaths than ones with narrower or no mangroves. Qualitative hypothesization of the protective role of mangroves, is, however, not new. As mentioned by Gedan et al. 2011, the potential role of mangroves in wind energy abatement was first identified and hypothesized by Fosberg 1971, who following a catastrophic storm on the coast of Bangladesh (erstwhile East Pakistan) emphasized the need of mangrove conservation from the perspectives of storm risk reduction. In the recent years, this claim is further supported by many empirical evidences. For example, Mitra, 2013 highlighted the protective role of mangroves in the Indian Sundarban delta during the Cyclone Aila in 2009. However, despite of wide variety of literature on qualitative assessment of mangroves' ability to arrest wind energy, quantitative estimates are limited. In a study conducted in the Gulf Coast of South Florida, Zhang et al. 2012 concluded that a 6-to-30-km-wide mangrove forest effectively attenuated storm and surges from a Category 3 hurricane 'Wilma'. According to the laboratory simulation, they argued that the inundation area by 'Wilma' would have extended more than 70% further inland without the mangrove zone. However, as like the previous cases of tsunami wave attenuation, a plethora of additional factors also remain responsible, and significant research gaps exists before an empirical generalization of factors can be attributed to such protective roles of mangroves.

Mangrove ecosystem services are also important from the perspective of shore line stabilization and sediment accumulation since both are imperative for flood risk reduction in coastal areas. Mangroves trap and stabilize sediment and dissipate surface wave energy through its complex and extend network of root systems, a process which has been considered as natural solution for controlling coastal erosion and abating the adverse consequences of sea level rise (Gedan et al., 2011; Mitra 2013). The complex network of submergible roots minimizes the action of waves and prevent the coast from erosion. In general, reduction of waves heights increases with the density of vegetation and depth of water; however, sediment accumulated by mangroves is estimated to be 25% higher during the low tide than the high tides (Mitra 2013). Nevertheless, the ability of mangroves to accumulate sediments also remain a complex function of several biophysical factors which, also, like the other cases, demands significant future research. However, based on the existing available literature, Lacambra et al., 2013 provided a comprehensive review of factors that are responsible for an effective mangrove based risk reduction. These factors essentially identify the specific physiological characteristics of mangroves that are pivotal for an effective risk reduction from coastal hazards. A modified version of the factors has been summarized in **Table 2.2**.

Table 2.2. Specific Characteristics of Mangroves and Its effectiveness for Coastal Disaster Risk Reduction

Characteristics of Mangroves	**Role in Coastal Disaster Risk Reduction**
Width	Wider mangrove cover leads to lesser physical damage to human habitation behind the forests.
Density	Higher density creates greater energy dissipation, along with higher sediment accumulation. This lead to a potential role of flood and surge height reduction.
Species and Forest Composition	Different species are associated with different drag forces. In addition, different species also have different coping capacities. Some species are prone to natural disasters, while, on the contrary, some species are resilient.
Height	Taller mangroves can provide effective resistance to large waves compared to shorter mangroves. In addition, in general, taller mangroves are associated with larger sediment accumulation.
Orientation of the Mangrove Forests	This relates to specific location of the forests and the exact point if impact. In general, if storm surge waves follow the regular tidal waves, it is likely the potential attenuation ability is higher.
Distance from the coast	In General, damage of mangroves in directly proportional to the distance from the coast. Mangrove shields exposed to the coastal are more likely to get damaged.
Root Systems	A robust and well developed root system is required to increase the drag.
Stiffness of the Plant	Wave or Wind attenuating ability depends on the Stiffness of the mangroves.

Modified from Lacambra et al. 2013

(b) Role of Mangroves in reduction of Socio-economic Vulnerability

As mentioned earlier, the existing literature on mangrove forests overwhelming focus on the regulating services of mangroves and its potential role in reducing the exposure to coastal hazards. However, considering the existing socio-economic scenario of the mangrove habitats, especially in South and Southeast Asia, the additional services (including provisioning, habitat and cultural) of mangroves are nothing less important than its regulating services. Collectively, these three types of ecosystem services are responsible for significant asset creation that are imperative to reduce the livelihood and economic vulnerability of coastal communities against natural disasters. In economic terms, Wells et al. 2006 and Spalding et al., 2010 argued that the value of mangrove ecosystem services range from USD 200,000 to USD 900,000 per hectare per year. Within the scope of provisioning services, mangroves are traditionally utilized for timber, wax, honey and charcoal production (Walters et al. 2008; Lacambra et al. 2013; DasGupta and Shaw,2013a, b). For example, the Matang mangrove provides a classic reference in which mangrove are sustainably utilized for asset creation. Almost 75% of this forest is designated as productive forest and exploited for wood resources, while the rest are conserved for promoting biodiversity. The 30-year rotation cycle of mangrove felling gives the highest net return. At present, the timber industry from Matang supports almost 2400 people and earns revenue of USD 6 million. The unproductive forest, on the other hand, supports about 10000 people with gross annual revenue of USD 12–30 million through sustainable fishing practice (MTC 2009; DasGupta & Shaw 2013a). In case of India, DasGupta and Shaw, 2013b mentioned that the communities living beside the mangrove habitats characteristically depend on mangroves for firewood, wax and honey. Kathiresan, 2012 mentioned about the ameliorative fuel value of mangroves, since one ton of mangrove firewood is equivalent to 5 tons of Indian coal and also burns without generating smoke. In addition, the mangrove pneumatophores are used to make bottle stoppers and floats, *Nypa* leaves are used to thatch roofs, mats and baskets. Honey and wax production is among other significant provisioning services of mangroves. For example, in case of Indian Sundarban Delta, nearly 2000 honey collectors survive on the honey collection from the mangroves. As mentioned by Kathiresan, 2012, the best quality of honey is produced from *Aegialitis rotundifolia* and *Cynometra ramiflora*, although the majority of honey comes from *Ceriops*. In lieu to this, mangroves provide a host of other provisioning services, e.g. fodder for livestocks, leaves for thatching, woods for house and boat construction etc. For example, mangrove species such as *Avicennia* provides cheap and nutritive food for livestocks, *Nypa* is used for thatching and *Rhizophora* *mucronata* are extensively used for house and boat constuction. Additionally, mangroves also provide food for humans, e.g. in Sri Lanka, the buttresses of *Heritiera sp.* are used for preparation of a popular drink called ‘arrack’ (Bandaranayake 1998).

Mangroves ecosystems are important nursery areas and habitats for commercially valuable shrimp, shellfish, and fish species. Globally, approximately 30% of the commercial fish species are mangrove dependent, and, in particular, mangrove estuaries are responsible for an annual catch of 30 million tons (estimation based on 2002) (Nagelkerken et al. 2008). Rönnbäck, 1999 estimated that annual market value of capture fisheries supported by mangroves ranges from USD 750 to 16750 per hectare. Despite the fact this figure is based on global average, and the local assessment may vary, Kathiresan 2012 mentioned that if scientifically managed, the combined production value (including fish and shrimps) of each hectare of mangrove may reach as high as USD 11300 per year. In addition, ecosystem services of mangroves are also imperative from the perspective of food security among the coastal communities, most of which depend on fishes for their daily protein intake.

Apart from the provisioning and habitat services of mangroves, cultural services of mangroves such as eco-tourism also immensely contribute in building local economy. Across the world, mangroves are among some of the most visited bird sanctuaries, tiger habitats and marine national parks. For example, Bennett and Reynolds, 1993 mentioned that the tourism industry in the Sarawak Mangrove Forest Reserve generates an annual revenue of USD 21.1 million. In addition, many local and region studies, urge mangrove based eco-tourism as a potential livelihood for communities living within and around the mangroves (e.g. Thomas & Fernandez 1994). However, it is also imperative to mention that unscientific tourism practices are also a major concern for mangrove ecosystem degradation (Spalding et al. 2010; DasGupta and Shaw, 2013a), hence, a careful balance is required for before tourism development in and around mangrove habitats.

The above observations of specific mangrove ecosystem services have been summarized purely to justify its application from a disaster risk reduction point of view, however, apart from these, mangrove provide a series of other regional and local services, such as pollution control, climate regulation, carbon sequestration etc. (Wells et al. 2006; Gilman et al. 2008; Spalding et al. 2010; Kathiresan 2012). In particular, the potential role of mangroves in carbon capture and storage have been increasing occupying the central position of the international programs and strategies such as ‘Blue Carbon’ and REDD (Reducing Emissions from Deforestation and Forest Degradation (Pendleton et al. 2012).

2.5.2. Utility of Mangrove based DRR in comparison to Engineered DRR

Despite of several benefits, mangrove based DRR also comes with certain limitations. For example, effectiveness of mangroves as 'Bio-shield' to Tsunami and/or storm surges primarily depend on the magnitude of the event; and as discussed, in case of severe intensity, mangroves may not provide any substantial resistance. It addition, the open gaps through the forests can channel and amplify a strong current by forcing it into the gaps, and may potentially increase the flood risk in the vicinity. Further, it can not completely resist the water since bio- shields are essentially porous. Despite of the fact, that it may, to a significant extent, reduce the wave energy from tsunami, storm and tidal surges, a minor flooding is almost inevitable in the areas just behind the mangroves. Furthermore, coastal communities have different views on bio-shielding, and one of the major problems cited so far, is the visibility of the seashore which remain crucial for decision making. Many fishermen use open areas close to the sea for drying and mending of nets and may oppose the new development of mangroves. Lastly, during a catastrophic event, the floating debris from the mangroves may typically hurt people located in the immediate vicinity. However, some of these potential challenges may easily be solved through careful planning and building community consensus.

Nevertheless, the utility of mangrove based disaster risk reduction remain highly imperative, not because it can arguably replace the traditional engineered measures for DRR, but as a compulsive alternative to many countries and regions who can not afford to build massive dykes to protect the communities. In such cases, mangroves become the natural, and perhaps, the only choice. However, in countries, where the local or the provincial government can afford hard engineering structures, combining manmade structures with mangroves and other coastal vegetation is likely to increase coastal protection (Gedan et al. 2011). Because mangrove protection is a low cost alternative to engineered barrier construction, it can be regarded as a cost effective approach, especially considering that 90% of the existing mangroves are located in developing nations. For example, in Vietnam, extensive plantation of mangrove has costed US$1.1 million but it helped reduce maintenance cost of the sea-dykes by US$7.3 million per year (World Disaster Report 2002). On the other hand, Gilman et al. 2008 mentioned that the replacement cost of existing mangroves with rock walls in Malaysia has been estimated to be USD 300,000 per km. They further reported, the cost of mangrove restoration ranges between USD 225–216,000 per ha, significantly lower than the cost of building sea dykes. For example, the cost of current mangrove restoration in Thailand is estimated USD 946 per ha, while the cost for protecting existing mangroves is capped to only USD 189 per ha. Needless to say, in comparison to engineered seawalls, this cost is negligible.

2.6. Status and Management of Mangroves in South and Southeast Asia

Being the most susceptible to hydro-meteorological hazards of coastal origin and having limited financial and technical capacity to manage coastal risks, South and Southeast Asia has been the most favored place for the advocacy of ecosystem based disaster risk reduction approaches (e.g. EJF 2006; Kiathiresan 2012; DasGupta & Shaw, 2013a). More so, the region's tropical and subtropical coast, being predominantly colonized by mangroves, remains a natural choice of mangrove based disaster risk reduction. However, as mentioned, mangroves of South and Southeast Asia remain critically degraded in comparison to other regions, and are fast disappearing due to a number of anthropogenic and environmental threats. This, in turn, reduces the scope and applicability of the mangrove-based risk reduction strategies. Although a multitude of factors are responsible for the accelerated rate of mangrove annihilation, Ogino et al.2010 argued that, in general, socio-economic vulnerability of the communities and lack of awareness can be held responsible for the degradation of mangrove forests. Therefore, as the region is fast loosing one of its vital coastal assets, it is imperative to understand the responsible factors and the strategies that can be applied to the management these fragile resources. This section, therefore, attempts to provide an analysis of the key factors of mangrove degradation along with the prospect of existing management practices based on the available literatures.

2.6.1. Distribution of Mangrove Ecosystems in South and Southeast Asia

As a region, South and Southeast Asia host nearly 40.4% of the global mangroves, covering a total of 6.16 million ha across its tropical and sub-tropical coast (Spalding et al. 2010). Mangroves mainly occur in stretches in the southern coast of Asia, throughout the Indian subcontinent, in almost all the Southeast Asian countries and on the islands in the Indian Ocean, Bay of Bengal, South China Sea, and the North Pacific Ocean. Bio-geographically classified as Indo-Malayan eco-zone or the 'oriental realm', these mangroves are the oldest and most diverse mangrove forests in the world (FAO 2007; Spalding et al. 2010). In terms of distribution, Indonesian mangroves alone accounts 22.6% of global mangrove reserve, whereas Malaysia (3.7%), Myanmar (Burma) (3.6%), Bangladesh (3.2%), India (2.7%) and the Philippines (1.9%) contribute significantly to this highly fragile ecosystem (Giri et al. 2011). Other South and Southeast Asian countries such as Thailand, Vietnam, Cambodia, Sri Lanka & Singapore have also significant amount of mangroves. While practically all the mangroves occur in small patches that develop in deltaic or estuarine habitats, Sundarbans Mangrove forests in the Ganges-Brahmaputra-Megna Delta are the only contiguous and largest coastal wetland system in the world (Gopal & Chauhan 2006). On the basis of common ecological and environmental settings, the Indo-Malayan mangroves have been broadly classified into six distinct mangrove zones, i.e. Indus Delta Mangroves, Godavari Krishna Mangroves, Sundarban Mangroves, Burmese Coast Mangroves, Indochina Mangroves and Sunda Shelf Mangroves. A brief summary of the specific characteristic of this six zones is furnished in **Table 2.3.**

Table 2.3. Distribution of Indo-Malayan Mangroves

Category	***Indus River Delta***	***Godavari-Krishna Mangroves***	***Sundarbans Mangroves***	***Burmese Coast Mangroves***	***Indochina Mangroves***	***Sunda Shelf Mangrove***
Type	Backwater-estuarine	Deltaic/Estuarine	Deltaic	Deltaic & Coastal	Coastal	Coastal
Major Rivers	• Indus	• Mahanadi • Godavari • Krishna	• Ganges • Brahmaputra • Meghna	• Ayeyarwady	• Mekong • Red River	• Mahakam River
Mangrove Diversity	Very Poor	Poor to Moderate	High	Moderate	High	Very High
Total Forest Area (sq.km.)*	5250 (approx.)	7000 (approx.)	10000 (approx.)	3822 (approx.)	26936 (approx.)	40000 (approx.)
Mangrove under Protected Area (sq. km.)*	823	920	2700	125	820	6,530
Country of Occurrence	Western of India & Eastern Coast of Pakistan	Eastern coast of India (Orissa to Tamil Nadu)	• Bangladesh • India	• Myanmar • Thailand-West Coast • Peninsular Malaysia	• Thailand (East Coast) • Cambodia • Vietnam • Malaysia • Philippines	• Eastern Malaysia • Indonesia • Brunei
Status	Critically Degraded	Degraded	Degraded	Critically degraded	Critically degraded	Degraded

Source: Assimilated by author from World Wide Fund for Nature Information Database on World Eco-regions, adopted from DasGupta & Shaw, 2013a (* Figures provide close approximation)

2.6.2. Loss of Indo-Malayan Mangroves

Information on the chronological country or region specific loss of mangroves is not rigorously documented. In most of the South and Southeast Asian countries, official statistics of mangrove forest cover is either unavailable or significantly outdated. Among a few in depth regional assessment of mangroves, United Nation's Food and Agricultural Organization (FAO) documented the global and country wise changes in mangrove cover till 2005. In the following year, Spalding et al. 2010 in their book 'World Mangrove Atlas' referred to this assessment as the latest regional level assessment in absence of any other comprehensive assessment over the last decade. According to this report, mangrove cover in South and Southeast Asia has reduced to at least by 25% from its original extent in 1980. Out of the net loss of nearly 1.9 million hectare of mangroves, 90% has been confined to six countries of the region, namely, Indonesia, Myanmar, Pakistan, Vietnam, Malaysia and India (FAO 2007). Importantly, these assessment is over a decade old, and there exists significant research gaps in regional level assessment of mangroves since 2005. Hence, in order to update this database, country specific reports and case studies were consulted. Table 2.4. depicts some of the latest available country specific assessment. Needless to say, this assessment represents close approximation since the data are not obtained by imposing identical methodologies.

Table 2.4. Extent of Mangrove Cover (in sq. km.) in South and Southeast Asian Countries

Country/ Year	1980	1990	% Change (1980-1990)	2000	% Change (1990-2000)	2005	Present	Assessment Year	% Change (2000-latest)
Pakistan	3450	2070	-40	1580	-23.67	1570	981.28[a]	2010	-37.89
India	5067	4670	-7.84	4482	-4.03	4480	4639[b]	2009	3.50
Bangladesh	4280	4600	7.48	4760	3.48	4760	4810[C]	2007	1.05
Myanmar	5550	5361	-3.41	5167	-3.62	5070	4379.21[d]	2007	-15.24
Indonesia	42000	35000	-16.67	31500	-10	29000	32440[e]	2009	2.98
Malaysia	6740	6420	-4.75	5895	-8.18	5650	5775[f]	2007	-2.03
Vietnam	2691.5	2135	-20.68	1575	-26.23	1570	1597.6[g]	2008	1.43
Philippines	2950	2730	-7.46	2500	-8.42	2400	2091[h]	2007	-16.36
Thailand	2800	2502	-10.64	2441	-2.44	2400	2296[i]	2007	-5.94

[a]Abbas et al., (2011), [b] FSI,(2011),[c] Bangladesh Forest Department (2008), [d] FAO,(2010), [e]Bakosurtanal (2010), [f] Chong (2007), [g]Govt. of Vietnam. (2008),[h]Padilla,(2008), [i]MFF-Thailand. (2011), *adopted from DasGupta and Shaw, 2013a*

The data presented in **Table 2.4.** depicts that, since the beginning of the last decade, India, Indonesia, and Vietnam showed an increasing trend in gross mangrove cover as compared to the massive declining trend observed in the previous two decades. Among all the countries, mangroves of Bangladesh remain largely unaffected over the years. On the contrary, Pakistan, Thailand, Myanmar, and the Philippines continued to suffer significant loss of mangroves. With a disappearing rate of more than 2% per year, mangroves in Pakistan and Myanmar, on a regional perspective, remain critically threatened.

2.6.3. Major Factors behind Mangrove Declination

Degradation of the Indo-Malayan mangroves has been a result of continuous developmental pressure exerted on the coastal areas of South and Southeast Asia. In the past, several mangrove forests were annihilated and converted to megacities like Singapore, Jakarta, Bangkok, Manila, Yangon, Kolkata (Calcutta), and Mumbai (Bombay). Yet, the loss has been predominantly severe in the last three decades. On a regional perspective, development of coastal agricultural land and shrimp farming ponds in intertidal areas are considered as the two most important factors behind mangrove delineation (FAO 2007; Giri et al. 2008). Of these, conversion of mangrove forest for agriculture is typically the primary cause of mangrove degradation in countries like India, Bangladesh, Myanmar, Thailand, and Indonesia. Giri et al. 2008 reported that agricultural development in coastal areas in these countries are responsible for nearly 82% of the reported loss during 1975–2005. For example, in case of the Ganges-Brahmaputra-Meghna Delta in India and Bangladesh and Ayeyarwady delta in Myanmar, more than 150,000 ha of mangroves were diverted for agricultural land development (Kathiresan 2011). In particular, the Ayeyarwady delta in Myanmar suffered extensive loss of mangroves due to agricultural expansion. It is estimated that, during 1954 to 1984, agricultural activity, especially rice production accounted for 24% (55873 ha) reduction of Ayeyarwady delta mangroves, and further, during the last two decades, conversion rate has increased by three folds (Oo, 2002).

On the other hand, shrimp cultivation in aquaculture ponds is the second largest anthropogenic cause of mangrove deforestation in the region. The process of shrimp farming is economically lucrative for the coastal communities. Particularly, with huge demands of commercially produced shrimp in the western countries, it ensures high economic return. 75% of the global commercial shrimps are produced in Asia and Thailand remains the single largest exporter of commercially produced shrimps. In the late eighties, skeptic rise in global price of commercially produced shrimps prompted South and Southeast Asian governments to support this traditional practice, which in turn, took the shape of an unsustainable, highly risky and polluting industry. The process destroyed nearly 50% of Thai mangroves (Barbier and Cox 2002). In a recent satellite-based observation, it is estimated that since 1975, approximately 41% (18816 ha) of Thailand mangroves, 63% (20956 ha) of Indonesian mangrove, 22% (7554 ha) of Indian mangrove, and 11% (1070 ha) of the Bangladeshi mangroves were diverted to shrimp ponds (Giri et al. 2008). During the same period of time, the Mekong Delta mangroves almost reduced to half of its original extent due to the exponential boom of aquaculture.

Apart from these two major delineating factors, mangroves of the region are also experiencing huge population growth and rapid coastal infrastructure development/urbanization in its vicinity. Even though, Giri et al. 2008 mentioned that since 1975, only 2% of mangrove forests were diverted for establishment of new coastal settlements in this region, yet, the problem of coastward migration, rapid industrialization is looming large on the horizon, especially in the backdrop of economic expansion in this region. For example, in recent years, Port Qasim at Karachi (Pakistan) and Port Mundra in Gujarat, India, are largely criticized of degrading the vulnerable Indus delta mangroves. In the eastern coast of India, Paradip port was built over dense patches of Mahanadi delta mangroves (Nanda 2011). Similar instances are also observed from the Malacca strait (Malaysia) (e.g. Port Klang and Malacca port), industrial states (Penang), and commercial centers (Malacca and Penang) were constructed over mangrove forested areas (Omar 2002).

Apart from these anthropogenic factors, currently, mangroves in the region also suffer from many adverse environmental factors, such as the changes in environmental boundary conditions, natural disasters and climate change. Among these, rising sea level, increased salinity, and reduction of freshwater flow are considered to be most crucial and potentially dangerous for the future sustainability of the mangroves in the region (Gliman 2008). For example, three major South and Southeast Asian rivers, namely, the Indus, Ganges, and the Mekong are listed among the top ten rivers of the world with substantial reduction of fresh water flow (Wong 2007). As a consequence, deltaic mangroves of these rivers remain at a great stake from considerable rise of water and soil salinity. It is reported that species diversity in the Indus River Delta mangroves has virtually reduced to only one with the sole dominance of *Avicennia marina* owing to extreme saline conditions.

Among the other environmental factors, erosion loss and submergence under the rising sea are widespread concern along the eastern coast of India, eastern and southern coast of Thailand, southern coast of Vietnam, and northern coast of Indonesia. In recent past, several islands of Sundarban delta, both in India and Bangladesh, suffered from severe erosion and inundation due to the rising sea level in the Bay of Bengal. Similarly, a recent assessment revealed that some 53 sq. km. of mangrove forests were affected in the eastern coast of Thailand, while another 43 sq. km. of mangroves were lost in the western coast as a result of severe coastal erosion (Thampanya et al. 2006). Similar instances can also be drawn from Indonesia, where a number of known mangrove patches have been degraded or eroded away. Erosion is severe in the coast of Java islands and other provinces such as Lampung, Northeast Sumatra, Kalimantan, West Sumatra (Padang), Nusa Tenggara, Papua, South Sulawesi and Bali. On the contrary, Irrawaddy delta mangroves in Myanmar are presently affected by increased sedimentation and coastal accretion. It is interesting that deposition in coastal areas may cause a decrease in the tidal prism in rivers running through the mangrove, resulting in the closing of tidal creeks and the degradation of the forest (Brown 2007). Similarly, the Segara Anakan Lagoon of the Central Java of Indonesia lost its complete mangrove habitat due to high sedimentation. In lieu with the above mentioned natural factors, coastal disasters are also a potential cause for degradation of mangroves in this region. Over the past, Indo-Malayan mangroves were subjected to several hydro-meteorological disasters of unprecedented magnitudes. The mangroves have shielded the coastal communities, however, in turn, it also incurred substantial losses. For example, following the Orissa Super Cyclone in 1999, Forest Survey of India assessed that at least 50% and 40% mangrove forests were lost in the two districts of Orissa (Jagatsinghpur and Kendrapara) which had significant share of the Mahanadi mangroves. Similarly, cyclonic storm 'Sidr' in 2007 destroyed some 30000 ha of Sundarban mangroves in Bangladesh. The Myanmar coast also lost sizable mangrove forest following the Cyclone 'Nargis' in 2008. Yet, the Indo-Malayan mangroves had the worst possible impact from the Indian Ocean Tsunami in 2004. Rough estimations revealed that almost 25,000 ha of mangroves were damaged in Indonesia, however, at the later stage, a more careful assessment mentioned that only 300 -750 ha mangrove were damaged (EJF 2006; Alongi 2008). In India, as per the official damage assessment report, the devastation of mangroves was greatly limited to the Nicobar Islands in the Andaman Sea. However, some reports informed that Pichavaram mangroves suffered 5–10% damage due to the Tsunami. In case of Thailand, reported loss of mangroves was about 306 ha (EJF 2006).

2.6.4. Management of Mangroves in South and Southeast Asia

South and Southeast Asia spans over several post conflict states and some of the world's poorest countries. Many South and Southeast Asian countries have low income despite of massive economic growth in the last decade. Most importantly, coastal areas of these countries are immensely populated, and the mangroves are surrounded by large proportion of economically deprived coastal communities. Hence, traditional livelihood dependence on mangroves and an exponential population growth forms a formidable challenge in managing the mangrove resources. Although, previously many governments considered the mangroves as 'wasteland' and overlooked their ecological and environmental values in developmental planning, a renewed interest in mangroves have particularly emerged after the Indian Ocean Tsunami in 2004. Consequently, at least over the last decade, mangroves have received some degree of conservational priority.

In general, the conservation of mangroves has been traditionally promoted through the protected area based management by inculcating appropriate legislations. Legislative protection of mangroves comes with the idea of 'in-situ conservation' by restricting public access into the forests. Globally, approximately 25% of the mangroves are presently conserved as 'Protected Areas'. However, in case of the South and Southeast Asia, rough estimation reveals that less than 20% of the mangroves presently possess such status (DasGupta and Shaw 2013a). Nevertheless, the history of mangrove protected areas in the region can be documented since the late colonial era, especially under the Forest Conservation Act, 1927 of the British India. Under this particular act, approximately 344870 ha of mangrove forests were transferred to Sindh Forest Department for effective conservation, which still forms one of the largest protected mangrove areas in Pakistan (Mukhtar & Hannan 2012). Similarly, this act was also instrumental for the protection of Sundarban mangroves both in India and Bangladesh. Nevertheless, on a regional perspective, legislative protection of mangroves through protected areas was predominantly ratified after the Ramsar Convention (1971) on ‘the Wetlands of International Importance’. Following the convention, Pakistan, India, the Philippines, and Indonesia formed National Mangrove Management Committee to promote mangrove conservation. Presently, all the South and Southeast Asian countries with dense to moderate mangroves have joined the convention with the latest addition of Myanmar in 2005. However, as mentioned, mangrove conservation received its priority only after the Indian Ocean Tsunami in 2004 (Mitra 2013). Following the Indian Ocean Tsunami, several countries have mentioned mangrove restoration as a national priority. Some of the country, such as Indonesia, Vietnam, India, also ratified the ‘coastal green belt’ concept for mangrove restoration. For example, since 2004, about 12000 ha of mangroves were planted by the Vietnamese government as coastal protection initiatives. On the other hand, Government of Bangladesh initiated massive plantation program of 120,000 ha following the Cyclone ‘Sidr’ in 2007. However, despite of such legislative reforms, poor implementation of forest laws largely proved conservation efforts futile in almost all the South and Southeast Asian countries. Rugged with poverty, coastal communities in these countries continued to invade the mangroves for their livelihood and continual survival, and as mentioned previously, majority of the mangroves were either converted to agricultural lands or shrimp farms.

2.6.5. Community based Mangrove Management in South and Southeast Asia

The institutional failure to recognize that the mangrove habitats serve as complex ‘socio-ecological’ systems, where community-mangrove relations are the key guiding principles for mangrove sustainability, led to the unsuccessful conservation and conflicts around the mangrove protected areas (Datta et al. 2012). This has led to significant advocacy for the implementation of ‘Sustainable Forest Management (SFM)’ principles in case of managing the existing mangrove resources. Developed just after the United Nations Conference on

Environment and Development (UNCED) in 1992, the principles of SFM lies in the 'wise-use' of forests by exploiting the forest resources within its regenerative capacity. It essentially allows traditional uses of forest in a regulated way, so that, the ecosystem services are not over exploited and at the same time, the dependent community continues to receive the traditional benefits from the forests. The concepts of SFM led to the evolution of the concepts of participatory forest management in the following years. This policy advocacy in the global platforms significantly influenced the national governments in the region to involve the local forest dependent communities in the erstwhile hierarchal forest management strategies. Therefore, since the early nineties, many countries in the region shifted towards a decentralized forest management regime by involving the local communities as an important stakeholder. This has also led to significant alterations of mangrove management strategies, and, consequently, many countries adopted the principles of participatory mangrove management or commonly known as Community based Mangrove management (CBMM). As mentioned by Datta et al. 2012, the rationale of CBMM lies in tapping '*the potential of local communities' involvement in accomplishing the vital activities of resource identification, priority development, choice and adaptation of appropriate technologies for formulating and implementing sustainable management practice*'. In simpler terms, it envisages people centric management of fragile mangrove resources, by establishing strong linkages with the communities and empowering them to protect the forests. In return, the communities are allowed to sustainably exploit the forests for their livelihood and other requirements. As argued by Melena, 2005, the key essence of CBMM relies on the principles of '*people first and sustainable mangrove forest management will follow*'. Consequently, Community-based Mangrove Management (CBMM) has gained wide recognition as potential alternatives to the traditional hierarchical mangrove management, especially in the backdrop of economically depressed coastal areas, where traditional dependence on mangroves are significantly high (Pomeroy & Carlos 1997; Ellis & Porter-Bolland 2008; Datta et al. 2012, DasGupta & Shaw 2013a). Hence, participatory mangrove management remains an important strategy for promoting mangrove based Eco-DRR strategies in coastal areas.

Within South and Southeast Asia, CBMM initiatives are very prominent in Thailand, Indonesia, Philippines, Bangladesh and India. For example, in case of Thailand, it is mentioned that a greater number of successful CBMM initiatives helped to maintain the desirable nationwide mangrove cover of more than 2000 sq. km (Datta et al. 2012). Similarly, CBMM is also credited to successful restoration of the Pichavaram mangroves, the second largest mangrove forest in India (Selvam, 2003). Identical instances are also available from the Philippines, Indonesia and Bangladesh (e.g. Walters 2004; Islam & Wahab 2005). However, on the other hand, despite of strong potential, the existing scope of CBMM is currently limited in countries like Vietnam and Myanmar due to lack of supportive policies and necessary governance mechanism (Oo 2002; Datta et al., 2012). For example, in case of Vietnam, CBMM is initiated under Protection Forest Management Boards (PFMBs) at the provincial level, but it neither contains any legal sanctity nor extends the forest rights to the managing communities. Therefore, despite of the fact, that participatory mangrove management has been well accredited by policy planners and academia, its field implication widely varies from case to case basis. A multitude of factors are held responsible for the lack of desirable outcome from CBMM such as lack of forest and property rights, inadequate institutional mechanism, tenurial security, poor incentive design etc. Although there is no empirical generalization of factors leading to its success, many argue, especially in the context of South and Southeast Asia, that participatory mangrove management, in some cases, has been implemented as mere strategic arrangement without adequate policy reforms. This vacuum, however, is not very well researched till date.

2.7. Status and Management of Mangroves in India

This section of the chapter is specially aimed to understand the existing opportunities and challenges of implementing mangrove based disaster risk reduction strategies in India. In particular, this section narrates the current mangrove management mechanism, its evolution over the previous decades and its effectivity in protection and restoration of the mangrove resources of the country.

2.7.1. Current Status of Mangroves in India

India is home to a variety of coastal and marine ecosystems that includes 4628 sq. km of diverse mangrove forests (Forest Survey of India 2013). Although these mangroves contribute for only 0.67% of the total designated forest area in India, their presence remain utterly important under the growing concern of global reduction of mangrove habitats as well as against the threats of climate related disasters that the country is presently undergoing. However, the current extent of mangroves is only a modest remaining of the past. Earliest available estimation reveals that despite of considerable loss over the precedent decades, mangrove habitats in India covered close to 6000 sq. km even during 1960s (FAO 2003; Gnanappazham and Selvam 2011). Since then, Indian mangroves suffered significant loss leading to a gross mangrove area of 4046 sq. km. in 1987. However, official statistics from 1987 to 2013 reveals that the extent of mangrove cover actually stabilized close to 4500 sq. km since 1995 (Forest Survey of India 2013).

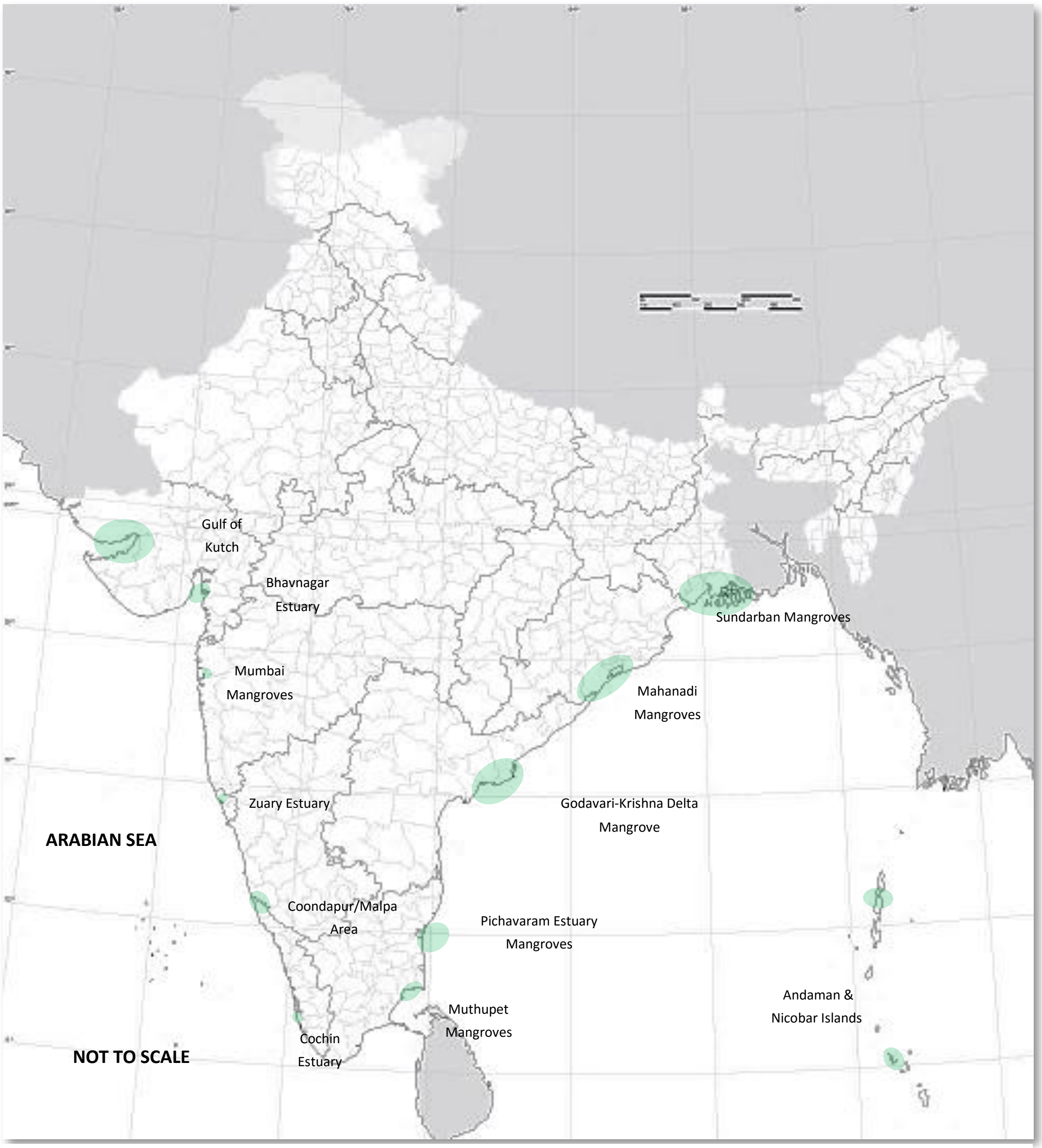


Figure 2.1. Major Mangrove Habitats in India (Adopted from DasGupta and Shaw, 2013b)

As per the latest statistics revealed by the Forest Survey of India 2013, almost 60% of the Indian mangroves are confined to the eastern coast of India while the Sundarban Mangroves being the largest occurring mangrove habitat in the country, alone accounts for nearly 46% of the entire mangrove extent of the country. On the other hand, the western coast of India and the Andaman & Nicobar Islands in the Bay of Bengal encompasses 27% and 13% respectively. Majority of the existing mangroves in India, presently, enjoys a high degree of legislative protection, although, historically, mangroves were considered as mosquito infested wasteland and were cleared to make space for human settlements, agricultural lands and so on. In addition, conservation and restoration of mangroves have also been prioritized in the 'Green India Mission' under the National Action Plan on Climate Change (2008) which sets an ambitious target of 1000 sq. km addition to the existing mangroves by the end of 2020 (DasGupta & Shaw, 2013b).

Despite of high degree of legislative protection, the mangroves along the Indian coast continues to remain critical. It has been estimated 100% of the mangrove species, 92% of other flowering plants, 60.8% of seaweeds, 23.8% of marine invertebrates and 21.2% of marine fish are threatened (ENVIS 2002). Out of the 39 species of mangroves that are widely encountered over the Indian coast, 37 species are considered under varied degree of extinction risks while 11 mangrove species are considered to be critically endangered (MoEF 2008). Such extinction risks are associated with various distinct factors and more often closely linked to direct or indirect human interventions. Several habitat specific studies reported that despite of protected status, local communities continue to invade the mangroves primarily for coastal agricultural land development and shrimp (pond) farming especially in the eastern coast (Ambastha et al. 2010; Pattanaik and Prasad 2011; Vyas and Sengupta 2012). In the past three decades (1975-2005), India lost 17,179 ha and 7554 ha of mangroves due to agricultural land conversion and shrimp cultivation respectively (Giri et al. 2008). Although clear felling for agricultural land reclamation has reduced considerably; recent remote sensing based evidences reveal that conversion to aquaculture ponds still remains as a significant threat especially to the mangroves along the eastern coast (Pattanaik and Narendra Prasad 2011; Ponnambalam et al. 2012). On the other hand, increased population pressure in the vicinity along the larger mangrove habitats, such as Sundarbans, provides significant risk of unsustainable exploitation of mangroves (Mandal et al. 2010).

Apart from the conventional use of mangroves by forest adjacent communities, recent industrial and infrastructural development in the coastal plains along with large quality municipal sewage disposal into the creeks and estuaries forms a formidable threat to the Indian mangroves. A good number of studies reveal that environmental pollution, especially the discharge of heavy metals and organic wastes, remain one of the most decisive factor behind the degradation and degeneration of mangrove habitats and overall deterioration of the ecological health (e.g. Bhattacharya et al. 2003; Agoramoorthy et al. 2007; Remani et al. 2010).

2.7.2. Management of Indian Mangroves

Until the late seventies, Indian mangroves were very much a part of the vast forest resources of the country and were managed accordingly at per with the other inland forests. As mentioned earlier, Indian mangroves received a special attention only after the Ramsar Convention (1971), followed by Convention concerning the Protection of the World Cultural and Natural Heritage (1972). These two conventions lead to steady conservative initiatives restricting deforestation of mangroves in India. The National Mangrove Committee (NMC) was formed as an advisory body to the Government of India to promote mangrove conservation. The Committee, on its first recommendation in 1979, suggested for scientific assessment and evaluation of the mangrove habitats in the country. The committee subsequently identified 15 potential sites for conservation of mangrove habitats during 1987. Based on their recommendation, the Ministry of Environment and Forests (MoEF) launched a scheme on Conservation and Management of Mangroves and Coral Reefs during 1986-87. The goal of this scheme was to develop the degraded mangrove ecosystems, maintain and enrich the biological diversity in mangrove areas and creating public awareness for protection of mangrove ecosystems at provincial level. The federal government also provided guidance and financial assistance to the provincial governments for the preparation and implementation of ‘Management Action Plans’ for the conservation and development of the degraded mangrove ecosystems. Implementation of the scheme has been largely successful, with a reported increase of 616 sq.km. of mangrove cover during the 1991-1999.

Presently, most of the Indian mangrove habitats enjoy strong legislative protection under the Indian Forest Conservation Act, 1980 as well as under the Wildlife (Protection) Act, 1972 (which designates the mangrove habitats as Marine and Coastal Protected areas). These two acts essentially categorize the forests in to various classes with respect to their degree of ecological importance. This categorization closely resembles with the different types of IUCN classified protected areas. Presently, the mangroves habitats are classified in either of the following category such as National Park (IUCN category II), Wildlife sanctuary (IUCN category IV), Reserve and protected forests (IUCN category IV/VI). More so, the designated status is often upgraded to provide more legal protection to the mangroves. For example, the core area of the Sundarban mangrove forests were initially declared as Tiger reserve in 1973, the same was declared as Wildlife sanctuary in 1977 and later in the year 1984, it received the status of a National Park. Importantly, this also implies the degree of restriction imposed on the piece of the mangrove.

The Indian forest management policy underwent a paradigm shift in the early nineties through the induction of Joint Forest Management (JFM), a federal government initiative to decentralize the management rights of the forests and to involve local communities and other stakeholders in the mainstream forest management. This participatory forest management scheme opened substantial legal avenues to involve the forest dependent communities and in turn, aimed to achieve its two defined objectives, i.e. community based ecological conservation and improvement of local livelihood through controlled exploitation of forest resources (Kumar 2002; Behera, & Engel 2006; Bhattacharya et al. 2010). This was a path breaking initiatives, which also decentralized the management of mangroves. Over the previous years, majority of the mangrove-protected areas were brought under the JFM mechanism. However, what is interesting is that, the JFM were introduced in the buffer areas of main mangrove habitats, while the core forested areas continued to remain as 'protected areas'.

Many of Indian mangroves are now managed through JFM mechanism where the community develops local strategies for sustainable management of the mangrove. This is primarily done through the consultation with the local forest department, scientific bodies, NGOs and other stakeholders. Effective contributions from all the relevant stakeholders are ensured through periodical discussions and workshops. Apart from the targeted mangrove conservation and restoration, several short and long-term developmental goals are also implemented through this community-based organization, popularly known as Joint Forest Management Committees (JFMC). For example, at present 65 JFMCs are given the responsibility of managing approximately 64000 ha of the Indian Sundarban. In all such cases, mangroves are primarily protected by the local communities and the near forest dwellers, who in turn, enjoys their traditional claim over the Non timber Forest Products (NTFP) such as wax, honey etc. In addition, they also receive substantial amount of forest revenue generated through rotation felling and tourism. Such participatory arrangement is especially prominent in the state of Tamil Nadu, Orissa, West Bengal and Gujarat. However, so far, there is no uniform standard of benefit sharing and it remains as per the provincial government's policy.

2.7.3. Opportunities and Challenges in Mangrove based DRR in India

In compassion to other countries in the region, India is essentially a mangrove rich country. The hot tropical environment with mighty rivers emptying into the sea provides many opportunities for the mangrove to colonize its coasts. In particular, the extended flat east coast of India, being typically exposed to the Bay of Bengal, provides the definite backdrop for mangrove based disaster risk reduction. However, as mentioned, despite of years of legislative protection and ample of conservative policies, mangrove continues to disappear and degrade. Hence, in order to promote such approach to safeguard millions of coastal communities living in these vulnerable coastal plains, an ameliorative strategy for mangrove conservation is highly imperative. Despite of the fact that India is particularly strong on the policy front with adequate legal support for conservation of mangroves, yet, effective implementation of forest legislations is often hampered by the lack of financial and human resources (ENVIS 2002). Majority of the Indian mangroves are situated in topographically complex and inaccessible areas, hence, the forest department had, so far, failed to establish its statutory rights over the mangroves. More so, the institutional mechanism for forest management in India, at all level of governments are characterized by poor infrastructure, lack of man power and lack of political will. In lieu to this, strict conservation of mangroves is essentially related to the loss of livelihood of the communities and may result in massive social disruption. All the above factors are indicative of the potential threats associated with strict legislative measures of mangrove conservation.

Under this backdrop, participatory mangrove management provides an ameliorative and alternative way to secure the mangrove resources; however, it also requires further fine-tuning. For example, so far, the outcome of JFM, both in the case of inland forests and mangroves, has been contradicting. While some researchers (e.g. Selvam 2003) argues the effectivity of the participatory mangrove management, many other also exemplifies its potential limitations (e.g. Datta et al. 2012). Importantly, despite of the fact the JFM is a federally administered policy, local level implementation, in particular, the ‘incentives’ largely varies according to the implementing partners, i.e. the provincial governments. In addition, many researchers have identified predominance of local political leaders, ineffective benefit sharing and the hostile attitude of local forest officials as the potential causes of non-functioning of the JFMCs (e.g. Behera & Engel 2006; Bhattacharya et al. 2010). On an institutional front, it is often argued that the existing JFM arrangement is still very much skewed in favor of the local forest departments. It makes the community responsible for afforestation and maintenance of the existing forests, while they may not have the one responsible for the degradation. In addition, community organizations responsible for the management of forests often suffer lack of tenurial security and legal sanctity. However, the most important issue of successful JFM implementation revolves around the community consensus over the derived incentives. Unequal distribution of resources and lack of transparency in resource harvesting often led to conflicts and loss of community interest in participatory management. Although these factors vary from case to case basis, meaningful representation of the mangrove dependent communities in the existing JFM arrangements remains crucial for the future sustainability of the Indian mangroves. Needless to say, this also will form the basis of a proactive mangrove based coastal disaster risk reduction strategy in the country.

2.8. Key Findings from the Literature Review

The chapter attempted to provide the conceptual and thematic review of three major aspects that forms the basis of this research work. Firstly, it provides a conceptual review of the evolution and application Disaster Risk Reduction (DRR) concepts. Focusing on the contemporary approaches of DRR, the chapter particularly focused on the Ecosystem-based Disaster Risk Reduction (Eco-DRR) and its applicability under the coastal hazard scenarios. Secondly, the chapter symptomatically focused on mangrove ecosystems and its ecosystem services, with a through discussion of its pivotal role in DRR. Thirdly, the chapter also narrates a thematic review of the chorological degradation of mangroves, its potential causes and the existing management practices in the regional backdrop of South and Southeast Asia, and with detailed illustration on the Indian mangroves. The key findings from this thee tiered desktop review can be summarized in the following points.

- ❖ Disaster Risk Reduction is all about reducing exposure, minimizing vulnerability and increasing coping capacities of the communities. As the Eqn. 2.3. suggests, the three most important variable that plays the pivotal role in DRR is the ‘Basic Vulnerability’ (Vb), ‘Exposure’(E) and ‘Coping Capacity’ (C). Particularly, in respect to rural resource-dependent communities, basic vulnerability i.e. the lack of physical amenities (connectivity, electricity, housing etc.) along with lack of human development (education, livelihood, health etc.) attributes to high disaster risks.
- ❖ Ecosystem based Disaster Risk Reduction, such as mangrove based DRR provides a low-cost alternative to traditional hard engineering based risk reduction measures. This is especially applicable for the developing or least developed countries, where resources are inadequate to build hard-engineered structures. In case of countries or communities that can afford engineered structures, an integrated approach, i.e. the combination of structural measures along with ecosystem-based solutions, is more likely to bring better results. In the backdrop of rural resource dependent communities, Eco-DRR approaches not only helps to minimize direct exposures from disasters, it also reduces the basic vulnerability by creating physical and economic assets.

- ❖ Even without disasters, eco-system based approaches generate net social and economic assets, which is typically responsible for reducing the socio-economic vulnerability of the community.
- ❖ Mangroves have high potential for Disaster Risk reduction. Especially, its role in reducing the exposure of tsunamis, storms and surges have been proved beyond doubts. In addition, the provisioning, habitat and cultural ecosystem services of mangroves are essential for reducing socio-economic vulnerability of the communities. However, significant knowledge gap exists in terms pinpointing the key attributing factors, such as the extent of storm or wave attenuating abilities.
- ❖ Despite of high potential of mangrove based DRR, South and Southeast Asia continues to loose mangroves in an unprecedented way. The two major delineating factors for mangrove degradation, i.e. agricultural land conversion and development of aquaculture ponds largely indicate the poor livelihood scenario along the South and Southeast Asian coast.
- ❖ Mangrove habitats in this region represents complex socio-ecological systems. Therefore, without knowing its boundary conditions, implementing protected area based management may invite potential conflicts. In such cases, participatory mangrove management has been identified as an ameliorative approach of mangrove conservation.
- ❖ In India, JFM has paved the way for participatory conservation of mangroves, which can be considered as the basis of community and ecosystem based disaster risk reduction. However, it may require may fine adjustments to effectively engage the community in the participatory process based on the local scenarios.

References

Abbas S., Qamer F.M., Hussain N., Saleem R., Nitin K.T. (2011): National level assessment of mangrove forest cover in Pakistan, ISPRS Achieves XXXVII-8/ W20, Workshop Proceedings: Earth Observation for Terrestrial Ecosystem.

Abel, N., Gorddard, R., Harman, B., Leitch, A., Langridge, J., Ryan, A., & Heyenga, S. (2011). Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study. *Environmental Science & Policy*, 14(3), 279-288.

ADB (2013). Asian Water Development outlook 2013, Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines: Asian Development Bank.

Agoramoorthy, G., Chena, F., Hsu, M.J., (2007). Threat of heavy metal pollution in halophytic and mangrove plants of Tamil Nadu, India. *Environmental Pollution* 155, 320-326.

Alongi, D. M. (2008). Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, 76(1), 1-13.

Ambastha, K.R., Hussain, S.A., Badola, R., Roy, P.S., (2010). Spatial analysis of anthropogenic disturbances in mangrove forests of Bhitarkanika Conservation Area, India. *Journal of Indian Society of Remote Sensing* 38, 67-83

Bakosurtanal (2009). National survey & mapping coordination agency, "Indonesia: peta mangrove Indonesia," Indonesian Mangrove Atlas.

Bandaranayake W.M., (1998): Traditional and Medicinal uses of Mangroves, *Mangroves and Salt Marshes*, Vol 2: PP 133-138

Bangladesh Forest Department (2008). National Forest and Tree Resources, Assessment Report 2005–2007.

Barbier, E. B., Koch, E. W., Silliman, B. R., Hacker, S. D., Wolanski, E., Primavera, J., ... & Reed, D. J. (2008). Coastal ecosystem-based management with nonlinear ecological functions and values. *Science*, 319 (5861), 321-323.

Barbier, E., & Cox, M. (2002). Economic and demographic factors affecting mangrove loss in the coastal provinces of Thailand, 1979-1996. *AMBIO: A Journal of the Human Environment*, 31(4), 351-357.

Behera, B., & Engel, S. (2006). Institutional analysis of evolution of joint forest management in India: A new institutional economics approach. *Forest Policy and Economics*, 8(4), 350-362

Bennett, E. L., & Reynolds, C. J. (1993). The value of a mangrove area in Sarawak. *Biodiversity & Conservation*, 2(4), 359-375.

Bhattacharya, B., Sarkar, S.K., Mukherjee, N., (2003). Organochlorine pesticide residues in sediments of a tropical mangrove estuary, India: implications for monitoring. *Environment International*, 29, 587-592.

Bhattacharya, P., Pradhan, L., & Yadav, G. (2010). Joint forest management in India: Experiences of two decades. *Resources, Conservation and Recycling*,54(8), 469-480

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (2014). At risk: natural hazards, people's vulnerability and disasters. Routledge.

Brown, B. (2007). Resilience thinking applied to the mangroves of Indonesia. IUCN and Mangrove Action Project, Yogyakarta, Indonesia.

Cannon, T. (2008). Vulnerability, 'innocent' disasters and the imperative of cultural understanding, *Disaster Prevention and Management*, Vol. 32 No. 3, pp. 350-357.

Carmen Lacambra, Daniel A. Friess, Tom Spencer and Iris Moller (2013): Bioshileds: Mangrove Ecosystems as Resilient Natural Coastal Defenses in The role of ecosystems in disaster risk reduction (Ed. Renaud et al.). United Nations University Press.

Carter, N. (1991) Disaster Management: A Disaster Manager's Handbook. Asian Development Bank, Manila.

Chong V.C. (2007): Mangrove Fisheries Linkage-the Malaysian perspective, *Bulletin of Marine Science*, Vol. 80(3), 755-772

Cline, E. H. (2014). 1177 BC: The Year Civilization Collapsed: Princeton University Press.

Cuny, F. (ed.) (1993) Prehospital and Disaster Medicine. University of Wisconsin, Madison.

Cutter, S. L., & Gall, M. (2015). Sendai targets at risk. *Nature Climate Change*, 5(8), 707-709.

Dahdouh-Guebas, Koedam, F.N., Danielsen, F., Sorensen, M.K., Olwig, M.F., Selvam,V., Danielsen F, Sørensen MK, Olwig MF, Selvam V, Parish F, Burgess ND, Suryadiputra N (2005). The Asian tsunami: a protective role for coastal vegetation. *Science* (Washington) 310(5748):643

Das S, (1999): Examining the Storm Protection Services of Mangroves of Orissa during the 1999 Cyclone, *Economic & Political Weekly*, Vol. XLVI No. 24 3.

Das, S., & Vincent, J. R. (2009). Mangroves protected villages and reduced death toll during Indian super cyclone. Proceedings of the National Academy of Sciences, 106(18), 7357-7360.

DasGupta, R., & Shaw, R. (2013a). Cumulative impacts of human interventions and climate change on mangrove ecosystems of South and Southeast Asia: an overview. *Journal of Ecosystems*, 2013.

DasGupta, R., & Shaw, R. (2013b). Changing perspectives of mangrove management in India–An analytical overview. *Ocean & Coastal Management*, 80, 107-118.

DasGupta, R., Shaw, R., & Abe, M. (2015). Environmental Recovery and Mangrove Conservation: Post Indian Ocean Tsunami Policy Responses in South and Southeast Asia. In Recovery from the Indian Ocean Tsunami (pp. 29-42). Springer Japan.

Datta, D., Chattopadhyay, R. N., & Guha, P. (2012). Community based mangrove management: A review on status and sustainability. *Journal of environmental management*, 107, 84-95.

de Boer, J. (1990). Definition and classification of disasters: introduction of a disaster severity scale. *The Journal of emergency medicine*, 8(5), 591-595.

de Guzman, E. M., & Unit, A. D. R. (2003). Towards total disaster risk management approach. United National Office for the Coordination of Humanitarian Affairs, Asian Disaster Response Unit.

de la Poterie, A. T., & Baudoin, M. A. (2015). From Yokohama to Sendai: Approaches to participation in international disaster risk reduction frameworks. *International Journal of Disaster Risk Science*, 6(2), 128-139.

Dixon J.A. (l989). The value of mangrove ecosystems, Tropical Coastal Area Management.

EJF (2006) Nature's defence against Tsunamis: a report on the impact of mangrove loss and shrimp farm development on coastal defence. In: Mangroves. Environmental Justice Foundation, London.

Ellis, E. A., & Porter-Bolland, L. (2008). Is community-based forest management more effective than protected areas? : A comparison of land use/land cover change in two neighboring study areas of the Central Yucatan Peninsula, Mexico. *Forest ecology and management*, 256(11), 1971-1983.

ENVIS (2002). Mangroves of India: State-of-the-art Report. Environmental Information System Centre, Centre of Advanced Study in Marine Biology, Annamalai University, India.

FAO, (2003). Status and Trends in Mangrove Area Extent Worldwide by Wilkie, M.L. and Fortuna, S. In: Forest Resources Assessment Working Paper No. 63. Forest Resources Division, FAO, Rome. (Unpublished).

FAO, (2007). The World's Mangrove 1980–2005, United Nations Food and Agriculture Organization.

FAO, (2010). Global Forest Resources Assessment, Country Report- Myanmar, 2010.

Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., & Silliman, B. R. (2011). The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. *Climatic Change*, 106(1), 7-29.

Gilman, E. L., Ellison, J., Duke, N. C., & Field, C. (2008). Threats to mangroves from climate change and adaptation options: a review. *Aquatic botany*, 89(2), 237-250.

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., ... & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, 20(1), 154-159.

Gnanappazham, L., Selvam, V., 2011. The dynamics in the distribution of mangrove forests in Pichavaram, South India-perception by user community and remote sensing. *Geocarto International*, 26 (6), 475e490.

Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, 68(3), 338-354.

Government of Vietnam (2008). Decision No. 1267/QD-BNN-KL, National Statistics on Forest Land, 2008.

Harada, K., & Imamura, F. (2005). Effects of coastal forest on tsunami hazard mitigation—a preliminary investigation. In Tsunamis (pp. 279-292). Springer Netherlands.

Hiraishi, T., & Harada, K. (2003). Greenbelt tsunami prevention in South-Pacific region. Report of the Port and Airport Research Institute, 42(2), 1-23.

Islam, M. S., & Wahab, M. A. (2005). A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture. In Aquatic Biodiversity II (pp. 165-190). Springer Netherlands.

Kathiresan K & Rajendran N (2005). Coastal mangrove forests mitigated tsunami. *Estuarine Coast Shelf Sciences*, 65(3):601–606.

Kathiresan, K. (2011). Threats to Mangroves in Training Course on Mangroves and Biodiversity, United Nations University, 2011, http://ocw.unu.edu/international-networkon-water-environment-and-health/unu-inweh-course-1-mangroves/ Course listing/.

Kathiresan, K. (2012). Importance of mangrove ecosystem. *International Journal of Marine Science*, 2(1).

Kelman, I., & Glantz, M. H. (2015). Analyzing the Sendai Framework for Disaster Risk Reduction. *International Journal of Disaster Risk Science,* 6(2), 105-106.

Kumar, S. (2002). Does "participation" in common pool resource management help the poor? A social cost–benefit analysis of joint forest management in Jharkhand, India. *World Development*, 30(5), 763-782.

Kunkel, C. M., Hallberg, R. W., & Oppenheimer, M. (2006). Coral reefs reduce tsunami impact in model simulations. *Geophysical Research Letters*, 33(23).

M. T. C. (2009) [Malaysian Timber Council], 'Matang Mangroves: a century of sustainable management,' *Timber Malaysia*, vol. 15, no.3, pp. 7–11.

Mandal, R.N., Das, C.S., Naskar, K.R.(2010). Dwindling Indian Sundarban mangrove: the way out. *Science & Culture* 76 (7-8), 275-282.

McEntire, D. (2012). Understanding and reducing vulnerability: from the approach of liabilities and capabilities. Disaster Prevention and Management: *An International Journal*, 21(2), 206-225.

Melana, D. M., Melana, E. E., & Mapalo, A. M. (2005). Mangroves management and development in the Philippines.

MFF, Thailand, National Strategy Action Plan, 2011–2013, 2011.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Wellbeing: Synthesis, Washington, DC, Island Press.

Mitra, A. (2013). Sensitivity of mangrove ecosystem to changing climate. Springer.

MoEF, GoI, 2008. Mangroves for The Future: National Strategy and Action Plan, India (Revised Draft).

Mukhtar, I., & Hannan, A. (2012). Constrains on mangrove forests and conservation projects in Pakistan. *Journal of Coastal Conservation*, 16(1), 51-62.

Nagelkerken, I., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., ... & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: a review. *Aquatic Botany*, 89(2), 155-185.

Nanda, P. K. (2011). The port of Paradip: mangrove forest to a major port. *Orissa Review*, 68-78.

Ogino, Y., Takeuchi, Y., Shaw, R., Shaw, R., & Krishnamurthy, R. (2010). Community perspective of mangrove protection and its implication to coastal zone management. Communities and Coastal Zone Management, 113-126.

Omar I. B. H. (2002). National report of Malaysia on the formulation of a trans-boundary diagnostic analysis and preliminary framework of a strategic action program for the Bay of Bengal, Tech. Rep., United Nations Environment Program.

Oo, N. (2002): Present state and problems of mangrove management in Myanmar. *Trees-Structure and Function*, 16(2), 218-223.

Padilla J.E. (2008). Analysis of Coastal and Marine Resources: A Contribution to the Philippine, World Bank Report.

Parish, F., (2006). Coastal vegetation and the Asian tsunami. 311, p. 37-38.

Pattanaik, C., Narendra Prasad, S. (2011). Assessment of aquaculture impact on mangroves of Mahanadi Delta (Orissa), East Coast of India using remote sensing & GIS. *Ocean & Coastal Management*, 54, 789-795.

Doswald N. & Estrella M. (2015). Promoting ecosystems for disaster risk reduction and climate change adaptation, Opportunities for Integration, UNEP

Pendleton L, Donato DC, Murray BC, Crooks S, Jenkins WA (2012). Estimating Global ''Blue Carbon'' Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems. PLoS ONE 7(9): e43542. doi:10.1371/journal.pone.0043542

Remani, K.N., Jayakumar, P., Jalaja, T.K., (2010). Environmental problem and management aspects of Vembanad Kol wetlands in south west coast of India. Nature, Environment and Pollution Technology 9 (2), 247-254.

Renaud, F. G., Sudmeier-Rieux, K., & Estrella, M. (2013). The role of ecosystems in disaster risk reduction. United Nations University Press.

Rönnbäck, P. (1999). The ecological basis for economic value of seafood production supported by mangrove ecosystems. Ecological Economics, 29(2), 235-252.

Rutherford, W. H., & De Boer, J. (1983). The definition and classification of disasters. *Injury*, 15(1), 10-12.

Sandilyan, S., & Kathiresan, K. (2012). Mangrove conservation: a global perspective. *Biodiversity and Conservation*, 21(14), 3523-3542.

Selvam, V., Ravichandran, K. K., Gnanappazham, L., & Navamuniyammal, M. (2003). Assessment of community-based restoration of Pichavaram mangrove wetland using remote sensing data. *Current science*, 85(6), 794-798.

Shaw, R. (2006). Indian Ocean tsunami and aftermath: need for environment-disaster synergy in the reconstruction process. *Disaster Prevention and Management: An International Journal*, 15(1), 5-20.

Shaw, R., Islam, A., & Mallick, F. (2013). Disaster, Risk and Evolution of the Concept. In Disaster Risk Reduction Approaches in Bangladesh (pp. 3-21). Springer Japan.

Shook, G. (1997). An assessment of disaster risk and its management in Thailand. *Disasters*, 21(1), 77-88.

Thampanya, U., Vermaat, J. E., Sinsakul, S., & Panapitukkul, N. (2006). Coastal erosion and mangrove progradation of Southern Thailand. *Estuarine, coastal and shelf science*, 68(1), 75-85.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G., & Rockström, J. (2006). Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, 30(1), 39-48.

Thomas, G., & Fernandez, T. V. (1994). Mangrove and tourism: management strategies. *Indian Forester*, 120(5), 406-412.

UNISDR (2005): Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters.

UNISDR (2009). "UNISDR terminology on disaster risk reduction." Geneva, Switzerland.

UNISDR (2012). Reducing Vulnerability and Exposure to Disasters, The Asia-Pacific Disaster Report 2012.

UNISDR (2014): Asia-Pacific Input Document for the Post-2015 Framework for Disaster Risk Reduction (HFA2).

Van Niekerk, D. (2008). From disaster relief to disaster risk reduction: A consideration of the evolving international relief mechanism. TD: *The Journal for Transdisciplinary Research in Southern Africa*, 4(2), 355-376.

Vermaat, J.E., and Thampanya, U., 2006. Mangroves mitigate tsunami damage: A further response. A further response. *Estuarine, Coastal and Shelf Science*. 69, p.1-3

Vo, Q. T., Kuenzer, C., Vo, Q. M., Moder, F., & Oppelt, N. (2012). Review of valuation methods for mangrove ecosystem services. *Ecological Indicators*, 23, 431-446.

Vyas, P., Sengupta, K., (2012). Mangrove conservation and restoration in the Indian Sundarbans. In: Sharing Lessons on Mangrove Restoration, Proceedings and a Call for Action from an MFF Regional Colloquium, pp. 93-101.

Walters, B. B. (2004). Local management of mangrove forests in the Philippines: successful conservation or efficient resource exploitation? *Human Ecology*, 32(2), 177-195.

Walters, B.B., Ro¨nnba¨ck, P., Kovacs, J.M., Crona, B., Hussain, S.A., Badola, R.,Primavera, J.H., Barbier, E., Dahdouh-Guebas, F., (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquatic Botany*. 89, 220–236.

Wells, S., Ravilous, C., Corcoran, E., 2006. In the Front Line: Shoreline Protection and Other Ecosystem Services from Mangroves and Coral Reefs. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, UK.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). At Risk: Natural Hazards. People's Vulnerability and Disasters, Routledge, London.

Wolanski, E. (2007). Synthesis. Thematic paper: Synthesis of the protective functions of coastal forests and trees against natural hazards. RAP Publication (FAO).

Wong, C. M., Williams, C. E., Pittock, J., Collier, U., & Schelle, P. (2007). World's top ten rivers at risk. Gland, Switzerland: WWF International.

World Disaster Report (2012): Available online at https://www.ifrc.org/Global/Publications/disasters/WDR/32600-WDR2002.pdf

World Risk Report (2011). United Nation University, Institute for Environment and Human Security.

Yanagisawa, H., Koshimura, S., Goto, K., Miyagi, T., Imamura, F., Ruangrassamee, A., & Tanavud, C. (2009). The reduction effects of mangrove forest on a tsunami based on field surveys at Pakarang Cape, Thailand and numerical analysis. *Estuarine, Coastal and Shelf Science,* 81(1), 27-37.

Zhang, K., Liu, H., Li, Y., Xu, H., Shen, J., Rhome, J., & Smith, T. J. (2012). The role of mangroves in attenuating storm surges. *Estuarine, Coastal and Shelf Science*, 102, 11-23.

CHAPTER 3: Resilience of Socio-Ecological System against Coastal Hazards

"Resilience is accepting your new reality, even if it's less good than the one you had before. You can fight it, you can do nothing but scream about what you've lost, or you can accept that and try to put together something that's good."

Elizabeth Edwards, American attorney and author

CHAPTER 3: Resilience of Socio-Ecological System against Coastal Hazards

The chapter narrates the key concepts of community resilience against coastal hazards and develops an indicator based ameliorative methodology to assess community resilience in Low-lying delta areas. This includes the development of a five dimensional resilience assessment framework, selection of appropriate indicators, and construction of an an index that is representative of the disaster and climate resilience of rural, resource-dependent coastal communities as observed in the Indian Sundarban Delta. In lieu with that, the chapter further narrates the implementation exercises of the above mentioned framework in the study area and illustrates the resilience profile of the 19 existing Community Development Blocks with the help of spatial maps and index scores. The chapter concludes with some of the specific findings and explanation of the observed variation of community resilience across the length and breadth of the delta.

Outline of the Chapter 3

Resilience of Socio-Ecological System against Coastal Hazards

3.1. Introduction to Socio-ecological Systems

The term 'Socio-ecological system' is generally used to denote the linked systems of people and nature. Originally proposed by Fikret Berkes and Carl Folke in 1998, the concept of 'Socio-Ecological System' has received wide attention in the recent years, and a plethora of associated terminologies such as 'coupled human-environment systems', 'eco-social systems' were also emerged simultaneously. Despite of some semantic differences, the idea of using these terminologies is to emphasize that humans must be seen as a part of nature or the larger ecosystem, complexly interlinked with the production, consumption and regeneration of vital ecological services that the mother nature provides (Folke 2006; Cote & Nightingale 2012). Furthermore, performance of this coupled human-nature system depend on the interlaying relationship between human and nature, often in a multiple and complex way. The Millennium Ecosystem Assessment in 2005, therefore emphasized the need of correlative management of natural and human systems in order to secure a sustainable future for both of these systems. Consequently, a new doctrine, named as 'Ecosystem-based management' emerged over the previous years which envisages '*an integrated approach of management that considers the entire ecosystem, including humans*' (Crowder & Norse 2008).

Coastal areas, in particular, are typical examples of highly dynamic socio-ecological systems. Being rich in natural ecosystem services, these areas have traditionally attracted resource dependent communities. As a result, coastal areas have undergone extensive changes over the past century (Adger 2005; MEA 2005). As mentioned in Chapter 2, this includes massive deforestation of mangroves and other coastal forests, land use alteration for settlement and agriculture, industrial and waterfront development etc. However, being sensitive to wide range of natural hazards, from floods, cyclones to sea level rise; impacts of discontinued ecosystem services is prominent as mentioned in several assessment reports over the last decade. Despite of massive economic development that the World's coast sustained over the last century, many researchers argue that the collective capacity of coastal systems, including both human and ecological systems, have been drastically reduced in some of the thickly populated coastal areas across the world, and that, the erosion of ecological or environmental resilience have particularly led to an increased vulnerability of the coastal communities (Adger 2005). In particular, rural, resource dependent coastal communities in the developing world, who survive over the performance of coastal ecosystem services forms the most vulnerable 'Socio-ecological' systems with extremely limited coping capacities to external stresses such as disaster and climate change (Adger 2005; Nicholls et al. 2007; Mcgranahan et al. 2007).

3.2. Concept of Resilience

The concept of resilience originally emerged from Holling, who introduced this theory in the field of ecology to understand the non-linear dynamics of ecosystems (Berkes et al. 2003). By the term resilience, Holling described the amount of external disturbance an ecosystem can sustain within its natural regenerative capacity. However, in the following years the concept of resilience became much popular among social as well as psychological scientists, who used this notion to define the capacity of social/ psychological systems to absorb external shocks. In the field of disaster and climate change studies, the concept, nevertheless, replaced the earlier concept of 'vulnerability' since the adoption of the Hyogo Framework of Action (HFA) in 2005. As have been mentioned in chapter 2, during the World Conference on Disaster Reduction (2005), held in Kobe, Japan, HFA urged the national governments to foster 'disaster resilient communities' through its proposed actions (UN/ISDR 2005). It can be, however, argued that, theoretically or in practice, both the concept of 'resilience' and 'vulnerability' can be considered as 'mutually exclusive' (Norris et al. 2008; Miller et al. 2010), i.e. 'resilient' systems are less 'vulnerable' and vice versa. In other words, vulnerability exists when resources are insufficient and fragile to create resistance or 'resilience' to an external stress (Norris et al. 2008). Nonetheless, over the last decade, especially after the adoption of Hyogo Framework for Action, a number of researchers, e.g. Twigg 2007, Cutter 2008, Cutter et al. 2010, Joerin & Shaw 2011, Joerin et al. 2012, Teo et al. 2013 have used the concept of resilience in defining social system's capacity to absorb external shocks. In particular, scholars such as Cutter et al. 2008, Cutter 2008, Béné et al.2012 favored the concept of resilience over vulnerability and described 'resilience' as 'pre-event', 'holistic' and 'adaptive concept'. It is, however, important to mention that despite of extensive research, there is, still, no common agreed definition of 'resilience'. As per the UNISDR official terminology, resilience is defined as –

> *"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions".*

However, from an extensive review of the current literature on disaster and climate resilience, the following three main properties can be highlighted as the desired characteristics of a resilient system, i.e. (1) Resilient Systems can absorb shocks or recurrent disturbances without significant deformation, (2) If deformed, it can recover quickly from an altered state and further can (3) restructure and reorganize itself through adaptive processes and practices (Klein et al. 1998; Adger et al. 2005; Folke 2006; Cutter et al. 2008; Cutter 2008; 2010; Joerin & Shaw 2011, Joerin et al. 2012).

3.3. Resilience of Socio-ecological Systems

In case of a socio-ecological system, it is however, still not clear what exactly forms a resilient system, despite of the fact it is seen as a desirable property of such system. Particularly, with respect to socio-ecological system, resilience is often concerned with the magnitude of the disturbance, both internal and external, within which the system can regenerate or recover quickly. For example, a forest fire may have the same impact of a high intensity storm on a typical socio-ecological system. Similarly, strong social and institutional capacity can overcome an immediate ecological crisis. Hence, more often, a multitude of factors are considered to be responsible for the resilience of coupled 'Human-Environment system' with dimensions ranging from social, economic, ecological as well as natural capacity to rebound. Nevertheless, it is evident from several arguments provided in favor of the role of a healthy ecosystems and its ability to counter the impacts of disasters, that ecosystem health and sustainability play a vital role in enhancing the resilience of socio-ecological systems. Therefore, as argued by Adger 2005, part of the resilience of such system lies in the regenerative capacity of ecosystems and their abilities to deliver resources and ecosystem services irrespective of the external stressor. However, it does not make a community resilient unless there are proper institutions and social capacity to counter the impacts of disasters. Therefore, resilience of 'Socio-ecological system' remains dependent of the complex intra and inter linkages between human and natural systems, and that, measurement of 'resilience' of such systems still remains a significant challenge (Adger 2000; Carpenter et al. 2005; Cutter et al. 2008).

3.4. Development of Coastal Community Resilience Index

Coastal areas, being complex socio-ecological systems, are bounded by its human and environmental limits. Therefore, 'community resilience' in coastal areas or the resilience of the coupled 'human-environment' system can be defined as the capacity of a linked 'socio-ecological system' to absorb recurrent disturbances without significant functional deformation. This capacity, however, remain a complicated function of several factors, ranging from social, infrastructural, economic and ecological features of the coupled system. Nevertheless, the term 'community resilience' itself has divergent views among different stakeholders. For example, policy planners usually view ‘resilience’ as a set of capacities that can be fostered through interventions to enhance the social capacity. Conversely, the scientific community put more emphasis on engineered or structural resilience that also increases community’s ability to rebound from an altered state (Cutter et al. 2010). Therefore, from the perspective of ‘socio-ecological systems’, the critical challenge is to merge different views on resilience and to interlink them through meaningful indicators and/or variables.

Over the past few years, several researchers have formulated quantitative as well as qualitative indicators with particular relevance to community resilience against natural disasters (e.g. USIOTWSP 2007; Cutter et al. 2008; Cutter et al. 2010; Peacock et al. 2010; Uy et al. 2011; Joerin &Shaw 2011; Joerin et al. 2012; Teo et al. 2013). One particular reason for such predominance of indicator based studies is that, it essentially reduces the complexity of the measuring progress, allows a comparative analysis among the adjacent places through mapping and further serves as an important tool for rapid decision making at local level (Cutter et al. 2008). Even though, majority of these frameworks were designed to assess community resilience in coastal areas (e.g. USIOTWSP 2007; Cutter et al. 2010; Peacock et al. 2010; Joerin et al.2012), associated illustrations are mostly drawn against coastal urban areas from the developed countries. Importantly, coastal urban areas, which can be rather considered as ‘socio-technical systems’, differ significantly from coastal rural areas. Undoubtedly, community dependence of coastal ecosystem services in the later plays a crucial role in defining resilience of a more dynamic and complex ‘socio-ecological’ system. Rural dependency on coastal resources, particularly in economically depressed coastal areas across the developing world, often makes the ‘human-environment’ relationship unsustainable which erodes resilience of such systems. For example, communities living in coastal rural areas characteristically depend on fisheries and agriculture, which has direct dependence on the coastal ecosystem services. Consequently, loss of coastal ecosystem services impairs the communities’ ability to respond to a crisis (Uy et al. 2011). Therefore, it is imperative that a new set of appropriate indicators are developed to assess resilience of coastal rural communities, considering they are complex and more heterogeneous socio-ecological systems.

3.4.1. Identification of Relevant Dimensions and Indicators

The initial phase of identification of appropriate indicators involves extensive background literature survey dealing with community resilience against natural disasters and climate change (e.g. Nicholls & Branson 1998; Adger 2000; Adger et al. 2005; USIOTWSP 2007; Cutter et al, 2008; Cutter et al. 2010; Peacock et al. 2010; Uy et al. 2011; Joerin &Shaw 2011;

Joerin et al. 2012; Teo et al. 2013). The specific objective was to identify the representative indicators that can translate the interrelatedness of coastal ‘socio-ecological’ systems. In addition, the study consulted several thematic case studies in order to capture specific components of coastal resilience, for example, role of risk insurance (Clark 1998), performance of local institutions, functional and managerial aspects of mangroves etc. (e.g. Balsco et al. 1996; Adger, 2000; Kathiresan & Rajendran 2005). Furthermore, the study also referred to research area specific literatures in order to understand the applicability of the specific indicators within the local context (e.g. Banerjee 1998; Stanley & Hait 2000; Hazra et al. 2002; Gopinath & Seralathan 2005; Gopal & Chauhan 2006; Mtira et al. 2009; Nandy & Bandhopadhyay 2011; CSE 2012).

In general, community resilience in coastal areas has been broadly classified as three tiered resilience, i.e. Morphological (physical), ecological and socio-economic resilience (Nicholls & Branson 1998). Importantly, the USIOTWSP 2007 framework for coastal resilience, one of the widely recognized coastal resilience assessment framework developed in the backdrop of the Indian Ocean Tsunami, 2004, highlighted the role of effective coastal zone management as a proxy to ecological resilience in coastal areas. The key argument of putting ‘coastal zone management’ as a dimension, is that, it is better representative of the nature and sustainability of human-environment relations in coastal areas, while at the same time, it also translates the ecological capacity of the ‘coupled human-environment’ system. In addition, several researchers mentioned the importance of ‘institutions’ because of its capacity to plan and implement specific policies that involves disaster and/or climate risk reduction. Likewise, ‘institutional resilience’ has emerged as a component of several proposed ‘resilience’ assessment frameworks (e.g. Cutter et al. 2008; Joerin & Shaw 2011; Joerin et al. 2012). In particular, in the backdrop of coastal resource dependent communities, local government and village institutions play an important role and are capable of implementing necessary decisions to foster resilient communities. In lieu to this, network of institutions can also trigger necessary societal changes to implant ‘resilience’. Hence, the study characteristically considered the dimension of ‘Institutional resilience’ considering the network and implementation capacity of the local institutions. Lastly, resilience is also considered as a factor of natural exposure. For example, resilience is often concerned with the magnitude of the disturbance as high susceptibility also leads to stronger possibilities for a system to deform (Berkes et al. 2003). Hence, another dimension, i.e. ‘Environmental/Natural Resilience’ were also included in the proposed framework. In summary, based on the existing literature review, the study proposed an inclusive five dimensional (socio-economic, physical, institutional, coastal zone management and environmental/natural) coastal community resilience assessment framework that is capable of measuring the resilience of a linked 'socio-ecological system' as observed in the study area or comparable 'socio-ecological' systems.

3.4.2. Selection Criteria and Justification of the Indicators and Variables

The key challenge, however, was to develop and customize relevant indicators under the above mentioned five dimensions that can comprehensively represent the resilience of a coupled 'socio-ecological system' as observed in Indian Sundarban. The main criteria for selecting these indicators was to analyze the availability of critical resources and capitals that are essential for the resilience of resource dependent coastal communities. In view of the above, the study developed a 5 x 5 x 5 uniform matrix that consisted **5** dimensions, **25** main indicators and **125** variables, consisting of quantitative (Q) (direct-value based), semi-quantitative (SQ) or proxy (using secondary criteria for subjective assessment), perspective (P) variables (relies on administrator's perspective and local experience). The summarized framework is furnished in **Table 3.1.** Following section justifies and narrates the selection criteria of some of the indicators and variables that were used in this framework.

- ***Indicators for Socio-Economic Resilience***

Importance of Social and Economic Resilience to natural disasters has been widely referred in all the four important policy research domains i.e., disaster risk reduction, climate change adaptation, environmental management and poverty reduction (Thomalla et al. 2006). Particularly, in case of a natural resource dependent community, socio-economic resilience primarily depends on two major aspects, i.e. community competency and pattern of resource utilization. In the present framework, indicators and variables used to measure 'socio-economic resilience' include 'Demography', 'Livelihood', 'Health' and 'Education and Awareness' are essentially the measure of the competency of the communities. In addition, inclusion of 'social-capital' contributes in the understanding of 'network and ties' within and outside the community, which can significantly enhance its capacity to counter external stress (Murphy 2007). Strong social bonding among the communities may also lead to faster recovery and increased participation in ecological conservation (Nakagawa and Shaw 2004; Murphy 2007). Importantly, apart from measuring the community competency, these indicators have certain underlying linkages with sustainable resource utilization, e.g. a demographical stress can easily contribute to poor ecological resilience. Therefore, variables under these indicators, as described in **Table 3.1.,** have been carefully chosen after extensive literature review (e.g. Cutter et al. 2010; Peacock et al. 2010; Joerin and Shaw 2011). Although majority of the variables are representative of the inherent capacity of the communities, variables such as 'livelihood dependence on coastal resources', 'population suffered discontinuation of livelihood aftermath disasters' are indirect measurement of ecological stress exerted by the communities (De Bruijn 2004; Adger 2005). Hence, these five indicators used for measuring socio-economic resilience not only contribute to measure the intrinsic capacity of the communities (community competency), but also attempts to understand its linkages with the existing ecological performances. This, in turn, establishes the interrelatedness of social competency and ecological resource exploitation. In addition, the framework also introduced some site-specific variables such as 'Below Poverty Level (BPL)' population and implementation of 'Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)' etc. which essentially attempts to examine the economic competency of the communities and indirect stress exerted by the 'social system' on the 'ecological system'.

- ***Indicators for Physical Resilience***

Communities, be it rural or urban, depend on a series of infrastructural facilities. Resilient infrastructure systems, particularly 'lifeline' services such as 'connectivity', 'use of electric power', 'water and other public services' are crucial for minimizing the disaster impacts and maximizing communities' coping capacities (McDaniels et al. 2008). Hence, researchers argue that Physical or infrastructural resilience needs to be robust and dynamic to foster resilient communities, and coastal communities are no exception. Bruneau et al. 2003 identified four specific components of structural resilience, i.e. coverage or extent, lower probabilities of failure, less-severe negative consequences when it fails and faster recovery from failures. Unfortunately, rural communities, especially in the developing countries, essentially lack modern infrastructural facilities such as potable water, improved public transportation, electricity etc. Therefore, it can provide little resistance to an external shock. In this present framework, Physical (or Infrastructural) resilience assessment indicators are largely derived from some of the existing frameworks such as Cutter et al 2008; Joerin & Shaw 2011 which recommends 'transportation', 'residential infrastructure', 'electricity', 'telecommunication' and 'water infrastructure' and sanitation as major indicators. The purpose of using such indicators is to measure the physical (infrastructural) capacity of a designated community-while on the other hand, to identify the basic vulnerabilities related to infrastructural deficiencies. By the term ‘physical’ capacity, it is referred to the minimum infrastructural support that is required for ‘day to day’ functioning. Although, the indicators are equally applicable to any urban areas, it is noteworthy to mention, that variable such as ‘all weather accessible roads’ are definite rural issues and performs as proxy for the seasonal (monsoonal) vulnerability of the study area. Likewise, ‘‘% of houses living under the average flood line’ replicates occasional tidal flooding in low lying coastal areas which are predominantly the characteristic of rural settlements across the study area.

- ***Indicators for Institutional Resilience***

Coastal rural areas, in general, consist of two major institutions, i.e. social development/administrative institutions and resource management institutions that have major functional role in community development and ecological conservation. The main functional role includes the enhancement of community competency to counter external hazards through implementation of appropriate policies and practices. Particularly in the back drop of the rural resource dependency, these institutions can be termed as agents of changes and are involved in a wide array of developmental works, including livelihood development, establishment of rural infrastructures and conservation of ecosystems and its services. Importantly, these institutions are essentially the bridging agents that link the social systems to the ecological systems, by increasing the capacity of both the systems against external and/or internal hazards. However, these institutions can be both, formal and Informal. For example, in India, formation of local level administrative institutions i.e. village panchayats (clusters) are one of the constitutional requirement to promote self-governance. The Block administration, which is the lowest administrative institution in India, supervise over number of panchayats and are essentially the strongest local government institution. In addition, there are several other informal institutions such as farmer’s group, fishermen group, forest protection group and faith based organizations responsible for the management of multitude of aspects, including water, forests and other natural resources, although at a much smaller scale. All these aspects are fundamental for the integrated management of ‘socio-ecological systems’ and to foster resilience among the communities.

The existing set of indicators and variables under the component of institutional resilience were largely designed against the socio-political understanding of the study area. This essentially attempts to examine the effectiveness and performance of the existing disaster and climate risk reduction mechanism, keeping the block offices (local government) at the central. Hence, the indicators such as 'Laws and Policy', 'Coordination' 'Emergency Response' 'Adaptive Action' and 'Governance' are essentially a measure of the existing scope of institutionalization of disaster risk reduction, climate change adaptation as well as the risk response mechanism of the local government. Further, the framework also incorporated administrative tribulations such as 'corruption', 'lack of financial capability' and 'coordination'. On a socio-ecological systems perspective, it can be mentioned that the above indicators and variables used thereunder, are representative of a robust and dynamic social system that are capable of absorbing external shocks.

Table 3.1. Dimensions, Indicators and Variables of the Coastal Community Resilience Assessment Framework

Dimension	Indicators	Sub-indicators/Variables	Relation to Overall Coastal Resilience	Indicator Type	Data Source
Socio-economic	**Demography***	a) Annual Average Growth Rate b) Population Density c)Age Dependency Ratio d) % of Rural Population e) % Backward/Tribal Population	- - - - -	Q Q Q Q Q	a) CD (2011/2001) b) CD (2001) c) CD (2001) d) CD (2001) e) CD (2001)
	Livelihood	a) % of Below Poverty Line population b) % of population lives on Coastal resources c) Implementation of MGNREGA (Livelihood Guarantee program) d)% of population lives on Eco-tourism e) % of population suffered discontinuation of livelihood aftermath disasters	- - + + -	Q Q Q Q SQ	a) CD (2011) b) DHDR (2009) c) BDO d) BDO e) BDO
	Health	a) Average Life Expectancy Birth b) Doctor: Population Ratio c) % of population having primary health facility within regular access d) General condition of Public heath e) Morbidity of major diseases (Malaria/TB etc.)	+ - + + -	SQ Q Q P SQ	a) BDO b) BDO c) BDO d) BDO e) BDO
	Social Capital	a) Social cohesion b) Acceptance of community leaders c) Frequency of village level meetings d) Occurrence of Conflicts/Riots/ Homicide incidents e) Community participation in shared interests	+ + + - +	P P SQ SQ SQ	a) BDO b) BDO c) CL+ BDO d) BDO/LPS e) BDO
	Education & Awareness	a) % of Adult Literacy Rate b) School dropout rate of children c) Capacity of existing Primary Schools to cater the demand d)Existing community awareness of Disaster & climate change e) Frequency of mass awareness camp run both by NGOs, CBOs etc.	+ - + + +	Q Q SQ P Q	a) Census data b) BDO c) BDO d) BDO e) BDO/BDMO
Physical	**Transportation**	a) % road compared to overall land use b) % of all weather accessible roads compared to existing road network c) % of waterways compared to overall land use d) Status of Jetties and inter island communication e) Availability of emergency vehicle/boats	+ + - + +	Q Q Q SQ SQ	a) LULC/DHDR b) LULC/DHDR c)LULC Map d) BDO /BDMO e) BDO/BDMO
	Residential Infrastructure	a) % of population with informal (slum etc.) settlements b) % of population in co-operative housing c)% of houses living under the avg. flood line d) % of population having ownership of their house e)% of population living extremely close to hazardous activity (port/industry)	- + - + -	SQ Q Q SQ SQ	a) BDO/BDMO b) BDO/BDMO c) BDO/BDMO d) BDO/BDMO e) BDO/BDMO
	Electricity	a) % population having access to electricity b) Number of hours of average disruption of electricity supply c) Service quality (Frequency of dropout or distribution failure etc.) d) % population having alterative source of electricity in case of disruption e) Implementation of renewable source of energy (Solar/wind etc.)	+ - - + +	Q SQ P SQ SQ	a) BDO b) BDO c)BDO d)BDO e)BDO
	Tele-communication	a) % population having mobile phone b) Quality of service / network accessibility c) % of population having radio/television d) % of population having internet connection e) Provision of fishermen tracking systems	+ + + + +	Q P SQ SQ Q	a) BDO b) BDO c)BDO d)BDO e)BDO

	Water & Sanitation	a) % population having access to safe drinking water b) Quality of supplied water (salinity or other chemical contaminant) c) Scarcity of Drinking water and seasonal variation of water availability d) % population having access to hygienic toilets e) Implication of Waste water disposal and treatment facility	+ + - + +	Q SQ P SQ Q	a) DSB +BDO b) BDO c) BDO/PHE d)BDO/PHE e) BDO/PHE
Institutional	**Laws & Policy**	a) Integration of DRR in developmental activities b) Implementation of CRZ Notification (based on number of violations) c) Administrative initiatives (notification/instructions etc.) of coastal greening (based on plantation under similar project) d) Frequency of DRR training organized by the block e) % of funds allocated to DRR activities	+ + + + +	P SQ SQ SQ SQ	a) BDO/BDMO b) BDO/BDMO c) BDO/BDMO d) BDO/BDMO e) BDO/BDMO
	Coordination	a) Coordination among government departments b) Coordination with political leaders c) Coordination with NGO (Number of joint program etc.) d) External assessment (Funding) received e) Coordination with neighboring blocks	+ + + + +	P P P P P	a) BDO b) BDO c) BDO d) BDO e) BDO
	Emergency Response	a) Existence of early warning system (extent of risk communication) b) Adequacy of trained emergency response team (volunteer etc.) c) Availability of Evacuation center (Number of Flood/cyclone shelter) d) Availability of Emergency Aids (Food, medicine, water etc.) e) Transparency in Aid distribution process (reported conflict etc.)	+ + + + +	P SQ Q SQ P	a) BDO/BDMO b) BDO c) BDO/DDMP d) BDO e) BDO
	Adaptive Action	a) Consideration of Climate change & DRR in developmental activity b) Development of forestry & Plantation at administrative initiatives c) Implementation of Disaster Insurance / Statutory aids to victims d) Implementation flood/erosion control technical measures only e) Implementation of rainwater harvesting scheme	+ + + + +	P P P P P	a) BDO/BDMO b) BDO c) BDO/DDMP d) BDO e) BDO
	Governance	a) Implementation of regular developmental plans b) Public Private partnerships in developmental activities c) Off-disaster activities of Block Disaster Management Authority d) Information sharing & risk communication with the community e) Adequacy of manpower in existing block administration	+ + + + +	P SQ P P Q	a) BDO/BDMO b) BDO c) BDO/BDMP d) BDO e) BDO
Coastal Zone Management	**Embankment & Shoreline**	a) % of vulnerable shoreline protected by dykes/embankments b) Average age of embankments c) Strength of Material & design used for building the embankments d) Frequency of maintenance of embankments e) Frequency of reported overtopping incidents	+ - + + -	Q SQ Q Q SQ	a) BDO/DDMP b) BDO c) BDO/DDMP d) BDO e) BDO
	Mangrove Management	a) % of mangrove cover compared to block size b) % of people directly depends mangroves (Wood, honey etc.) c) Activity of FPC (CBMM) in conservation of mangroves d) Performance of Forest Department in mangrove conservation e) Frequency of organized mangrove felling in recent past	+ - + + -	Q Q P P SQ	a) LULC Map b) BDO c) BDO d)BDO e) BDO
	Coastal Bio-diversity conservation	a) Frequency of Animal Poaching incidents (tiger, deer etc.) b) Performance of Forest Department in promotion of Bio-diversity c) Activity of Eco-Development and Forest Protection Committee. d) Reported reduction in species e.g. Fish species, turtle, tiger prawns etc. e) Frequency of monitoring overfishing in tidal waters	- + + - +	Q P SQ SQ P	a) BDO b) BDO c) BDO d) BDO e) BDO
	Coastal Pollution control	a) Quality of water around the block b) Discharge of industrial waste in coastal waters from the block c) Discharge of domestic waste in coastal waters from the block d) Occurrence Oil spilling incidents from jetties e) Frequency of monitoring of coastal water quality	+ - - - +	SQ SQ SQ SQ SQ	a) BDO + RP b) BDO c) BDO d) BDO e) BDO
	Coastal Land Use	a) % of coastal sensitive land (500m) reclaimed for agriculture (10 years) b) Extent of fish cultivating pond compared to block land use c) Extent of coastal land diversion for settlements/infrastructure d) Extent of mining and other drilling activities e) Extent of coastal land rehabilitation (Greenbelt etc.)	- - - - +	SQ Q SQ Q Q	a) BDO b)BDO c)BDO d)BDO e)BDO
Environmental/Natural	**Frequency of Natural Disaster**	a) Frequency of flood occurrence and degree of damage b) Frequency of cyclone occurrence and degree of damage c) Extent of Coastal erosion and degree of damage d) Frequency of heavy tidal inceptions causing substantial damage e) Extent of Earthquake & Tsunami vulnerability* (Cummins ,2007)	- - - - -	SQ SQ SQ SQ SQ	a) BDO/BDMO b) BDO/RP c) BDO/RP d) BDO/R e)RP
	Climate components	a) Extent of physical impact caused by sea level rise b) Relative rate of sea level rise in the block c) Reduction of availability of freshwater (surface +subsurface) d) Extent of rise in river water salinity e) Extent of mangrove deterioration (loss of species) due to salinity	- - - - -	SQ SQ SQ SQ SQ	a) BDO/RP/R b)RP/EI c)RP d)RP e)RP/EI
	Geo-physical components	a) Decadal loss of shorelines/permanent inundation area b) Extent of change in tidal patterns leading to river piracy/damage to dykes	- -	SQ SQ	a) RP/R b) BDO/BDMO

		c) Extent of Natural accretion (bio-shielded coastline)	-	SQ	c)SQ
		d) Extent of natural subsidence due to compaction	-	SQ	d)SQ
		e) Protective measures (bouldering/cementing) to control erosion	+	SQ	e)BDO/BDMO
	Bio-Geochemical Components	a) Extent of contamination of ground water in coastal aquifers (e.g. Arsenic)	-	SQ	a) RP/R/BDO
		b) % of total population affected by such contaminated water	-	SQ	b) BDO
		c) Extent of chemical pollution in mangrove food chain	-	P	c) RP/EI
		d) Extent of loss of soil fertility (agricultural impact) due to sea level rise	-	P	d) BDO
		e) Mitigation level of existing chemical contamination	+	P	e)BDO
	Environmental Safeguard Measures	a) Extent of Implementation of Natural Hazard Maps in planning	+	P	a) BDO
		b) Implementation of Environmental Protection Act	+	P	b) BDO
		c) Extent of Control in Deep aquifer pumping	+	P	c)BDO
		d)Extent of monitoring and Maintenance of environmental database	+	SQ	d)BDO
		e) Involvement of Scientific communities in Environmental R & D	+	SQ	e) BDO

Relation to Overall community resilience:
(-) Denotes the specific variables is indirectly proportional to overall community resilience, i.e. increase of particular component will lead to reduction of overall resilience score. **(+)** Denotes the specific indicators is directly proportional to overall community resilience, i.e. increase of particular component will lead to increment of overall community resilience

Abbreviations:
CD: Census Data, **DHDR:** District Human Development Report, **BDO:** Block Development Office/Officer, **CL**: Community Leaders**, BDMO**: Block Disaster Management Officer, **DSB:** District Statistical Handbook, **RP**: Research Papers, R: Reports, **EI:** Expert Interview, **CBMM**: Community based Mangrove Management. **CBBDCM:** Community based Bio-diversity Conservation and Management, **FPC:** Forest Protection Committee

*Some of the data were later updated (mostly in June/July 2013) after the provisional publication of the 2011 census report.

- ***Indicators for Coastal Zone Management***

'Coastal Zone Management' is an integrated process that combines a complex set of social, economic and environmental factors for sustainable development of the coasts (Vandermeulen 1998). Over the years, such high degree of complexity not only resulted in specific management challenges but also destroyed coastal ecosystems to a great extent. Number of researchers in recent years have, therefore, reemphasized the importance of coastal ecosystems for disaster risk reduction purposes. These approaches are extensively categorized as 'Ecosystem based Disaster Risk Reduction Approaches' and have been thoroughly discussed in Chapter 2. For example, Kathiresan & Rajendran 2005, showed a statistical correlation from the Tsunami affected Tamil Nadu coast of India, where they observed that existence of mangrove has strong negative correlation with loss of human lives. However, the key question revolves around that how effectively the coastal resources are conserved and what would be the best management practices to ensure that such ecosystem services continue to benefit coastal communities. Therefore, from the perspective of Socio-ecological systems, coastal zone management is an effective tool that ensures sustainable management of ecological resources. In view of the above, the present framework consists a distinct dimension of 'Coastal Zone Management' which includes the 'management' of both the biotic and abiotic coastal resources. The main purpose of the used indicators is to quantify the ecological actions that were up taken by the designated community. In particular, specific variables that were framed under the coastal zone management have special reference to the ecological performance of the exotic Sundarban mangroves.

Among the five indicators, four have, therefore, strong connection with the ecological capacity (i.e. Mangrove management, Bio-diversity conservation, Aquatic pollution control and Coastal Land use), while the remaining, 'embankment and shoreline management' largely defines the survivability of the local communities and a site specific component of coastal zone management in Indian Sundarban. As discussed in **chapter 1**, earthen embankments essentially serve as the lifeline of the low lying reclaimed islands, however, most of them remain primitive and over 100 years old. During the Cyclone 'Aila' in 2009, these extensive network were tested to its capacity, and over 400 km long embankment collapsed under the influence of nearly 5-meter high storm surge (see Chapter 7 for further details). Therefore, with regards to human survivability, sustainable management of these embankments remain extremely crucial. On the contrary, the entire Sundarban delta was once covered under the extensive mangrove forest, which over a period of nearly 200 years, dwindled to approximately 2500 sq. km. Loss of mangroves also led to loss of bio-diversity. Unfortunately, however, despite of strong legislative protection, mangroves continue to annihilate under the growing influence of human intervention. Hence, conservation of bio-diversity, pollution control and control of land use alteration are indicative of the effectiveness of existing mangrove management mechanism. Needless to say, these indicators are representative of the ecological resilience of the communities.

- ***Indicators for Environmental/Natural Resilience***

Each of the designated community is believed to have different exposure to natural hazards and are intrinsically less or more resilient. As mentioned earlier, natural or environmental resilience mostly corresponds to the exposure of specific coastal and terrestrial hazards, e.g. coastal erosion, relative sea level rise, salinity and arsenic contamination which has large spatial variation across the study area. Therefore, indicators used for this assessment typically attempted to understand the frequency of natural disasters, impact of climate change (sea level rise) and other geo-physical, bio-geochemical risk associated as observed at the local level. Further, a specific indicator 'environmental safeguard action' was introduced to incorporate precise actions that are being taken in order to counter the environmental threats arising from the different components mentioned above. This component can be regarded as specific and direct action to minimize the exposure of a specific hazard on the community.

3.5. Assessment of Coastal Community's Resilience in Indian Sundarban

In order to assess the disaster and climate resilience of the communities living in Indian Sundarban, an institutional survey was conducted over the 19 existing Community Development Blocks (CBDs) **[Figure 3.1.],** which are the lowest administrative units as per the administrative hierarchy of Government of India. In this regard, it is important to mention the precise definition of the community, since the word 'community' can be interpreted in many different ways. The study essentially adhered to the definition of 'community' proposed by Young & Schmid 1966 who mentioned that the '*physical boundaries of a community can generally be determined accurately if the community is staked out by political precincts and*

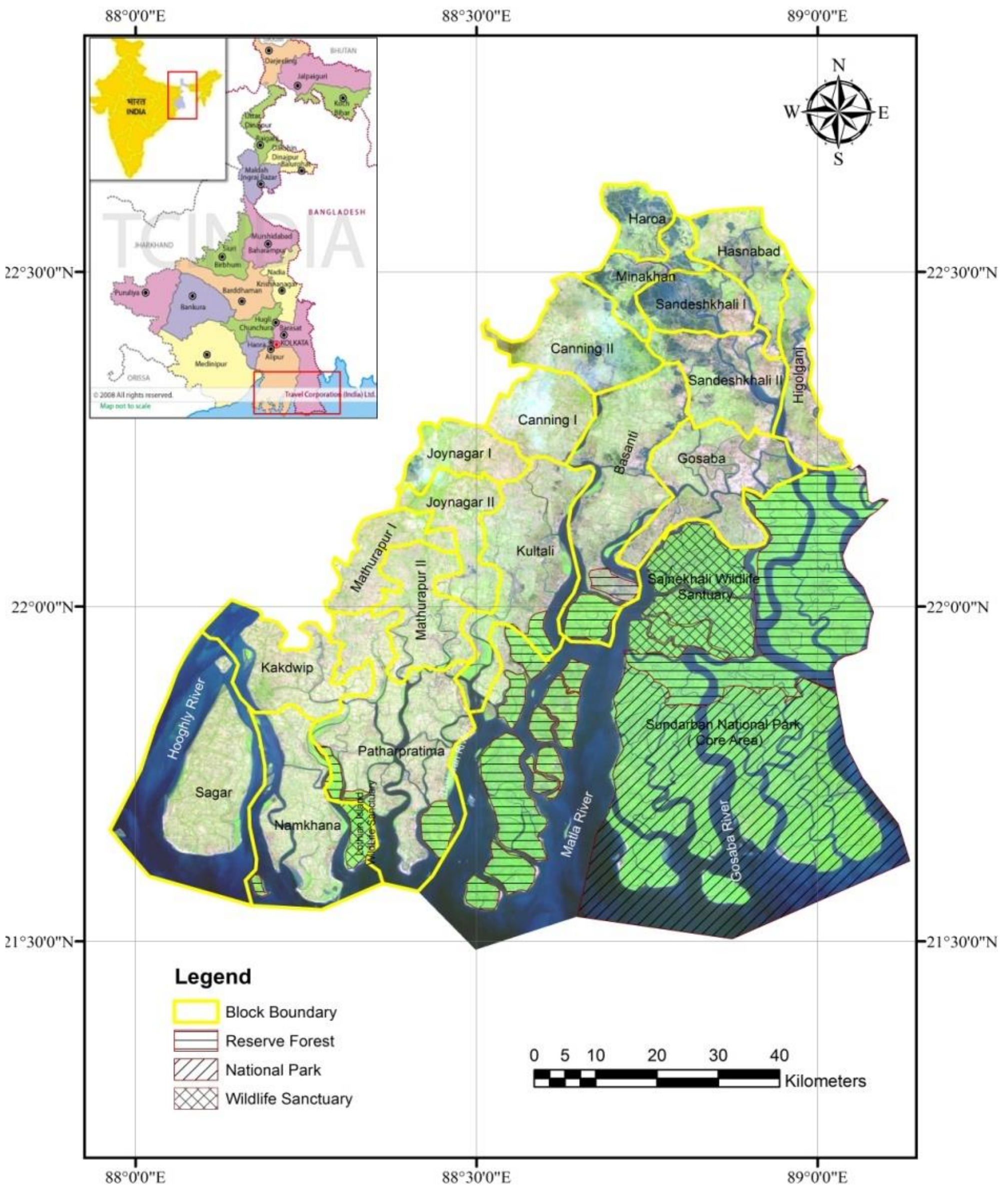


Figure 3.1. Location of 19 Coastal Blocks in the Indian Sundarban Delta

administrative districts' (Young & Schmid 1966). Therefore, the lowest administrative boundary, i.e. the Community Development Block (CDB) were chosen for this purpose. **Figure 3.1. and table 3.2.** provides the location and other details of the existing 19 coastal blocks of Indian Sundarban.

Table 3.2. Demographic Profile of the 19 CBDs of Indian Sundarban

Name Of the CDB	Area in Sq. Km	Census (2001)	Census (2011)	Density Person/km^2	Decadal Growth Rate	Literacy Rate (%)	Below Poverty Level Population (%)
Joynagar I	131.01	219090	259980	1984	18.66	66.67	39.57
Joynagar II	186.25	209145	246955	1326	18.08	60.09	42.60
Kultali	306.18	187989	231855	757	23.33	60.81	46.36
Mathurapur I	147.30	164650	194069	1318	17.87	66.00	34.43
Mathurapur II	227.45	198281	219541	965	10.72	68.94	39.59
Kakdwip	252.74	239326	286325	1133	19.64	71.38	34.91
Sagar	282.11	185644	211096	748	13.71	78.92	44.46
Namkhana	370.61	160627	181869	491	13.22	79.38	48.17
Pathor Pratima	484.47	288394	333687	689	15.71	73.44	49.13
Canning I	187.86	244627	297995	1586	21.82	61.23	31.05
Canning II	214.93	195967	248521	1156	26.82	52.72	50.32
Gosaba	296.73	222822	244721	825	9.83	69.67	38.02
Basanti	404.21	278592	331973	821	19.16	58.12	64.89
Hingolgang	238.8	156400	159585	668	2.04	70.07	44.50
Hasnabad	153.07	177521	196880	1286	10.91	63.45	28.69
Sandeshkhali I	182.3	140476	164185	901	16.88	58.45	58.29
Sandeshkhali II	197.21	136318	160828	816	17.98	59.31	59.70
Minakhan	158.82	168965	191908	1208	13.58	58.65	38.42
Haroa	152.73	182522	214248	1403	17.38	62.82	33.73

In the second step, a questionnaire was formulated based on the above mentioned CCRI framework that consists 5 dimensions, 25 indicators and 125 variables (***See Annexure 1***). These questionnaires were responded by the respective Block Development Officers (BDOs) [the administrative head of the CDBs] in each of the 19 blocks. However, in order to ascertain the reliability of the data, other associated administrative officers (e.g. Block Disaster Management Officer, Fisheries and agricultural officer etc.) were also interviewed simultaneously. A Likert scale of 1 to 5 was used to rank each variable as well as indicators (i.e., scoring of the variables); where '1' refers to 'very poor' and 'five' was designated as 'Very Good'. For quantitative indicators, '5' actually represents the best practices and/or examples. For e.g., the average coastal population density in low elevated coastal areas is 114/sq.km (Small and Nicholls 2003), therefore, if the density of the block is less than 114/sq.km, it is it is assigned 'five' depicting very high resilience. In addition, the Likert scale were designed according to the national, regional and international best practices/standards. In case of the semi-quantitative variables, the subjective responses were classified against some secondary screening. For example, extent of social cohesions was evaluated as the number of reported crimes etc. In case of perspective variable. The study mostly relied on the collective experience of the respondents. Field survey was conducted in all the 19 CDBs of Indian Sundarban by specific visits to each block and responses were gathered mostly in an interview mode.

Figure 3.2. Characteristic features of the Indian Sundarban Delta (A) Mangrove being planted in front of earthen embankments (Pathor Pratima Block) (B) Aquaculture Ponds being constructed at the expense of Mangroves (Sandeshkhali II) (C) Some of the Blocks are well connected by Railways and other formal transportation (Mathurapur I Block), while (D) Unsafe water transportation is predominant form of transportation in extreme coastal blocks.

Another important aspect of the present framework is the prioritization of components (variables, indicators as well as dimensions) for each administrative block. Therefore, the framework introduced a 'weightage scale' ranging from 1 to 5. The respondents (Block Development Officers) were asked to prioritize the impact of a particular component by weighing them between 1 (Not Important) to 5 (Very significant). For example, under demography (indicator), the respondents can prioritize each of the five variables [i.e. Annual

Average Population Growth Rate (v_1), population density (v_2), age dependency ratio (v_3), % of rural population (v_4), % of Backward/Tribal Population (v_5)] (***see Table 3.1***). The weighted score of demography is then calculated as

$$\text{Score}_{\textit{Demography}} = \frac{w1v1 + w2v2 + w3v3 + w4v4 + w5v5}{w1 + w2 + w3 + w4 + w5} \quad \text{.................} \textit{ Eqn. 3.1.}$$

Where, v_n *(n=1 to 5)* represents the score of the variables and w_n *(n=1 to 5)* represents the assigned weightage to each variable.

Weighted mean score of each dimension is calculated from the indicator scores obtained using ***Equation 3.1.*** For example, the weighted mean score of socio-economic dimension is calculated by the weighted average score of each of the indicators under it.

$$\text{Weighted Mean Score (socio} - \text{economic)} = \frac{w1iDeomgraphy + w2ilivelihood + w3iHealth + w4iEducation + w5iSocial\ Capital}{w1+w2+w3+w4+w5} \quad \text{..} \textit{ Eqn. 3.2.}$$

Where i_n represents the score of indicators obtained from equation 3.1. and w_n *(n=1 to 5)* represents the assigned weightage to each indicator.

Finally, composite resilience score was calculated from the weighted mean score of the five dimensions i.e. socio-economic, physical, institutional, Coastal Zone Management (CZM) & Natural/Environmental ***(Equation 3.2).***

$$\text{Composite Resilience Score} = \frac{w1d_{socio-economic} + w2d_{physical} + w3d_{institutional} + w4d_{CZM} + w5d_{Natural}}{w1 + w2 + w3 + w4 + w5}$$

.... *Eqn. 3.3.*

Where, d_n represents the weighted mean score of each dimension obtained from equation 3.2 and w_n *(n=1 to 5)* represents the assigned weightage to each dimension.

Based on the highest and lowest resilience scores irrespective of the dimensions (i.e. 2.51 and 4.09), the blocks were segregated into five different groups i.e. very low, low, moderate, high and very high resilient by equal interval classification method. The ranges were classified as Very High (> 4.0), High (4.0 > 3.5), Moderate (3.5>3.0), Low (3.0 >2.5) and Very Low (2.5>2.0) using equal interval classification method from the obtained High and Low resilience scores irrespective of dimension. ArcGIS 10.2. were used for the creation of spatial maps for data visualization.

3.6. Results

3.6.1. Overall Resileince Profile

The composite score obatined from the above 19 coastal blocks indicated extensive spatial varriation of community resileince across the Indian Sundarban delta. The overall composite score ranges from 3.63 (Highest) to 2.51 (Lowest) for Mathurapur I and Gosaba respectively. On the basis of overall scores, out of the 19 blocks, only one (Mathurapur I) was classified as a 'high' resilient block, whereas, 7 blocks are found to be 'moderately resilient' and rest 11 blocks are found to be in the category of 'low resileince'. **Table 3.3 and Figure 3.3.** outlines the summary of the observation and index based scores corrosponding to each dimention.

Table 3.3. Results of Community Resilience in Indian Sundarban

Name of the Block	Socio-Economic	Physical	Institutional	Coastal Zone Mgt.	Natural/Environmental	Composite Score	Assigned Resilience Category
Mathurapur I	3.31	3.41	3.55	3.95	3.92	3.63	High
Joynagar I	2.76	3.50	3.41	3.59	4.09	3.47	Moderate
Haroa	3.35	3.24	3.73	3.52	3.47	3.46	Moderate
Namkhana	3.22	3.42	3.09	2.92	3.16	3.16	Moderate
Joynagar II	2.71	2.87	3.32	2.94	3.92	3.15	Moderate
Mathurapur II	3.43	2.74	3.48	3.13	2.78	3.11	Moderate
Canning II	2.54	2.86	3.12	3.20	3.72	3.09	Moderate
Kultali	2.58	2.68	3.35	3.56	3.20	3.07	Moderate
Minakhan	2.78	3.46	3.13	2.68	2.93	3.00	Low
Basanti	2.78	2.53	3.43	2.80	3.34	2.97	Low
Sagar	3.35	2.54	2.73	3.02	3.10	2.95	Low
Hingolganj	3.06	2.51	2.70	3.37	2.91	2.91	Low
Sandeshkhali II	2.31	3.10	2.28	3.37	3.02	2.81	Low
Patharpratima	2.70	2.50	3.18	2.99	2.66	2.81	Low
Hasnabad	3.01	3.17	2.72	2.68	2.17	2.75	Low
Canning I	2.93	2.82	2.50	2.42	3.02	2.74	Low
Kakdwip	2.55	2.75	2.76	2.62	2.94	2.72	Low
Sandeshkhali I	2.86	2.42	2.85	2.93	2.07	2.63	Low
Gosaba	2.42	2.14	2.29	2.92	2.80	2.51	Low

For Block wise detailed resilience profile, see Annexure 2.

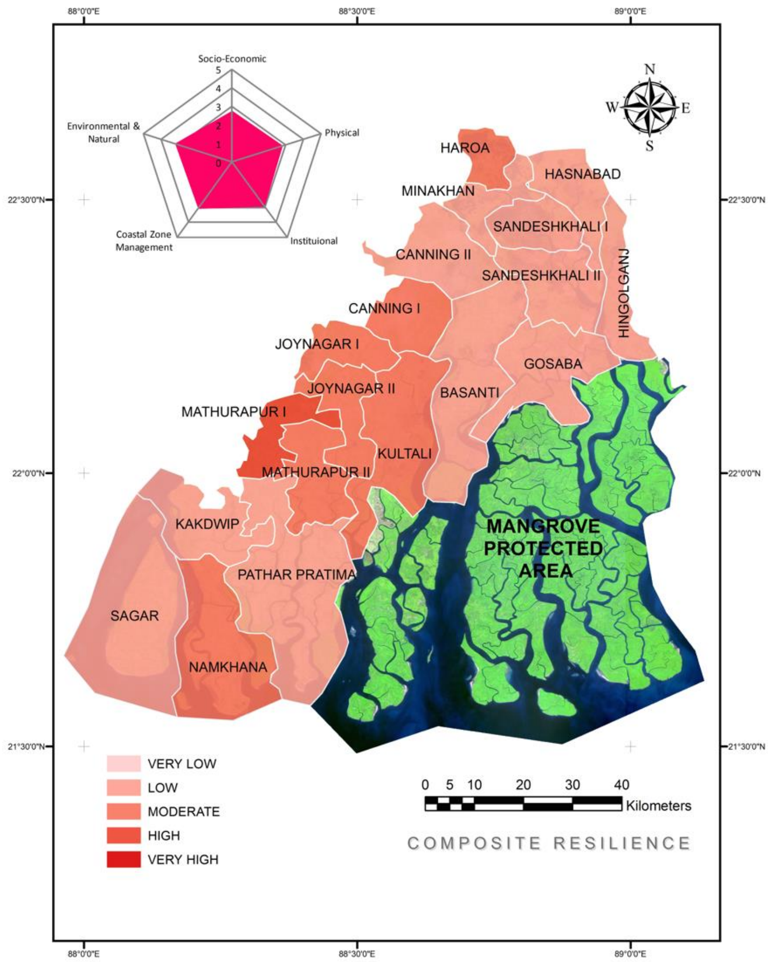


Figure 3.3. Composite Resilience Profile of the Indian Sundarban Delta

In order to determine which of the five components contributes significantly on the overall resilience score, a simple correlation analysis ($p<0.05$) was carried out using the MS Excel data nalayss pack to understand the specific interlinakges among the observed scores under each dimention. The result suggests that the composite score is significantly influenced by mainly three factors, i.e. Institutional resilience ($r=0.80$), Natural/Envronmental resilience ($r=0.77$) along with Coastal Zone Management ($r=0.70$). The results primarily confirms the role of local instituions and their performance as the key component of community resileince in the study area. On the other hand, quite understandably, composite resilience follows an inversely proportional relationship with the exposure, i.e. communities with low natural/ environmental resilience (i.e. high exposure) are less resilient and vice versa. In addition, the results suggests that 'Community resilience', in general, improves with the effective coastal zone management and this observation is in line with the documented evidences from several researchers working on socio-ecological systems (e.g. Adger et al., 2005). Conversely, socio-economic ($r=0.47$) and physical resilience (r=0.67) were found to contribute moderately to overall resilience of the community. In general, majority of the extreme coastal blocks, that are situated against the open sea, are found to be poor resilient. However, this is not only a result of their high exposure (i.e. poor natural resilience), but also lack of other essential capacity. Following section provides a detailed account against each of the five dimension.

3.6.2. Socio-Economic Resilience

Except some of the interior blocks, socio-economic resilience of the study area was observed to be uniformly poor and can be generally categorized between 'very low' to 'low' (**Figure 3.4**.). Among the five indicators used for this assessment, demography, health and livelihood are the key concern for this region. In particular, considering the majority of the delta population consists rural-resource dependent communities, population density in blocks such as Joynagar I (1984/sq. km.), Canning I (1586/sq.km.) are alarming. In lieu to that, annual growth rates for blocks of Kultali, Canning I & Canning II crosses 2% per year **(Table 3.2).** As mentioned by the officials, this also includes some regular migratory population from across the international border of Bangladesh. In addition, a significant portion of the population (36.5%) are designated as Scheduled Caste and Scheduled Tribe (Backward population). The proportion of this backward population tends to increase with the proximity to the mangrove protected areas.

- As expected from the demographic profile, livelihood resilience also strongly indicates a poverty stricken and economically deprived society in almost all across the delta. In particular, blocks with high coastal exposure i.e. Pathar Pratima, Kakdwip, Kultali, Basanti, Gosaba & Sandeshkhali II experience significantly low socio-economic resilience due to poor livelihood scenario. This is presumably due to physical isolation and excessive dependence on coastal resources which is clearly inadequate for a sustainable living. On an average, nearly 90% of the communities, directly or indirectly, live on mono-crop agriculture. The present study coincides with the post 'Cyclone Aila' recovery period and loss of livelihood due to saline water intrusion in coastal agricultural lands have been particularly prominent in the extreme coastal blocks. In addition, a gradual trend of depleting ecosystem services such as poor fish catch was also identified in the respective block offices of Gosaba, Pathar Pratima, Sandeshkhali I and II. From this assessment, it is evident that except some of the interior blocks such as Mathurapur I, Mathurapur II and Joynagar I, which consists some semi-urban areas, livelihood choices are exceptionally limited leading to unparalleled poverty. The average Below Poverty Level Population (BPL) in the delta is estimated as 43.5%, while in blocks surrounding the mangrove protected areas, this figure reaches well over 50% **(Table 3.2).**

- As argued by Pomeroy et al. 2006, low literacy rate further plays a crucial role in lack of livelihood diversification in case of resource dependent communities. Similar observation is also applicable in blocks with low literacy rate such as Gosaba, Canning II, Minakhan Sandeshkhali I &II, Basanti since majority of the communities in these blocks live on mono

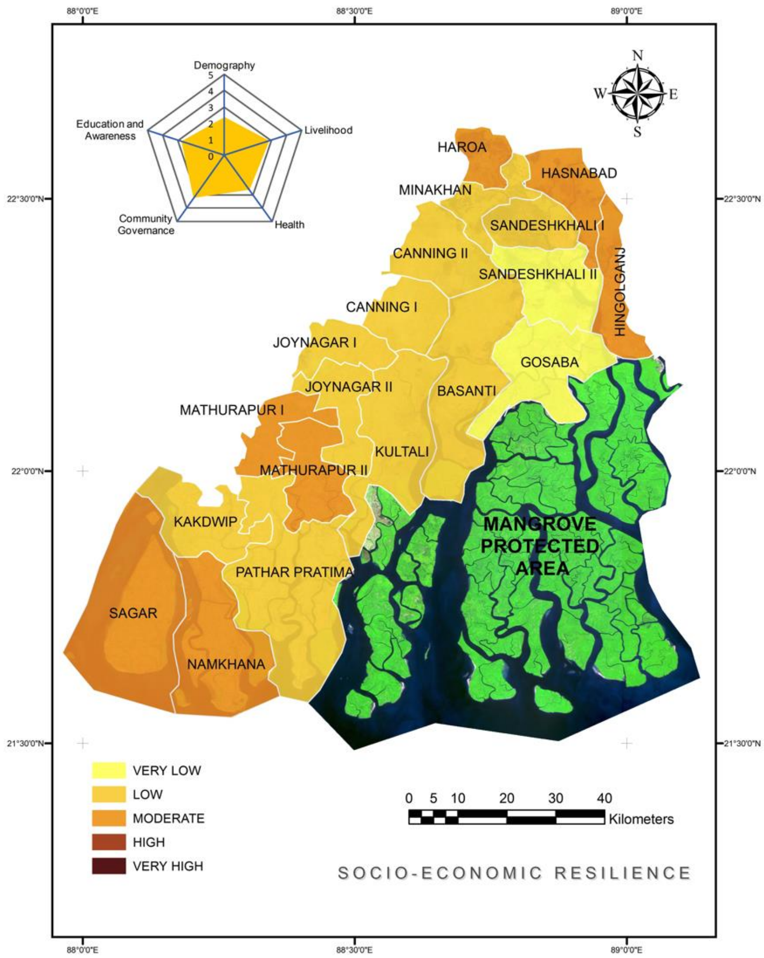


Figure: 3.4. Socio-Economic Resilience Profile of the Indian Sundarban Delta

crop agriculture or work as labor. Part of this is also linked with the low literacy rates prevailing over these blocks. On the contrary, Sagar and Namkhana Block are good example of how literacy and education helps in diversifying rural livelihoods. Despite of the fact that these block have been exemplified as critical hazard prone area by number of researchers (e.g. Bandhopadhyay 1997; Gopinath & Seralathan 2005; Gopinath 2010), it shows a better socio-economic resilience compared to other extreme coastal blocks. This can be partly attributed higher rates of literacy and economic opportunities from religious and recreational tourism that both these blocks exploit extensively.

- Regarding the public health scenario, the officials mentioned of high prevalence of communicable diseases, particularly the outbreak of diarrhea other water borne diseases. In addition, a recent study has reported remarkably high prevalence of mental health problems due to strong presence of various psycho-social stressors, including natural disasters and migration of the male members in search of livelihood (Kanjilal, et al. 2010). Despite of the fact that the general life expectancy is similar to that of the national average, officials mentioned about several premature deaths due to snake bites and boat capsize. Regardless of this fact, the rural health infrastructure remains underdeveloped. Although, majority of the blocks have primary health centers, and in addition sub-division hospitals are located in the Kakdwip, Canning I block, shortage of frontline workers including doctors and equipment are long-standing problems. Some of the semi-urbanized blocks have small private medical facilities, however, this too remain not very well equipped. At present, there is no emergency health responsive mechanism and all the blocks depend on external support from the provincial government in this regard.
- Despite of large occurrence of poverty, in general, there are few outbreaks of communal violence and/or organized crimes which is representative of strong social bonding of the communities. Local leaders are generally well-accepted by the communities, although, in recent years, there has been significant increase in political violence. Except in few cases, particularly blocks such as Kultali, Minakhan, Hasnabad where crime rates are relatively high over shared resources (particularly aquaculture ponds), officials mentioned about strong social bonding prevailing among the communities.

3.6.3. Physical Resilience

Spatial variation of physical resilience follows almost the similar trend of socio-economic resilience and the dimensional scores ranges between poor to moderate resilience category **[Figure 3.5].** Among the five indicators used to assess physical resilience of the communities, 'transportation', 'electricity' and 'water and sanitation' are the primary concern for the delta **[inset of Figure 3.5].** Undoubtedly, the region remains one of the most backward areas of the country with unavailability of basic physical infrastructure. As mentioned earlier, within the territorial area of Indian Sundarban, there is only 50 km of railway line and less than 300 km of all weather metal road-which essentially indicate the communities' exceptional physical isolation from the rest of the world. For example, in extreme coastal blocks such as Pathar

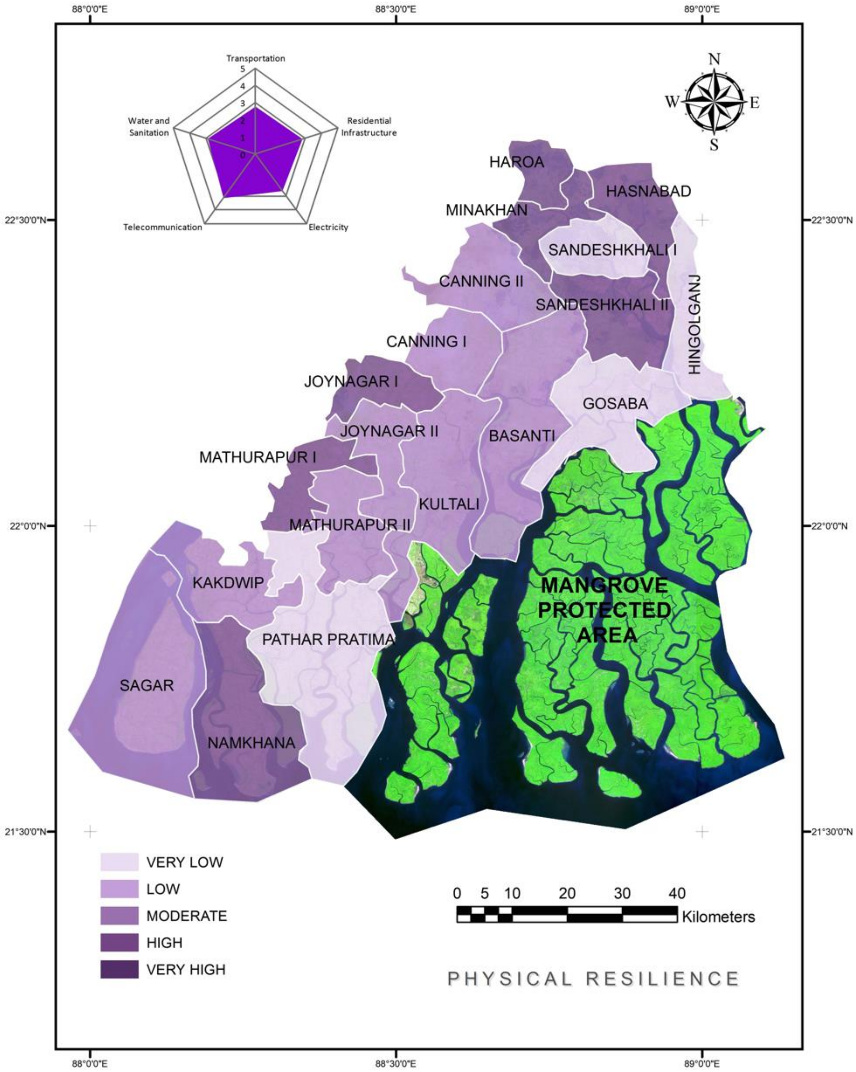


Figure 3.5. Physical Resilience Profile of the Indian Sundarban Delta

Pratima, Gosaba, Hasnabad, Minakhan, the extent of road coverage is well below 0.5 km/sq. km, and again, majority of these roads can not be accessed during monsoons.

- Both the land and water transportation is characterized by poor, inefficient form of public transportation, therefore, physical connectivity of remains the foremost challenge. Most of the southern blocks can only be accessed through waterways. However, in blocks such as Gosaba, Sandeshkhali I & II, Basanti, motorized public transport is rare and people rely on semi-motorized boats, locally engineered rickshaws etc. Transportation safety is another important issues, since incidents of boat capsize are very common. However, interior blocks, such as Joynagar I, Mathurapur I, Canning I, Hasnabad and Haroa are somewhat well connected by railways and formal public transportation network.
- The scenario of household electricity connection is also equally poor with less than 5% of the communities living in blocks such as Sagar, Gosaba, Pathar Pratima, Basanti, and Kultali

have formal electricity connections. Although, previously these islands were not connected to the main supply grid and relied on the solar or other locally generated electricity, efforts are on for extension of rural electrifications under the Provincial Government initiative *'Sabar Ghare Alo'* (Lights in every house). However, at present, even compared to the extent of provincial coverage of household electricity (37.5%), majority of the Indian Sundarban Delta remain in the 'Dark Zone'.

- In general, more than 70% of the local communities in the extreme coastal blocks such Sagar, Gosaba, Namkhana, Pathar Pratima, lives in earthen houses that are highly prone to cyclone damage. All these blocks eventually suffered from the Cyclone Aila and reported high causality and damage. Following the cyclone 'Aila' in 2009, some positive changes, however, took place with construction of 14 new cyclone shelters and demarcation of other resilient structures as emergency shelter. In addition, some government grants were also distributed to build resilient public houses.

Figure 3.6. (Clockwise): (A) An Hourly Vessel (also depending on tides) to Sagar islands that remains the only entry point to this block, (B) Embankments are also used as major peripheral roads, often inaccessible during monsoon and at the time of disasters (C) Poor Housing conditions in Bali Islands, one of the most affected area in Gosaba Block (D) Overcrowded Country Boats used for majority of inter island water transportation

Source: Author (2013-14)

- One of the major problem of the Indian Sundarban Delta is the lack of potable water availability. Except semi-urban blocks such as Joynagar I, Kakdwip, and Canning I, public water supply through formal water distribution network is rare, hence majority of the communities depend on deep tube wells as their main source of drinking water. In addition, the occurrence of high water salinity in the shallow aquifers also creates significant problem for water consumption. Further, blocks such as Hasnabad, Sandeshkhali I, Sandeshkhali II have also reported to have arsenic contamination in their groundwater which severely affect the rural water security. At present, none of the blocks have centralized sewage treatment facilities, however, in semi-urban areas, sock pits are common.
- Surprisingly, despite of widespread poverty and unavailability of domestic electricity supply, more than 60% of the population use mobile phones. In addition, as mentioned by the local officials, over 70% of the population have access to either radio and/or television which indicates that the existing telecommunication infrastructure is satisfactory. Information sharing (early warning messages) through mobile messaging has also been started on trial basis in blocks such as Canning I & II, Basanti, Sandeshkhali I & II, however, the formal early warning systems available in each block remain mostly non-functional.

3.6.4. Institutional Resilience

Despite of the same administrative framework, institutional resilience in the Indian Sundarban varies widely among the existing blocks and can be generally categorized between 'low' to 'moderate' resilience category **(Figure 3.7.).** These can be, however, referred as a measure of the performance of the respective block offices and other associated village institutions in proactive risk reduction. Results indicate a minor relationship between the proximity to the administrative headquarters and the institutional resilience of a particular block. For example, interior blocks such as Haroa, Joynagar-I, Mathurapur-I which are close to the administrative headquarters have better capacity in terms of responding to disaster due to improved availability of necessary human and logistic resources. However, it can also be argued that densely populated semi-urbanized blocks are better organized in terms of their local institutions.

Among the five indicators used to measure institutional resilience, local level implementation of laws/policies and adaptive actions are the most important sectors that need significant attention for majority of the blocks **[s*ee inset of Figure 3.7*].** For example, vast number of brickfields and aquaculture ponds have recently been constructed illegally, however, seldom legal actions are taken against these activities. Therefore, implementation of the Government regulations such as CRZ Notification remain a critical challenge for the many of the extreme coastal blocks. With specific focus on the Disaster Risk Reduction policies, most of the block have recently developed a 'Block Disaster Management Plan' under the guidance of District Disaster Management Authority (DDMA). However, majority of the block officers also mentioned about lack of funding for DRR training and capacity building. As a result, some capacity development program which were initiated after the 'Cyclone Aila' had to be discontinued.

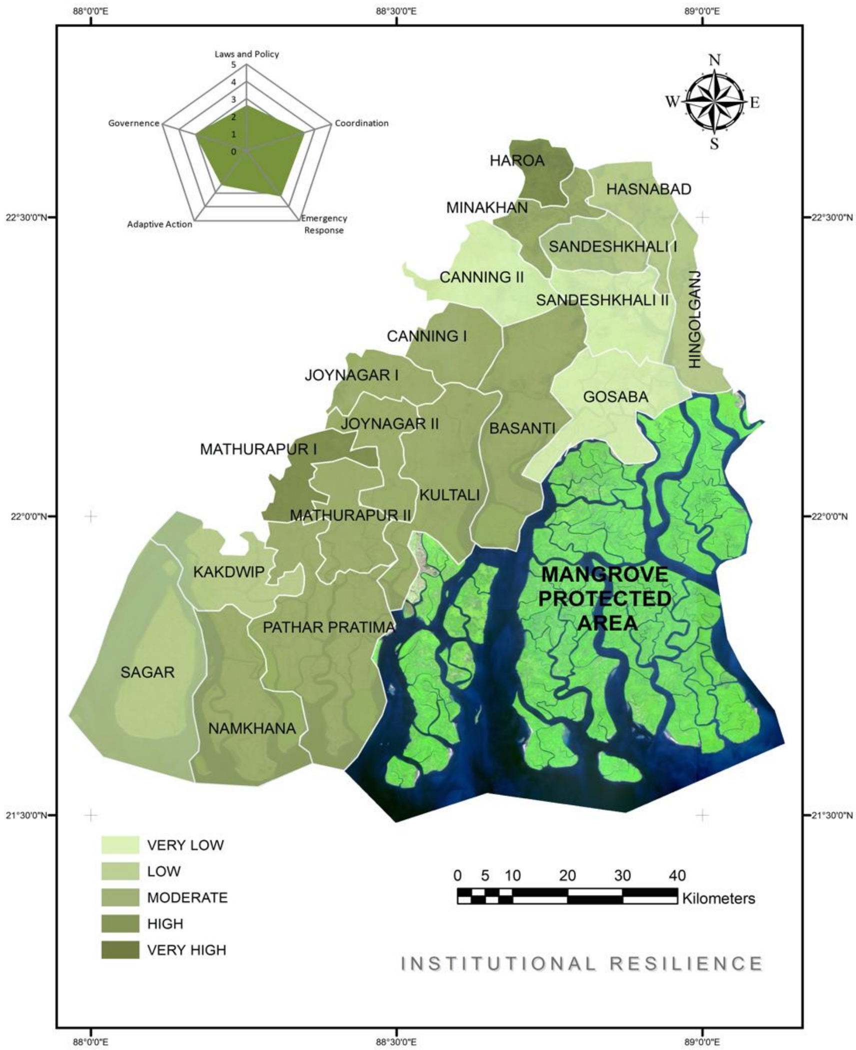


Figure 3.7. Institutional Resilience Profile of the Indian Sundarban Delta

In general, emergency response and management has improved since the Cyclone Aila, although still remain at the very nascent stage. Despite having a block disaster management plan with clear allocation of responsibilities, most of the blocks lack necessary physical and human resources. Moreover, strong vigilance is required in aid and emergency responses, since, in some cases, people who are politically powerful (community leaders) are accused of manipulating aid distribution system in the past. Such cases were particularly reported from Gosaba, Namkhana, and Sagar blocks in the post Aila period. This observation was also supported from some local NGO reports (e.g. Mukhopadhyay 2009).

Nevertheless, as discussed earlier, 'adaptive action' is other important component where all the blocks need to improve. Given the existing climate and environmental threats persisting over the communities, it is highly imperative that proper institutional arrangement is set up to promote anticipatory adaptation in case of livelihood, agriculture and water resource management. At present, adaptive action is only confined to a mangrove plantation program fostered through the 'Green Sundarban' Project in blocks such as Pathar Pratima, Namkhana, Kultali although sustainability of this project remain in severe turmoil (*see* Chapter 6 for more details). However, despite of wide spread damage in coastal agriculture caused by the Cyclone Aila, any of the village or block level institutions (e.g. blocks such as Gosaba, Pathar Pratima, Namkhana, Sandeshkhali I & II) is yet to initiate adaptive measures such as flood or disaster insurance scheme, salinity resilient crop cultivation etc. Similarly, under the current set up, it is observed that only few blocks try to include specific disaster risk reduction activities within the scope of local development.

3.6.5. Coastal Zone Management

Pro-active management of coastal resources and sustainable environmental practices largely reduces the risks from coastal hazards (USIOTWSP 2007). With special reference to coastal rural areas, a robust ecosystem and its services can provide the best possible resistance to external hazards, and therefore, remain highly imperative for the overall resilience of the communities. Since, the Sundarban Delta represents the world largest contiguous mangrove forests, it is imperative that these ecosystems are conserved to the core and probably restored to its old glory. In the present assessment, obtained scores under the CZM dimension demonstrates that interior blocks, such as Mathurapur I & II and Joynagar I manages their coastal zones more effectively [*See* Figure 3.8.] However, it is also necessary to mention that, for these blocks coastal exposure is limited to small channels and creeks. Therefore, extent of embankment, mangrove coverage is negligible for these blocks limiting their scopes for coastal zone management. On the contrary, resilience scores obtained for the blocks like Joynagar II, Namkhana, Minakhan, Basanti, Hasnabad, Canning I, Kakdwip, Sandeshkhali I were found to be significantly low.

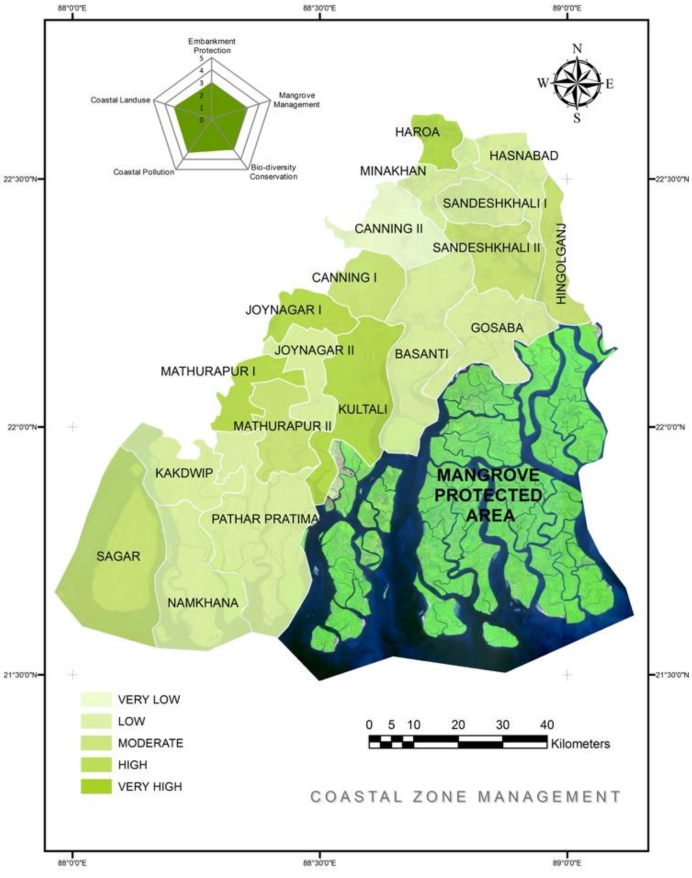


Figure: 3.8. CZM Profile of the Indian Sundarban Delta

- Out of the five components used to measure CZM resilience **[inset of Figure 3.8.],** the most crucial has been the embankment management. Embankment essentially serves as the critical coastal infrastructure for this tide-dominated delta. Blocks such as Gosaba, Namkhana, Sagar, Kakdwip, Basanti, Minakhan, Kultali, Sandeshkhali I & II essentially survive on semi-engineered earthen embankments; failure of which results in immediate flooding. Among the extreme coastal blocks, Gosaba, Sagar, Pathar Pratima have extensive embankment network almost covering the entire periphery of the blocks. Except about 50 km sea dykes, majority of these embankments are over centuries old and are made of local earth. Nearly 472 km of embankment were washed away in the previous cyclone, and much of the damage were concentrated in the blocks of Gosaba, Sandeshkhali I &II, Namkhana and Pathar Pratima.
- Despite of the fact that several protective measures have been enforced to conserve the mangroves of Indian Sundarban, human intervention to mangrove forests continues under lack of supervisions and community participation. In addition, land use alteration is

prominent in Canning I and Kakdwip block due to the expansion of the sub-divisional township. On the other hand, as mentioned earlier, since the communities of the extreme coastal blocks mostly depend on coastal resources, unsustainable methods coupled with overfishing have led to significant decrease in fish population in the estuarine creeks. In addition, collection of prawn seeds by nets of fine mesh is a predominant form of rural livelihood in Gosaba, Basanti, Sandeshkhali I & II. This is an ecologically destructive practice with severe impact on the aquatic bio-diversity. Further, unsustainable practices of fishing and aquaculture through large scale conversion of coastal land have also been observed in the eastern part of the delta, especially in blocks like Minakhan, Hasnabad and Haroa. Importantly, aquaculture has strong implications in local economy and serves as a lucrative livelihood option for the local communities, yet, it also posses significant environmental challenge for this eco-fragile delta.

3.6.6. Natural or Environmental Resilience

Environmental/Natural Resilience is associated with the geographical location and geophysical characteristics that determine the disaster risk exposure of a particular block. In the present assessment, resilience score obtained under the Environmental / Natural dimension **[Figure 3.9]** closely corresponds to the existing scientific understanding of disaster and climatic risk profile of Indian Sundarban. In general, interior blocks are resilient compared to the extreme coastal blocks as the later face more severe risk from cyclonic storms and associated storm surges. Out of the five indicators, disaster frequency and geophysical components are of primary concern for this region **[see inset Figure 3.9]** For example, coastal blocks such as Gosaba, Sandeshkhali I, Patharpratima and Kakdwip experienced low resilience scores due high disaster frequency from a variety of coastal hazards such as heavy tidal inceptions, storms and surge flooding, erosion. On the eastern part of the delta, Hasnabad, Hingolganj and Sandeshkhali-I also experience high exposure of natural disasters, particularly from flooding and river bank erosion. The south-western block of Sagar shows moderate resilience despite of the fact that part of the block is severely prone to coastal erosion. This can be related to the existence of large sand dune systems, coastal protective plantations and some recently developed engineered sea dykes in Sagar islands.

Despite of it locations in arsenic contaminated lower Gangetic basin, fortunately majority of the blocks remain contamination free. However, this is apparently because of the exploitation of deep aquifers instead of the shallow aquifers, which not only has high salinity but also, in

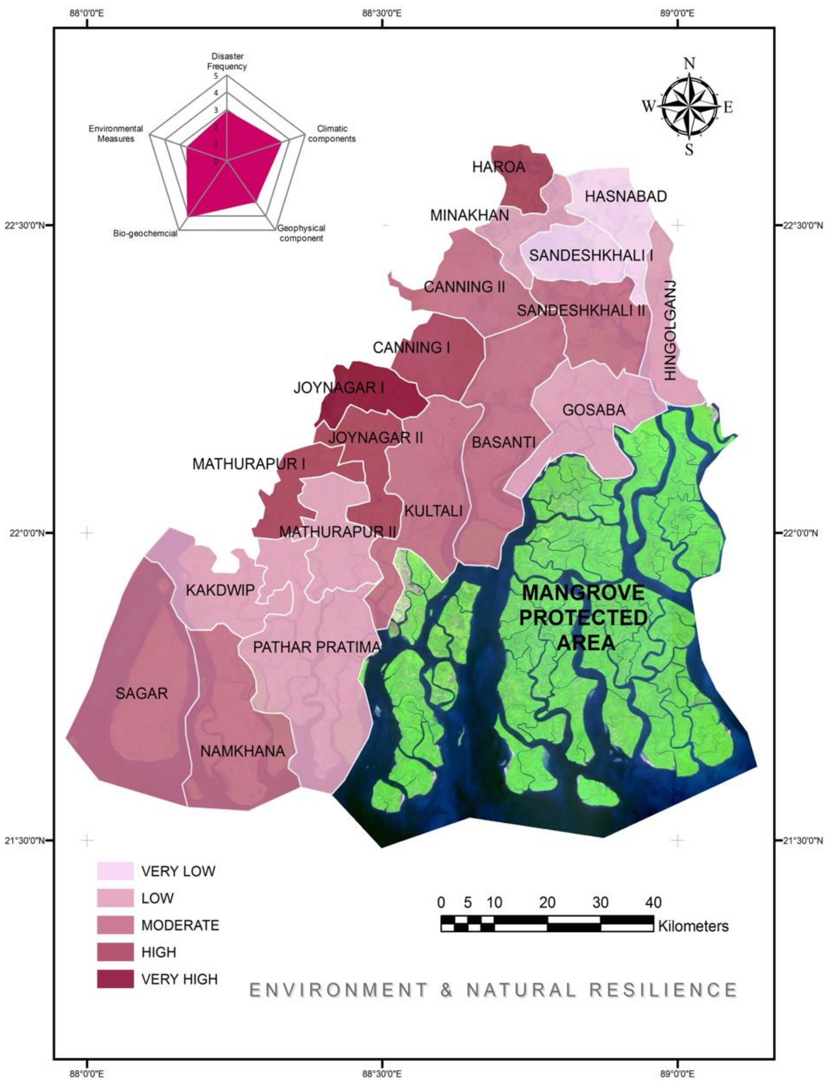


Figure: 3.9. Environmental/Natural Resilience Profile of the Indian Sundarban Delta

cases, are arsenic contaminated. As per the officials, significant number of public tube wells located in Hasnabad, Hingolganj and Sandeshkhali I Blocks are found to have high arsenic levels leading to further lowering of their natural resilience.

3.7. Conclusion

Integration of social, ecological, human and natural factors in overall resilience assessment significantly enhance the ability to understand the severity of a possible disaster and subsequently to prepare for it. It further helps to carefully plan and execute pre-disaster developmental priorities in order to minimize the impacts of a future catastrophes. The desired endeavor of this present assessment was to link the current socio-economic, scientific and ecological knowledge through an appropriate resilience assessment framework in order to understand the capacities of the complex ‘socio-ecological’ system of Indian Sundarban. The study also addressed the interrelatedness of these components and tried to identify the synergic relationship between these components. In general, it has been observed that community resilience in Indian Sundarban follows an inversely proportional relationship with coastal exposure (Environmental/Natural resilience), i.e. ‘resilience’ tends to decrease with the proximity to the sea. Understandably, due to its immediacy to sea, extreme coastal areas are at the forefront of the impact caused by climate induced disasters. However, this is being further escalated by lack of institutional resilience, significant developmental deficit in the extreme coastal blocks, which essentially lead to negligible coping capacity of the communities against external stressors. Despite of the fact that the performance of each and every indicators is imperative for an inclusive resilience to coastal hazards, overcoming the existing lack of human and infrastructural development deficit remains highly imperative in order to enhance the resilience of the communities.

From a ‘socio-ecological systems’ perspective, it is important to understand the major factors that are hindering the performance of the interlinked social and ecological systems, which should maintain a complementary and co-evolutionary relationship in order to foster ‘resilience’. Despite of the fact the ‘resilience’ is a continuous process, and the current assessment only provides a snapshot view, this assessment primarily indicates the **lack of human** and **physical development** as the major factors that hinders such co-evolutionary relationship, and that, the observed developmental deficits are the key barriers for enhancing community’s resilience. For example, lack of human development can be characterized by high poverty, exceptional growth rate, poor and primitive livelihood, lack of education etc. which are the key factors that restricts the community to be intrinsically resilient. Conversely, lack of physical development such as poor connectivity, primitive form of transportation, lack of electricity, water and sanitation makes the community externally vulnerable even against minor shocks. Irrespective of the fact that the assessment also found the effectiveness of institutions or coastal zone management, it can be strongly argued that without fulfilling these developmental deficits, it is highly unlikely that institutions can perform in a desired way. Therefore, in order to foster a resilient community in the backdrop of Indian Sundarban, firstly, the developmental deficits need to be fulfilled by locally applicable economic development. Secondly, it remains imperative to strengthen the local institutions to enhance their DRM capacity, promote anticipatory adaptation measures and active community development towards minimizing the future risks form coastal disasters, particularly from severe to very severe tropical storms such as cyclone Aila.

References

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human geography*, 24(3): 347-364.

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science*, 309(5737), 1036-1039.

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. IDS Working Papers, 2012(405): 1-61.

Berkes, F. and Folke, C. (1998): Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge: Cambridge University Press.

Berkes, F., J. Colding, and C. Folke. (2003). Navigating social-ecological systems: Building resilience for complexity and change. Cambridge University Press, Cambridge, UK.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M. & von Winterfeldt, D.2003. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake spectra*, 19(4): 733-752

Cote, M., & Nightingale, A. J. (2012). Resilience thinking meets social theory Situating social change in socio-ecological systems (SES) research. Progress in *Human Geography*, 36(4), 475-489.

Crowder, L., & Norse, E. (2008). Essential ecological insights for marine ecosystem-based management and marine spatial planning. *Marine Policy*, 32(5), 772-778.

Cutter, S. (2008): A framework for measuring coastal hazard resilience in New Jersey communities. White Paper for the Urban Coast Institute.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008): A place-based model for understanding community resilience to natural disasters. *Global Environmental change*, 18(4), 598-606.

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010): Disaster resilience indicators for benchmarking baseline conditions. *Journal of Homeland Security and Emergency Management*, 7(1).

Danielsen, F., Sørensen, M. K., Olwig, M. F., Selvam, V., Parish, F., Burgess, N. D. & Suryadiputra, N. (2005). The Asian tsunami: a protective role for coastal vegetation. *Science* (Washington), 310(5748):643.

De Bruijn, K. M. 2004. Resilience indicators for flood risk management systems of lowland rivers. *International Journal of River Basin Management*, 2(3): 199-210.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global environmental change*, 16(3), 253-267.

Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, 68(3), 338-354.

Gopinath, G. (2010). Critical coastal issues of Sagar Island, east coast of India. *Environmental monitoring and assessment*, 160(1-4):555-561.

Gopinath, G., & Seralathan, P. (2005). Rapid erosion of the coast of Sagar island, West Bengal-India. *Environmental Geology*, 48(8), 1058-1067.

INCCA, 2010 Climate Change and India; A 4 x 4 Assessment, available online at http://www.moef.nic.in/downloads/public-information/fin-rpt-incca.pdf

Joerin, J., & Shaw, R. (2011). Mapping climate and disaster resilience in cities in Community, Environment and Disaster Risk Management, Emerald Publications, UK, 6, 47-61.

Joerin, J., Shaw, R., Takeuchi, Y., & Krishnamurthy, R. (2012): Action-oriented resilience assessment of communities in Chennai, India. *Environmental Hazards*, 11(3), 226-241.

Kanjilal, B., Mazumdar, P. G., Mukherjee, M., Mondal, S., Barman, D., Singh, S., & Mandal, A. (2010). Health care in the Sundarbans (India): Challenges and plan for a better future. Future Health Systems Research Programme, Institute of Health Management Research (IIHMR): Jaipur and Kolkata.

Kathiresan, K., & Rajendran, N. (2005). Coastal mangrove forests mitigated tsunami. *Estuarine, Coastal and Shelf Science,* 65(3): 601-606.

Klein, R. J., Smit, M. J., Goosen, H., & Hulsbergen, C. H. (1998). Resilience and vulnerability: Coastal dynamics or Dutch dikes? *Geographical Journal*, 259-268.

Knutson T.R., Mcbride J.L., Chan J., Emanuel K., Holland G., Landsea C., Held I, Kossin J.P., Srivastava A.K. & Sugi M. 2010. Tropical Cyclones and Climate Change, *Nature Geoscience*, 3:157-163

Mandal, R.N., Das, C.S., Naskar, K.R., (2010). Dwindling Indian Sundarban mangrove: the way out. *Science & Culture* 76 (7-8): 275-282.

McDaniels, T., Chang, S., Cole, D., Mikawoz, J., & Longstaff, H. (2008). Fostering resilience to extreme events within infrastructure systems: characterizing decision contexts for mitigation and adaptation. *Global Environmental Change*, 18(2): 310-318.

McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19(1): 17-37.

Millennium Ecosystem Assessment (2005): Ecosystems and human well-being: biodiversity synthesis. Washington, DC: Island Press, 2005.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., ... & Nelson, D. (2010). Resilience and vulnerability: complementary or conflicting concepts? *Ecology and Society*, 15(3):11.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem. (2007). Small islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental

Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687-716.

Mitra, A., Gangopadhyay, A., Dube, A., Schmidt, A. C., & Banerjee, K. (2009). Observed changes in water mass properties in the Indian Sundarbans (northwestern Bay of Bengal) during 1980–2007. *Current Science*, 97(10), 1445-1452.

Mukhopadhyay A. (2009). Cyclone Aila and the Sundarbans: An Enquiry into the Disaster and Politics of Aid and Relief (http://www.mcrg.ac.in/pp26.pdf)

Murphy, B. L. (2007). Locating social capital in resilient community-level emergency management. *Natural Hazards*, 41(2), 297-315.

Nakagawa, Y. & Shaw, R. (2004). Social Capital: A Missing Link to Disaster Recovery, *International Journal of Mass Emergencies and Disasters*, 5–34

Nicholls R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe. (2007). Coastal systems and low-lying areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 315-356

Nicholls, R.J. & Cazenave, A. (2010). Sea-Level Rise and Its Impact on Coastal Zones, *Science*, 328: 1517-1520

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*,41(1-2): 127-150.

Peacock, W. G., Brody, S. D., Seitz, W. A., Merrell, W. J., Vedlitz, A., Zahran, S., Harris, C & Stickney, R. (2010). Advancing Resilience of Coastal Localities: Developing, Implementing, and Sustaining the Use of Coastal Resilience Indicators: A Final Report. Hazard Reduction and Recovery Center. Final report for NOAA CSC grant no. NA07NOS4730147.

Small, C., & Nicholls, R. J. (2003). A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 584-599

Stanley, D. J., & Hait, A. K. (2000). Holocene depositional patterns, neotectonics and Sundarban mangroves in the western Ganges-Brahmaputra delta. *Journal of Coastal Research*, 26-39.

Teo, M., Goonetilleke, A., & Ziyath, A. M. (2013). An integrated framework for assessing community resilience in disaster management. In Proceedings of the 9th Annual International Conference of the International Institute for Infrastructure Renewal and Reconstruction, Risk-informed Disaster Management: Planning for Response, Recovery and Resilience.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G., & Rockström, J. (2006). Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, 30(1), 39-48

Turner, R. K., Subak, S., & Adger, W. N. (1996). Pressures, trends, and impacts in coastal zones: interactions between socioeconomic and natural systems. *Environmental management*, 20(2), 159-173.

Twigg, J. (2009). Characteristics of a disaster-resilient community: a guidance note (version 2).

UN/ISDR (2005): "Hyogo framework for action 2005-2015: building the resilience of nations and communities to disasters." [final report of the World Conference on Disaster Reduction (A/CONF. 206/6). 2005].

USIOTWSP (U.S. Indian Ocean Tsunami Warning System Program) 2007: How Resilient is Your Coastal Community? A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Coastal Hazards. U.S. Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development and partners, Bangkok, Thailand.

Uy, N., Takeuchi, Y., & Shaw, R. 2011. Local adaptation for livelihood resilience in Albay, Philippines. *Environmental Hazards*, 10(2): 139-153.

Vandermeulen, H. 1998. The development of marine indicators for coastal zone management. *Ocean & Coastal Management*, 39(1): 63-71.

Young, P. V. & Schmid, C. F. (1966): Scientific social surveys and research (p. 519). Englewood Cliffs: Prentice-Hall.

CHAPTER 4: Participatory Action Planning for Coastal Resilience

'Planning is bringing the future into the present so that you can do something about it now.'

Alan Lakein, US Author

CHAPTER 4: Participatory Action Planning for Coastal Resilience

This chapter narrates the participatory research exercises conducted to prioritize the 25 main indicators that were previously used to assess coastal community's disaster and climate resilience. For this purpose, four blocks, including two from 'Low Resilience' and another two from 'Moderate Resilience' were chosen as potential research sites. The chapter essentially describes the research findings from four Focus Group Discussions (FGDs) and a follow-up questionnaire survey (n=268) conducted with the Cyclone 'Aila' affected communities from these four blocks. In the first step, the FGDs were used to identify the potential indicators, relevant tasks and broad actions required to enhance community's disaster and climate resilience. From the FGDs, a total of 18 tasks and 54 broad actions were identified. In the next stage of the research, a questionnaire was designed with the identified tasks and actions for the prioritization process. Respondents of this questionnaire were firstly asked to rank each desired 'actions' in a 3-Point Likert scale while in the second step they were asked to rank the five key 'Tasks'. Three of the five prioritized 'tasks', i.e. 'enhancing livelihood resilience', 'conservation of mangroves' and 'protection of the embankments' were later taken for detailed action planning.

Outline of Chapter 4

4.1. Introduction

The results obtained from the previous assessment of coastal community's resilience through the five dimensional Coastal Community Resilience Assessment Framework provided an overall impression of the disaster and climate resilience of the delta, especially in-terms of its socio-economic, physical, institutional, ecological and natural capacity (See Chapter 3). Index based scores further assisted to identify the relative priority of specific indicators within each dimension. However, this indicator based assessment has two major limitations which essentially hinders the comprehensive understanding of community resilience in the study area. Firstly, the assessment is based on the survey inputs received from the block officials, therefore, scores and specific weightage assigned to each indicator is mostly the reflection of the local institutions rather than the community in question. In addition, although the under-performing indicators could be identified from this assessment, little is known about what corrective actions are required to overcome the existing deficiencies. In this regard, institutional perspectives, alone, may fall short of community expectations and capacities. Secondly, despite of the fact that this assessment draws a comparative spatial profile of community resilience against coastal hazards and climate change, as argued by Cutter et al. 2008 in their DROP (Disaster Resilience of Place) Model, community competency, i.e. how well the community functions in pre and post disasters phases, is largely dependent on the inherent property of the 'place'. An additional complexity arises from the distinct topographical, ecological and physical features of the 19 coastal blocks, which essentially support the above observation made by Cutter et al. 2008. Considering the above, this chapter attempts to describe a specific research exercise of identification and prioritization of relevant indicators and actions through a structured participatory planning process, often denoted as 'Community or Participatory Action Planning'.

4.2. 'Community Action Planning' for Coastal Resilience

'Community Action Planning' (CAP) is a 'bottom-up', participatory planning tool that have been extensively used in recent disaster and developmental research (e.g. Hamdi and Goethert 1997; Parasar et al. 2011; Parasar et al. 2013; Shepard et al. 2015). This tool was development based on the argument that communities are the best judge of their risks, and given sufficient resources, they are capable of managing their risk. In this process, people or communities are considered to be the primary stakeholders as well as the objects of development and are set to the core of the planning exercises. It attempts to mobilize the living knowledge (experiences) from and within the communities through methodical research interventions, thereby, act as a supplementary of the traditional hierarchical planning process. Often referred as a 'Problem Solving Technique', this planning exercise can serve a number of thematic objectives, which includes identification of specific problems, bridging policy and implementation gaps, strategies and actions for dealing with the problems, and a rudimentary work program describing who and what is to be done (Chevalier & Buckles 2013). The planning process can be both qualitative or quantitative, or even a meaningful combination. In general, the CAP process includes three major steps, firstly, the problem identification and prioritization, secondly, identifying strategies and options and lastly, identifying potential implementers for these actions. Needless to say, since actions and implementers are both site specific, one important aspect of this process is the appropriate representation of community, in terms of choosing place, time and members for the said research exercises.

This particular research exercise, primarily attempted to identify specific problems and its probable corrective actions that are contributing to the observed lack of resilience, especially during the recovery from Cyclone Aila. In addition, the second objective way to identify and pinpoint specific tasks, actions and potential implementers for the same. Therefore, in numerical terms, the main aim of this research exercise is to identify and prioritize the key attributing indicators out of the 25 indicators used in the previous assessment mentioned in **Chapter 3**. In addition, it also aims to formulate a series of probable corrective actions under the identified indicators. In summary, the research exercise follows the below mentioned research steps to attain the mentioned objectives **(Table 4.1.)**

Table 4.1. Community Action Planning: Research Steps

	Objectives	Tools Used	Desired Community Characteristics
Step I: identification of specific problems, their root causes and probable corrective actions	a) To validate the relevance of the 25 indicators within the local context. b) To identify specific problems corresponding to each indicators	Focus Group Discussion	Affected by Cyclone Aila or previous disaster experience (including all social groups)
Step 2: Formulation of Tasks and actions	To identify specific tasks and actions under each tasks	Focus Group Discussion	Affected by Cyclone Aila or previous disaster experience (including all social groups)
Step 3: prioritization of tasks and actions	To conduct an opinion survey to prioritize the tasks and actions.	Household Questionnaire Survey *(n=268)*	Cyclone Aila affected Households in selected blocks

4.2.1. Selection of Representative Study Sites

As mentioned earlier, Community Action Planning (CAP) demands a very careful selection of research sites since priorities and actions depends on a particular community, which is often defined by shared public interests within smaller geographic scales. Therefore, an arbitrary selection of sites would be potentially misleading and the results from the survey may not be applicable for the entire study area. In consideration of the above, the study used specific selection criteria for choosing the locations and in particular, the community. The main philosophy of choosing these sites is that, it should be representative of the distinct social, economic and ecological features of the delta, so that, the selected tasks and actions are somewhat relevant to the whole of the study area. Following section describes the specific selection criteria for choosing the blocks for the above mentioned research exercises.

(a) The overall resilience profile of the delta primarily indicates that the majority of the blocks fall within the category of ‘Low’ and ‘Moderate’ resilience. Therefore, it is imperative that research locations should be representative of these two categories. Hence, this was used as the preliminary selection criteria and accordingly blocks were chosen from both ‘Low’ and ‘Moderate’ resilient category.

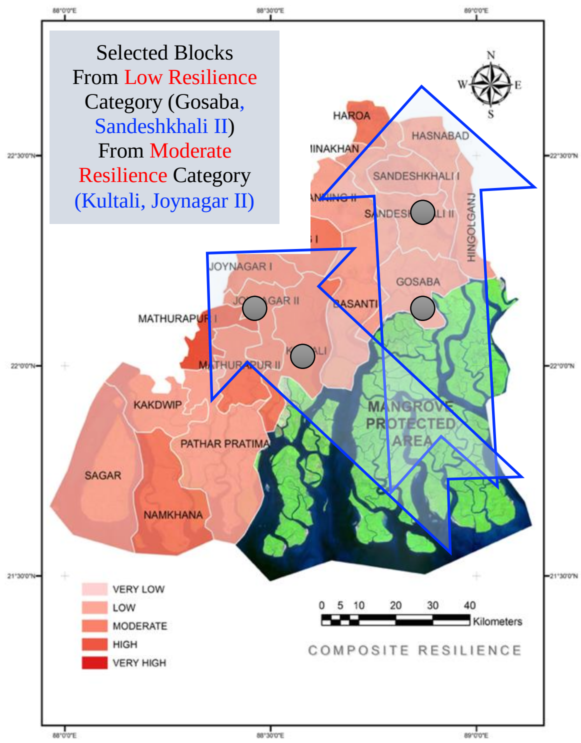


Figure 4.1. Selected Blocks for Community Action Planning

(b) Secondly, the other important factor for the Indian Sundarban is the existence of the vast tract of mangrove forests located in the south-eastern corner of the delta. As argued previously, in coastal rural areas, ecological performances of the mangroves play a crucial role for the resilience of the communities, and that social and ecological resilience often follows a co-evolutionary pathway (Adger 2000; Adger et al. 2010). Therefore, it can be hypothesized that priorities may differ between these two communities, i.e. less or more dependent on the mangroves. Hence, proximity from the mangrove protected areas were also taken as additional selection criteria.

(c) Lastly, another factor that was considered was the size and social stature of the community which should be representative of the specific characteristics features of the delta. For example, blocks such as Joynagar-I and Canning-I were avoided since it represents semi-urban communities which, in most of the cases, are not representative of the main population of the delta.

Based on the above three selection criteria, four representative blocks i.e. Gosaba, Sandeshkhali II, Kultali and Joynagar II were selected for the CAP process **(Figure 4.1. and Table 4.2).** While Gosaba and Sandeshkhali II are representative of the 'Low' resilient block, Kultali and Joynagar II belongs to the moderate resilience category. In addition, Gosaba and Kultali are in close proximity to the mangrove protected areas, where as, the other two blocks are bit distantly located. The details of the blocks along with its main socio-economic characteristics is furnished in **Table 4.2.**

Regarding the selection of the community, the study primarily focused to the people who have suffered from the Cyclone 'Aila' in 2009 or at least have some previous disaster experiences. In addition, preference was given to different occupational groups including the heterogeneity of income, social and economic status.

Table 4.2. Comparative Profile of the Four Blocks Selected for the Community Action Planning

Name of the Block	Proximity to Mangrove	Observed Resilience	Population (2011)	Population Density (per/sq. km.)	Poverty Level (%)	Main Occupation Of the Communities
Gosaba	Adjacent	Low	222822	825	38.02	Agriculture, Fishing, Forest Product
Sandeshkhali II	Far (approx. 30 km)	Low	160828	816	58.45	Agriculture, Fishing
Joynagar II	Far (approx. 20 km)	Moderate	246955	1326	42.60	Agriculture, Fishing, Service
Kultali	Adjacent	Moderate	231855	757	46.36	Agriculture, Fishing

Figure 4.2. Damage incurred during the Cyclone Aila in 2009, (A) A damaged school building in Gosaba Block (B) Damaged club houses in Kultali (C) Flooded villages after the Cyclone Aila (D) Collapse of embankments and loss of connectivity

Source: District Disaster Management Authority, 2009

4.2.2. Focus Group Discussions

After the sites were finalized, a total of four Focus Group Discussion were organized in each of the above mentioned blocks. These FGDs were conducted through the mediation of the local block offices and were largely attended by cyclone 'Aila' affected local communities from the respective blocks (8 to 10 numbers). In each FGDs, the discussion nearly lasted about one and half hours including approximately 15 minutes of pre-briefing session. Participants at the FGDs included a cross-section of community representatives from various occupational and social background such as farmers, fishermen, teachers, small businessman/shop owners, civil volunteers etc. The main aim of these FGDs were to understand the specific problems of the community that they consider to be important in order to strengthen their resilience from the coastal hazards, particularly from the Cyclone Aila like event in near future. In addition, along with each identified problems, participants were requested to identify probable actions which may initiate corrective measures in accordance to the identified problem. Standard FGD protocols were adopted and the author himself acted as the moderator of the discussions. Key

Figure 4.3. (Clockwise) (A) FGD in Gosaba Block (B) FGD in Sandeshkhali II Block (C) FGD in Kultali Block (D) FGD in Joynagar II Block

questions that were discussed during the FGDs are mentioned in following paragraphs and summarized in **Box 4.1.**

The FGDs started with an engagement question of the collective experience on the suffering of the communities during the Cyclone Aila. Thereafter, the communities were asked to clarify

Box 4.1. Key Questions used for the Focus Group Discussion

(Engagement questions):

How much did you/your neighbors suffer from the Cyclone 'Aila'?

(Exploration Questions):

What according to you is the major causes for sufferings from cyclones including pre and post disaster scenario?

What specific tasks and actions do you prefer in order to avoid similar consequences?

How can you better prepare for next disasters?

(Exit Questions):

What can you do at your own sphere of influence (individual/household)?

what specific lack of amenities that they encountered before, during and after the Aila that triggered the most adverse consequences. In the exploration questions, communities were also asked to explain the root causes of the problems and requested to suggest specific local level actions to overcome the challenges.

Based on the Focus Group Discussions, a ‘Problem Tree Analysis’ was conducted over the obtained information in each of the block. During the analysis, all the identified problems were segregated based on the five specified dimensions mentioned in the Coastal Community Resilience Assessment Framework. Each problem was further analyzed along with its probable root causes and the suggested broad corrective actions. At least three corrective actions against each of the indicator were also shortlisted from the specific inputs from the communities, with a careful screening based on repetitions (frequencies) during the FGD process. A total of 18 indicators and 54 probable corrective actions were finally compiled as the main output of the FGDs. For example, communities, in general, mentioned about poor livelihood scenario with resulted in poor economic resilience. This identified problem closely corresponds to the ‘Livelihood’ indicator in the ‘Community Resilience Assessment Framework’ used in the previous assessment **(*see* Figure 4.4).** In order to overcome this deficiency, the main ‘Task’ would be to improve increase livelihood opportunities for which three specific actions such as development of alterative livelihood, implementation of livelihood guarantee act and enhancement of the current livelihood were taken up. The following example provides the process of developing ‘tasks’ and actions from the FGD process. Similar exercises were also conducted for other identified problems and thereafter corresponding actions were formulated.

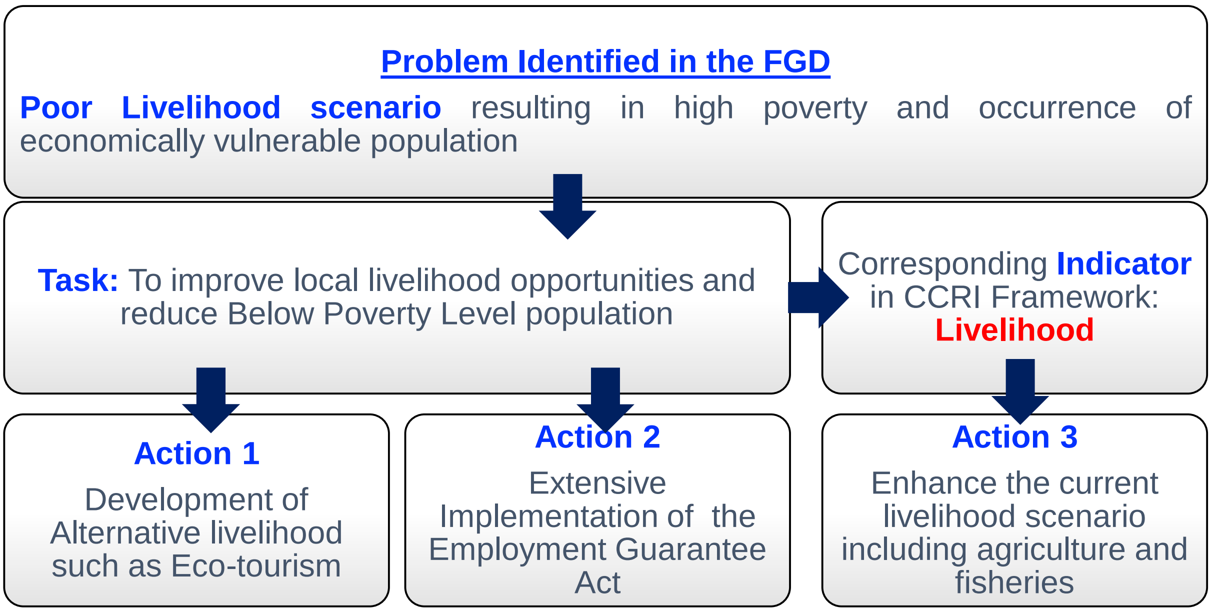


Figure 4.4.: Examples of Developing Tasks and Actions

4.2.3. Questionnaire Survey

Focus Group Discussions conducted over the four representative blocks identified a total of 18 tasks (*corresponding to 18 indicators used in the resilience assessment framework*) and 54 necessary actions (18 x 3) were shortlisted on the basis of the discussion. These tasks and actions are listed in the **Table 4.3.** and discussed in the section 4.4. Based on this, a questionnaire was developed for relative prioritization of the tasks and actions. Respondents of this questionnaire were firstly asked to rank each desired actions under the 18 tasks in a 3-Point Likert scale while in the second step, they were asked to prioritize five key 'Tasks' **(Annexure 3).** The survey consisted of a total of 268 households in Aila affected villages (as recommended by the block officers) from the above mentioned four blocks and was conducted with individual visit to each household. The questionnaires were later analyzed using Microsoft excel.

4.3. Results

4.3.1. Results of Focus Group Discussions

(a) FGD at the Gosaba Block

FGD in the Gosaba block was attended by 10 people including farmers, forest product collectors, fishermen, teachers, panchayat worker and local shop owners. At the outset, all the participants mentioned about the physical isolation of the block that have traditionally hindered their development opportunity, and as a result, communities have very limited economic and physical capacity leading to their poor resilience against coastal hazards. Furthermore, this block, which is a cluster of small low-lying deltaic islands, can only be accessed through country boats and therefore, connectivity remains a serious challenge for the communities. They additionally mentioned that the block, with its entire rural population, primarily survives on agriculture, fisheries and forest product collection and such high resource dependency creates the problem for a rational share of natural resources, e.g. land, water, fish catch, forest products etc. In addition, due to its vulnerable topography, the block remains highly prone to tidal and surge flooding and severe coastal erosion. In particular, the participants highlighted the high sedimentation in the river beds and subsequent clogging of the river channels as the major cause of these events. **Figure 4.5**. depicts the major problems along with their root causes and probable solutions that were identified during the FGD process.

According to the participants, exceptional damage caused by the Cyclone Aila in this block can be attributed to mainly three factors. Firstly, the cyclone resulted in a 5-meter storm surge, which, in most cases, overtopped the existing earthen embankments and/or breached the embankments. Nearly 70 km long stretch of embankments in this block collapsed during the

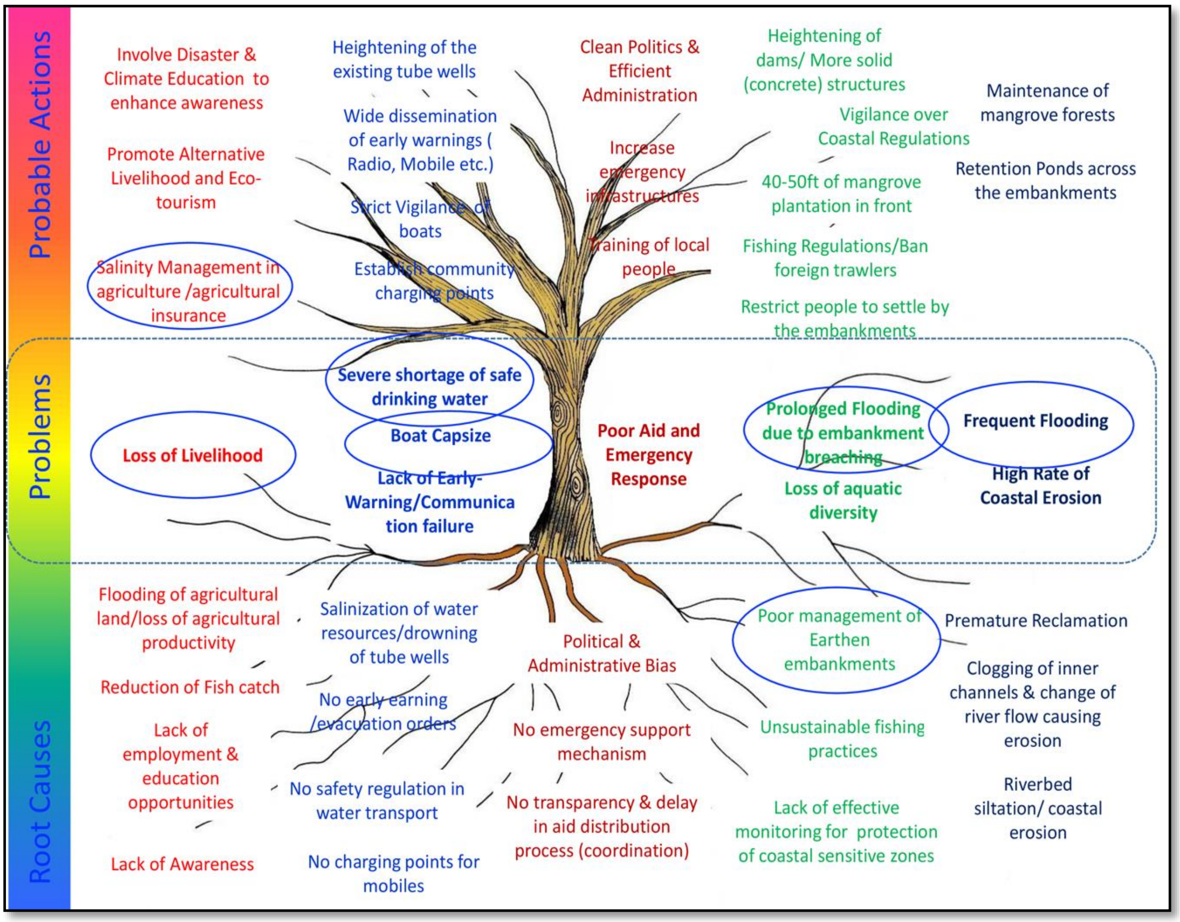


Figure 4.5. Problem Tree Analysis for Gosaba Block
[Blue circle denotes significant repetition and common consensus among the participants]

‘Aila’, leading to immediate flooding. In particular, since the average elevation of the block is below the high tide level, the situation did not improve as long as two to three months until the embankments were re-erected. In view of the above, participants mentioned about the need of heightening the existing embankments as well as developing barrier plantation to reduce the impact of storm surges. Secondly, the participants mentioned about lack of disaster awareness that led to confusion among the communities to decide their probable course of action at the time of cyclone. Some of the participants also highlighted the lack of early warning and evacuation places. In addition, they also mentioned about great delay in receiving relief from the local government. In lieu to that, they also revealed about poor transparency and political biasness in aid distribution process leading to social and political fragmentation in the post Aila recovery period. In order to overcome such challenges, participants provided several social and physical corrective mechanism such as evacuation mock drills, promoting formal and informal disaster education, mobile based early warning message and promoting transparency in aid distribution process. Thirdly, all of the participants mentioned that the storm and associated surge triggered a massive discontinuation of livelihood and drinking water sources. All the drinking water facilities including the tube wells were lost and prolonged flooding of the fertile agricultural land led to unfavorable soil and water salinity scenario disrupting local agriculture to a large extent. Sever lack of rice production followed two to three years, which has been well documented from a satellite based study conducted by Haldar and Debnath (2014). The consequent economic impact on the communities led to massive outward migration of male members in search of livelihood. In order to overcome these challenges, participants revealed several possible actions such as enhancing the scopes of existing livelihood with specific reference to improved agricultural techniques for salinity management, promotion of alternative livelihood, eco-tourism etc.

(b) FGD at the Sandeshkhali II Block

Characteristically, Sandeshkhali II Block almost share the similar features of Gosaba and also have been categorized under 'Low' resilience group. Similar to Gosaba, the block is highly prone to coastal erosion and have been reclaimed from the mangrove forests over a century ago. FGD at the Sandeshkhali II Block was attended by nine people including farmers, fisherman, school teachers, vendors and local shop owners. Importantly, Sandeshkhali II block is too among the worst affected blocks in the Cyclone Aila. Despite of the fact that parts of the block have some road connectivity, majority of the habitation needs to be accessed through waterways, and according to the participants, frequency and safety of water transportation remains a major concern of the communities. Participants also revealed that the block also has very limited livelihood opportunities and majority of the communities are involved in mono-crop agriculture, inland fishing and aquaculture. The identified problems are quite similar to Gosaba, as collapse of embankments also led to extensive and long-term flooding in the block and led to massive disruption of agriculture. In addition, drinking water sources were severely damaged due to drowning of the tube wells. Regarding the livelihood, participants mentioned that many people looked up the existing '100 days' work scheme since there were no alternative provisions for livelihood. Furthermore, it was also reported due to the prolonged flooding, many farmers lost the financial capital to start small business or other activities. The situation led to significant outward migration. As mentioned by the participants, more than 30% of the male members of the villages migrated to cities in various parts of the country or even outside. On the other hand, in order to solve the existing drinking water crisis, participant also urged for heightening of the existing tube wells (to avoid drowning during the flood) and demanded for public water supply schemes **(see Figure 4.6).** Citing high occurrence of river bank erosion,

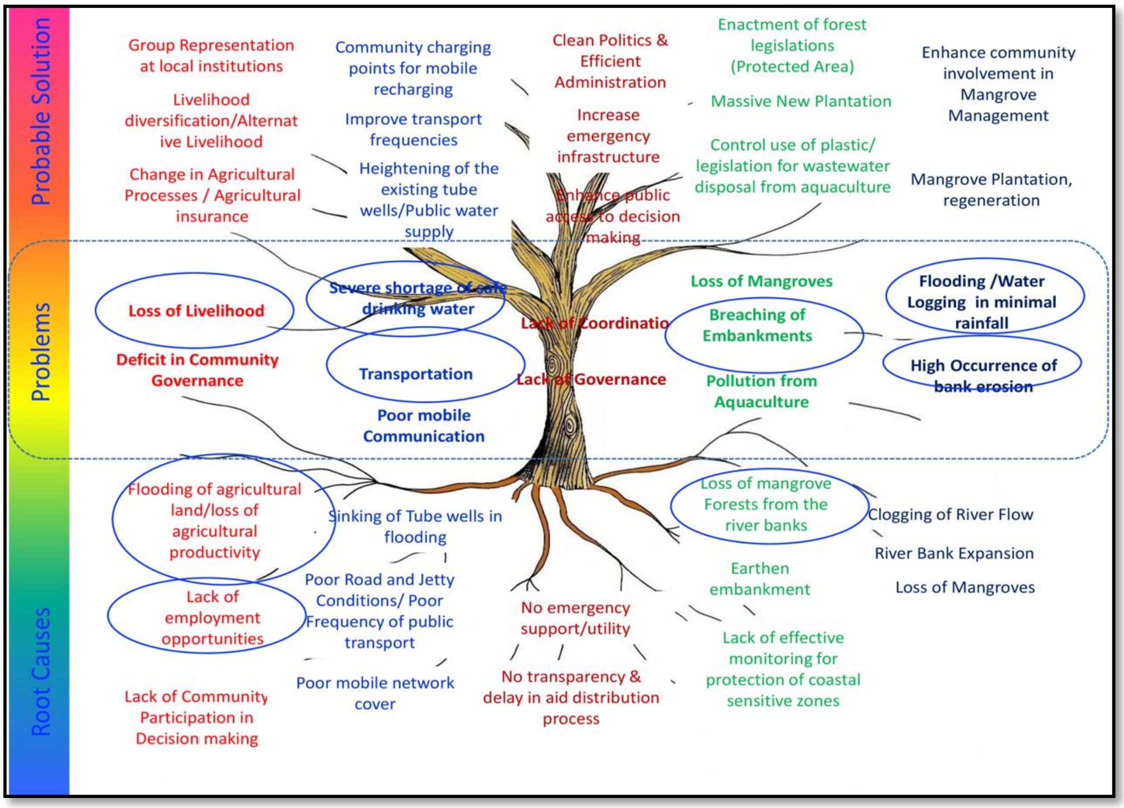


Figure 4.6. Problem Tree Analysis for Sandeshkhali II Block
Blue circle denotes high repetition and common consensus among the participants

participant revealed that changes in river banks and high rate of erosion is the tragic consequences of mangrove annihilation in the past. However, they also revealed the illegal construction of aquaculture ponds under the supervision of local elites which is a formidable threat for the small patches of existing mangroves in the block. They also feared that this may further destroy the remaining mangroves, which have already caused many changes in their locality such as high rate of erosion and frequent flooding during the monsoon. Participant fishermen also related its consequence in lack of fish catch over the years. In their suggested action, they urged that mangrove should be developed as a potential mean for soil accumulation and river bank erosion control. In addition, they also highlighted the degradation of water quality due to high sedimentation in the river beds and pollution from aquaculture ponds. **Figure 4.6.** depicts some of the major problems along with their root causes and probable solutions that were identified during the FGD process.

(c) FGD at the Joynagar II Block

The Joynagar II block has been classified as 'Moderate' resilience block and characteristically, it is slightly different from the rest of the three blocks. In particular, majority of this block can be accessed through roads and therefore the block is somehow better connected. In addition, the occurrence of the Joynagar township in close proximity is an added advantage. The FGD in Joynagar II block was attended by eight representatives of different occupational groups including farmers, fishermen, teachers, civil volunteer, NGO representatives. At the outset, the participants mentioned that although some parts of the block are well connected through an arterial road, connectivity in the interior areas of the block still remains a problem. Therefore, part of the community has to live in isolation as the participants urged to improve the rural road connectivity. In general, the identified problems are fairly similar to the other blocks since they also mentioned of significant discontinuation of agro-based livelihood and shortage of drinking water supply after the cyclone Aila. **Figure 4.7.** lists some of the major identified problem, their root causes and probable solutions.

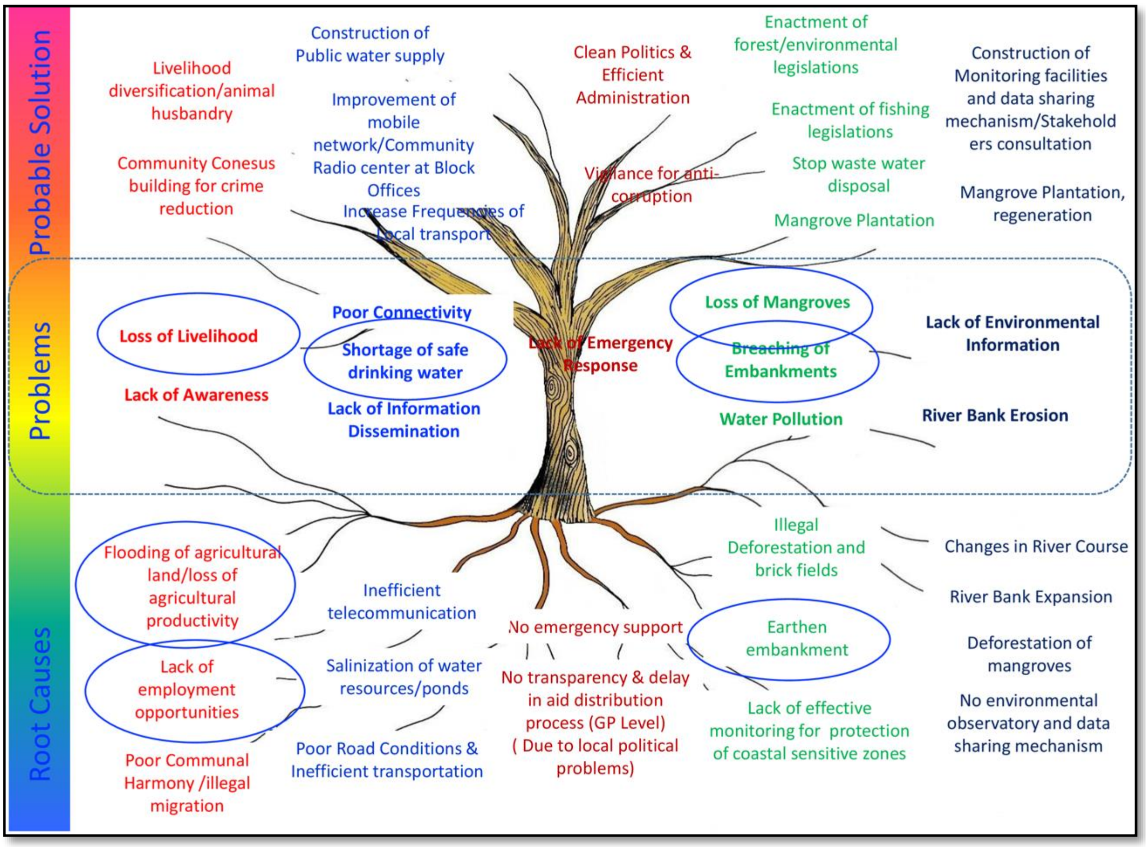


Figure 4.7. Problem Tree Analysis for Joynagar II Block
Blue circle denotes high repetition and common consensus among the participants

Apart from the existing poor livelihood scenario, participants also mentioned about the problem of mangrove degradation due to construction of aquaculture ponds and brickfields. This has also led unlawful development of vulnerable river banks within the block periphery and as a result, there has been severe coastal erosion in recent years. Furthermore, the fisherman representative complained about the unscientific ways of collecting prawn seeds using nets of fine mesh that essentially disrupts the other aquatic species. One of the interesting feature of this block is the occurrence of several scientific NGOs (e.g. Neempeeth Krishi Vigyan Kendra) who are engaged in environmental data collection and dissemination of environmental information among the communities. The participants mentioned this has been particularly beneficial since it helped the communities to select their crop and overcome the adverse environmental scenarios. Consequently, they urged to scale up such activities along with technical guidance and capacity building for the local farmers and fishermen.

c) FGD at the Kultali Block

The FGD conducted in the Kultali Block was was attended by 9 people including representatives from different occupational groups as like in the previous cases. At the outset, participants highlighted the transitional nature of the block, i.e. part of the communities live very close to mangrove forests and characteristically depend on the forest resources for the daily survival. While on the other hand, part of this block is also linked to Joynagar II and has comparatively better infrastructure facilities, in term of physical access. However, the interior villages, as mentioned by the participants, still lack enhanced physical access. The block suffered moderately during the cyclone Aila, compared to Gosaba and Sandeshkhali II. However, prolonged flooding due to breaching of embankments also led to partial discontinuation of community livelihood. As in the previous cases, agriculture was primarily affected by occurrence of Aila induced residual salinity. In addition, participant revealed the limited scope of existing livelihoods and mentioned about uncompetitive agricultural output and overall declining production. Unlike the other blocks, where, in general, strong community bonding is observed, participants mentioned about poor social bonding between the communities within the block, as a consequence of high influx of migrant pollution from the neighboring Bangladesh. This block has been traditionally known for community unrest over various social and economic issues, and therefore, maintenance of law of order, predominantly in the aftermath of disasters and in the aid distribution process have been highlighted during the FGD. The summary of major identified problems along with their root causes and solutions is furnished in **Figure 4.8.**

Apart from these, other problem shared by the participants are identical of the other three blocks. For example, the riverine areas of the block suffer from frequent tidal flooding and bank erosion. Furthermore, despite with its close proximity to the mangrove protected areas, degradation of mangrove forests is prominent in the forest fringing areas of the block. Participants also mentioned about the adverse impacts of unlawfully constructed new brick fields that use mangrove woods as fuel. In addition, they also mentioned about the unsustainable fishing practices and propagation of aquaculture ponds that are triggering several adverse consequences.

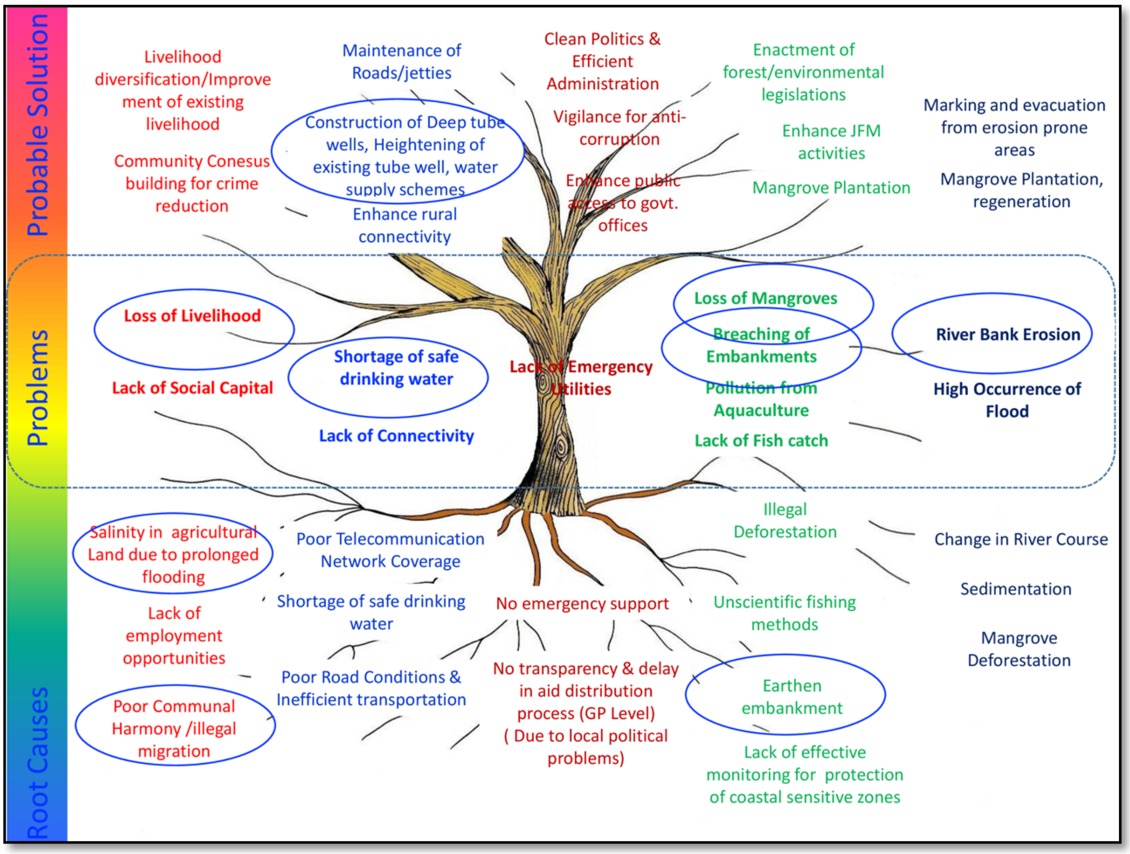


Figure 4.8. Problem Tree Analysis for Kultali Block

Blue circle denotes high repetition and common consensus among the participants

4.3.2. Formulation of Tasks and Actions

As mentioned earlier, the main purpose of the FGDs was to identify specific problems, their root causes and probable corrective actions for the identified problems. As evident from the above FGD results, a multitude of factors are responsible behind the observed ‘low’ or ‘Moderate’ resilience of the communities in the four selected blocks of Indian Sundarban. What is more interesting is that, despite of some site specific factors, more or less, some commonalities can be identified from the above observations. Nonetheless, it is important to consider each of the identified problems in order to comprehensively understand the existing resilience scenario of the communities. Therefore, all the mentioned problems were considered for the development of a questionnaire and a total of 18 problems were identified. This can be roughly allocated under the 18 main indicators used in ‘Coastal Community Resilience Assessment Framework’ (see Chapter 3). The identified indicators are marked in blue in **Table 4.3.**

Table 4.3. Major attributing Indicators identified from the Focus Group Discussions

Socio-economical	Physical	Institutional	Coastal zone management	Environmental & natural
(SE-1)Demography	(PH-1)Transportation	(IN-1)Laws & Policies	(CZM-1) Embankment & Shoreline Protection	(EN-1)Frequency of Natural Disasters
(SE-2)livelihood	(PH-2)Residential Infrastructure	(IN-2)Coordination	(CZM-2)Mangrove Management	(EN-2)Climatic Components
(SE-3)Health	(PH-3)Electricity	(IN-3)Emergency Response	(CZM-3) Coastal Bio-diversity Conservation	(EN-3)Geo-physical Components
(SE-4)Community Governance & Social Capital	(PH-4)Tele-communication	(IN-4)Adaptive Actions	(CZM-4)Coastal Pollution	(EN-4)Bio-geochemical Components
(SE-5)Education & Awareness	(PH-5)Water and Sanitation	(IN-5)Governance	(CZM-5)Coastal Land use	(EN-5) Environmental Safeguard Actions

Here it is important to mention that the identified indicators from the FGD process slightly differ with the previous assessment of community resilience through the use of CCRI framework and Index based scores. For example, in case of the socio-economic dimension, two main underperforming indicators were ‘Health’ and ‘Demography’. Understandably, these indicators have not been mentioned during the FGDs since these do not directly affect the communities during the normal operation. Similarly, performance of other indicators such as ‘electricity’ (under physical dimension) have been found to be uniformly poor across the delta, however, communities did not mention directly about the extent of electricity coverage. Although, some participants mentioned about lack of charging facilities for their mobile phones which led to poor communication aftermath the cyclone. Similarly, on the institutional dimension, the earlier assessment observed virtually no ‘adaptive actions’ were up taken by the local government. However, this particular indicator was also not directly mentioned by the communities. Instead they suggested that improvement of current agricultural facilities and individual adjustments are necessary. On the contrary, indicators such as ‘livelihood’, ‘transportation’ ‘water and sanitation’, ‘education and awareness’ ‘coordination’, ‘embankment and shoreline protection’, ‘mangrove management’ were found to be extremely crucial in both the assessments.

The other important outcome of the FGDs is the list of suggested actions against each of the identified problems. Despite of the fact, these actions are broad-based and site specific, it provides an important insight for what is to be done in order to overcome the existing challenges. Hence, the suggested actions during these four FGDs were carefully screened and customized in the context of broader applicability irrespective of specific locations. The following **table 4.4.** provides the detailed list of 18 'Tasks' and 54 'Actions' corresponding to these 18 indicators. In the next step of the research, a questionnaire was developed based on these 18 tasks and 54 actions for the household level prioritization of tasks and actions **(see Annexure 3).**

Table 4.4. List of Identified Tasks and Actions based on the outputs of the Focus Group Discussions

Required Tasks	Corresponding Indicator	Proposed Actions
Task 1(SE-2): Increase Livelihood opportunities *viz.-a-viz.* Reduce BPL Population	Socio-Economic (SE-1: Livelihood)	**A-1:** Development of Alternative livelihood such as Eco-tourism **A-2:** Implementation of Livelihood Guarantee Act (MGNREGA) **A-3:** Improve existing livelihood and local business /market
Task 2 (SE-4) : Promotion of People Participation in Decision Making Process	Socio-Economic (SE-4: Community Governance and Social Capital)	**A-1:** Strengthening the existing Panchayat system **A-2:** Formation of specific groups such as Youth, women etc. **A-3:**Reduce corruption/biasness in political process
Task 3 (SE-5): Enhance Disaster and Environmental Awareness	Socio-Economic (SE-4: Education & Awareness)	**A-1:** Wide campaigning including street dramas etc. **A-2:** Disaster/Environmental Education at Primary Schools **A-3:** Evacuation Mock Drills and Guidance
Task 4 (PH-1): Enhance safe mobility through land and water across the Indian Sundarban	Physical (PH-1: Transportation)	**A-1:** Improvement of Jetties and Boat Condition **A-2**: Improvement of frequencies Local transports and boats **A-3:** Strict vigilance over the safety conditions, especially for boats
Task 5 (PH-4):Enhance tele-communication facilitates	Physical (PH-4: Telecommunication)	**A-1:** Promote localized radio (community radio) **A-2:** Increase community charging points for mobiles **A-3:** Construct /Improve the existing mobile services
Task 6 (PH-5) : Develop Improved Source of Drinking water facilities	Physical (PH-5: Water and Sanitation)	**A-1:** More number of deep and safe tube wells among villages **A-2:** Regular monitoring of existing tube wells (in terms of salinity/arsenic) **A-3:** Community water supply schemes (piped water)
Task 7 (IN-2): Enhance coordination between various stakeholders with the local community	Institutional (IN-1: Coordination)	**A-1:** Conduct periodical meetings **A-2:** Sharing of information for developmental plans **A-3:**Increased access to government offices
Task 8 (IN-3): Develop quick and effective Emergency Response Mechanism	Institutional (IN-2: Emergency Response)	**A-1:** Training of local people for relief and responses **A-2:** Increase emergency infrastructure such as ambulance, evacuation boats etc. **A-3:**Develop transparency in aid distribution
Task 9 (IN-5): Promote Good Governance at Institutional Level	Institutional (IN-5: Emergency Response)	**A-1:** Clean and Transparent Governmental mechanism **A-2:** Increase manpower and efficiencies **A-3:** Increase community access to decision making.
Task 10 (CZM-1) : Strengthen the Embankment Network	Coastal Zone Management (CZM-1: Embankment Management)	**A-1:** Rising the height of embankments **A-2:** Plantation of mangroves in front of embankments **A-3:** Change embankment materials (Stone etc.)
Task11(CZM-2):Conservation, protection and regeneration of mangroves	Coastal Zone Management (CZM-2: Mangrove Conservation)	**A-1:** Plantation of mangroves by Forest Department **A-2:** Conservation of existing mangroves (protected area) **A-3:** Enhancing activities of Joint Forest Management

Task 12(CZM-3): Protection of Aquatic Diversity for Future	Coastal Zone Management (CZM-3: Bio-Diversity Conservation)	**A-1:** Control of unscientific fish catch (prawn seed catch) **A-2:** Ban foreign trawlers (fishing) in Sundarban waters **A-3:** Develop alternative livelihood for fishermen
Task 13 (CZM-4): To make the river water free from anthropogenic pollution	Coastal Zone Management (CZM-4: Coastal Pollution)	**A-1:** Stop using plastic bags and non-biodegradable material in Sundarban area **A-2:** Develop common sewerage systems **A-3:** Control discharge of wastewater in Sundarban, especially from aquaculture
Task 14 (EN-1): Reduce Number of Flooding incidents	Environmental and Natural (EN-1: Disaster Frequency)	**A-1:** Mangroves plantation for sediment accretion **A-2:** Retention Ponds near river banks to protect agricultural land **A-3:** Stop settling very close to the river
Task 15(EN-2): Enhance resilience to Climate Change threats	Environmental and Natural (EN-2: Climate Components)	**A-1:** Plantation of mangroves everywhere as possible. **A-2:** Implement Disaster and Climate Insurance **A-3 :** Adjust your individual practices according to the changes.
Task 16 (EN-3): Controlling Coastal Erosion and Land loss	Environmental and Natural (EN-3: Geophysical Components)	**A-1:** Spreading Boulders in erosion prone areas. **A-2:** Deserting erosion prone areas. **A-3**: Plantation of mangroves in erosion prone areas.
Task 17 (EN-4): Reduce salinity impact in existing salinity affected areas	Environmental and Natural (EN-4: Biogeochemical Components)	**A-1:** Construction of piped fresh water supply schemes. **A-2:** Control of Deep tube well construction in salinity affected areas. **A-3:** Construction of Rainwater harvesting facilities and ponds.
Task 18 (EN-5): Promote efficient environmental monitoring, documentation and reporting.	Environmental and Natural (EN-5: Environmental Safeguard Actions)	**A-1:** Setting up local laboratories and testing facilities. **A-2:** Sharing environmental data and guidelines with the community. **A-3:** Stakeholders consultation for environmental action.

4.3.3. Results of Questionnaire Survey

As mentioned in section **4.3.3,** the questionnaire survey was conducted in the same four blocks with the help of local volunteers. At the outset, 70 Households were targeted from each blocks, however some questionnaire had to be cancelled at the later stage due to incomplete information. The total sample size was 268 with the following distribution, i.e. Gosaba (65), Sandeshkhali II (70), Kultali (67) and Joynagar II (66). The location of the household survey was also carefully chosen and as a principle, villages which remained among the worst affected areas from the Cyclone Aila were selected for the household survey (as suggested by the respective BDOs). The questionnaire was translated into local language (Bengali) for easy understanding of the communities. Nevertheless, in general, questionnaires were filled with one to one interview mode by visiting households and prior to filling the survey form, a detailed explanation of the survey intent and filling up instruction were thoroughly communicated. **Figure 4.9.** depicts the survey location in details.

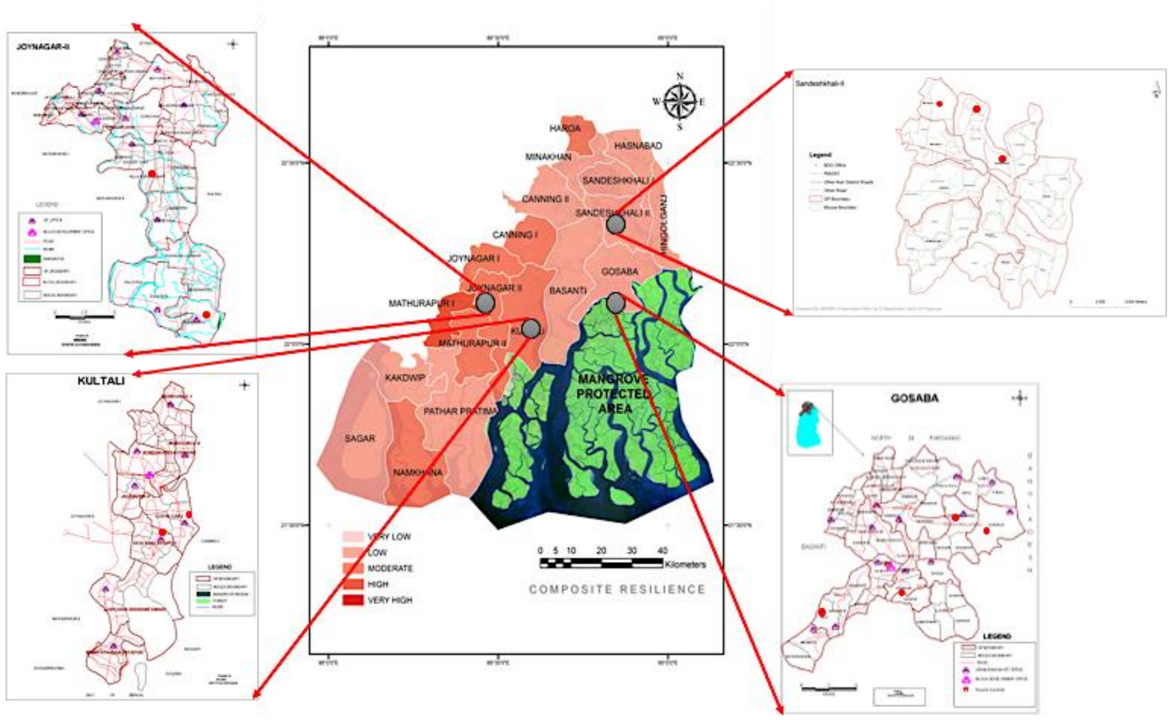


Figure 4.9. Household Survey Locations in Four Community Development Block of Indian Sundarban

(a) Respondents Profile

The profile of the respondents is summarized in **Table 4.5.** In general, majority of the respondents were male. In addition, the respondents profile also includes diverse occupation group (based on main source of household income) with major representation from agricultural and fishing communities. However, in Joynagar II, majority of the respondents were from various other categories such as local business man, labors, primary school teachers and persons involved in service sectors.

Table 4.5. Respondent Profile from the Questionnaire Survey

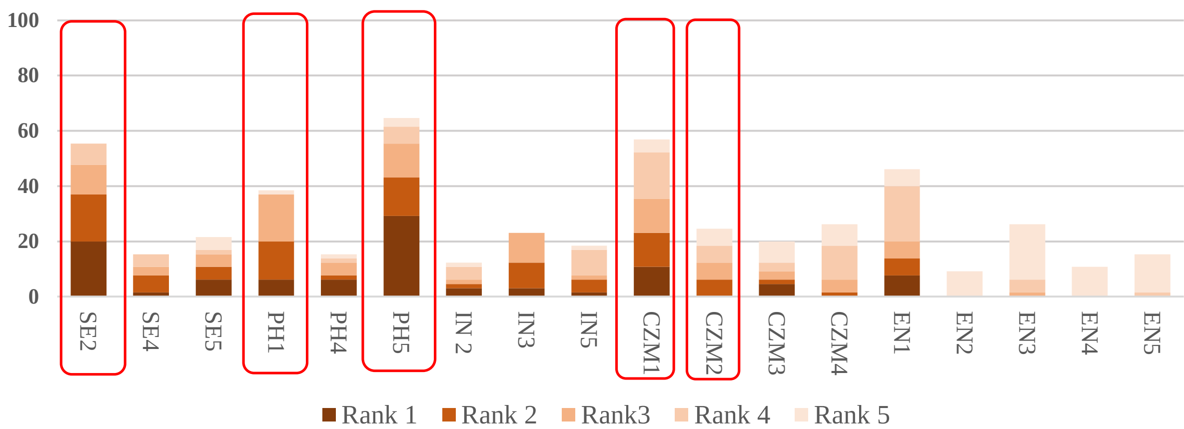
Block	Sample Size/Locations	Male/Female	Education	Occupation/Household Main Income Source
Gosaba	65 Households from Bali I, Bali II and Rangabelia Village Panchayats	Male-68% Female-32%	Illiterate-Nil Primary School-25% Secondary School-32% High school or above-32%	Agriculture-54% Fishing-14%, Others=32%
Sandeshkhali II	70 Households from Durgamandap, Sandeshkhali, Jeliakhali Village Panchayats	Male-69% Female-31%	Illiterate-Nil Primary School-17% Secondary School-23% High school or above-60%	Agriculture-47% Fishing-42%, Others-11%

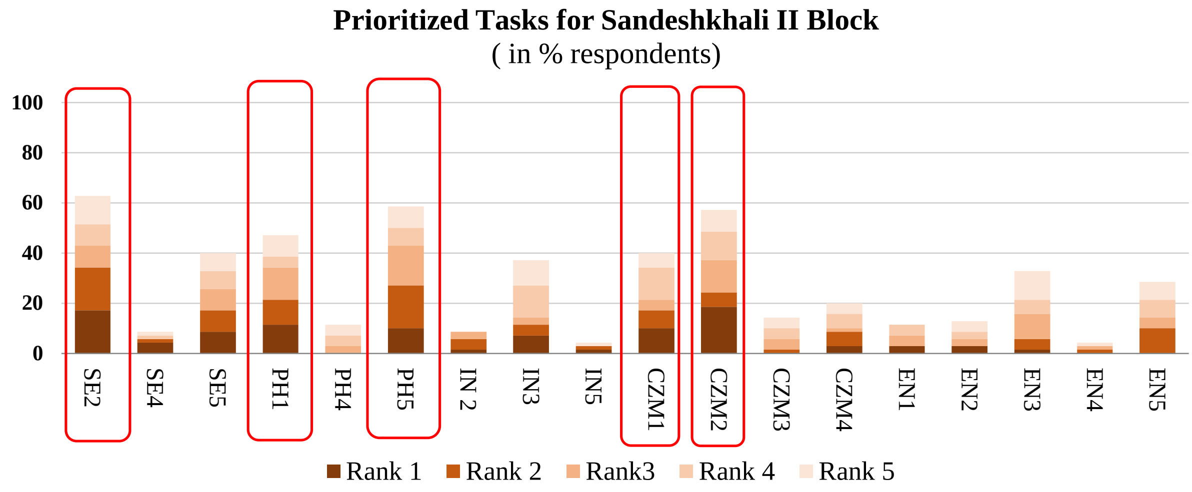
Joynagar II	66 Households from Chuprijhara and Nalgora Village Panchayats	Male-74% Female-26%	Illiterate-9% Primary School-24% Secondary School-38% High school or above-29%	Agriculture-35% Fishing18%, Others-47%
Kultali	67Households from Deulbari Debipur and Gopal Ganj Village Panchayats	Male-73% Female-27%	Illiterate-9% Primary School-57% Secondary School-20% High school or above-14%	Agriculture-56% Fishing-28%, Others-15%

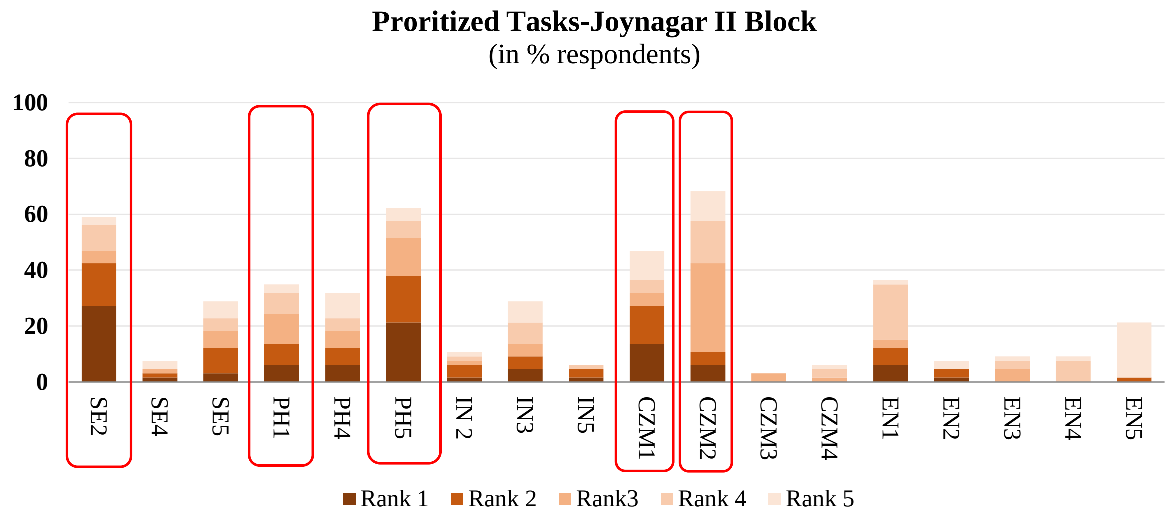
(b) Prioritization of Tasks

The results obtained from the four surveyed blocks showed some distinctive variation in terms of their prioritized 'tasks' **(Figure 4.10).** As mentioned previously, these can be attributed to the specific issues that are persisting within the local context, often confined within smaller scales such as village and/or panchayats. However, in general the prioritized indicators remained strongly aligned to the finding of the FGDs (marked in blue circles) and further there are also some commonalities among these blocks. Therefore, some uniformly applicable 'tasks' could be identified from the prioritization process (marked within red boxes in Figure 4.10). Consequently, it becomes imperative to address these issues irrespective of the scale and stature of the communities. In addition, these tasks remain equally applicable across the length and breadth of the delta. The following paragraphs describes the prioritized tasks that were commonly consented by the majority of the surveyed communities.

Priorotized Tasks for Gosaba Block
(in % of Respondents)







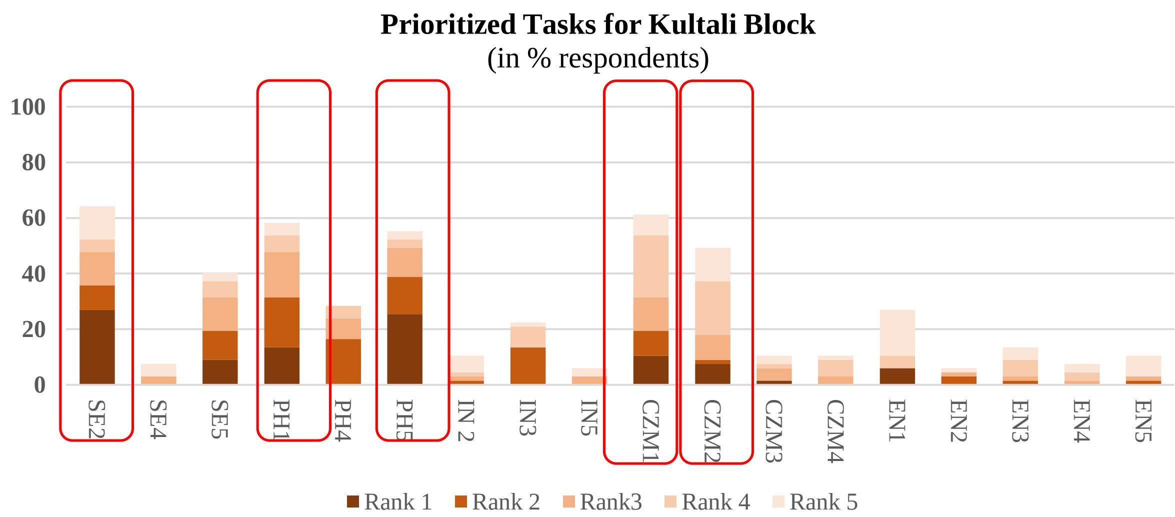


Figure 4.10. Prioritization of Tasks [Sample Size: Gosaba (65), Sandeshkhali II (70), Joynagar II (66), Kultali (67)]

(i) Task 1 (SE-1): Increase Livelihood opportunities viz.-a-viz. Reduce BPL Population

Dysfunctional livelihood has been identified among the most distinguishable problem and consequently, the preferred task of 'increasing livelihood opportunities *viz.-a-viz*. Reduce BPL Population' received extensive priority in all the four blocks. For example, more than half of the communities have attached at least some priority to the Task 1, which ranges from 64.18% in Kultali Block, 62.86% in Sandeshkhali II Block, 59.09% in Joynagar II Block and 55.38% in Gosaba Block. Out of the entire surveyed population, on an average 20% of the respondents have assigned their first or highest priority against the 'Task 1'. This unique sense of urgency is deeply rooted in the loss of agricultural productivity after the cyclone Aila and a consequent economic failure in the agro-based rural societies. It was reported earlier during the FGDs that virtually there were no crops for the consecutive two to three years due to high salinity occurrences in the agriculture fields. The economic stress further magnified with an additional psychosocial stress as the male members of the households either changed their occupation or migrated to other parts of the country leaving their families (mostly women and elderly) behind.

(ii) Task 4 (PH-1): Enhance safe mobility through land and water across the Indian Sundarban

Lack of physical connectivity and unsafe transportation has been a traditional problem of Indian Sundarban Delta. This issue has been earlier identified in the several government reports including the District Human Development Reports which emphasized that physical isolation is a major determinant for lack of infrastructural and human development in the Sundarban region. No wonder, an overwhelming majority of the respondents reaffirmed the concern. Consequently, on an average, nearly 50% of the communities assigned some sort of priority to the Task 4. For example, nearly 58.21% of the respondents in Kultali Block have highlighted the need for enhancing safe mobility in the delta, followed by Sandeshkhali II (47.14%), Gosaba (38.46%) and Joynagar II (34.85%). In terms of priority ranking, nearly 10% of the communities assigned their highest priority against this particular task.

(iii) Task 6 (PH-5): Develop Improved Source of Drinking water facilities

Scarcity of drinking water, as a consequence of Aila induced flooding, is a recent, multi-dimensional problem that the communities have encountered since 2009. Although, the problem of salinity and/or arsenic contamination was present previously, the impact areas were largely restricted to small isolated pockets, thereby, minimizing its potential adverse consequences. Over the last three decades, the main source of drinking water in the delta has been the hand pumped tube wells, which are tapping deep water aquifers. However, during the Aila, a good number of the tube wells were drowned and left for no use. This created an unprecedented drinking water crisis almost all across the delta, especially in the extreme coastal blocks. Despite of the fact that the local government responded fairly with heightening of the existing tube wells and/or creating new tube-wells, this has led to a widespread panic among the communities. The findings of this survey is vastly a reflection of that, and as a result, it was observed that close to 60% of the population attached some sort of priority to Task 6 (Develop Improved Source of Drinking water facilities). In addition, on an average more than 20% of the respondents highlighted this task as their highest priority.

(iv) <u>Task 10 (CZM-1): Strengthen the Embankment Network</u>

Earthen embankment is the most critical coastal infrastructure in this low-lying Indian Sundarban delta, and as mentioned previously, serves as a lifeline for the communities. Apart from protecting the communities from the tides and surges, it also serves, in many cases, as the peripheral and arterial road of the remote islands. The unprecedented damage caused by the Cyclone Aila is more often referred to the failure of more than 400 km long earthen embankment which resulted in immediate and prolonged flooding. Therefore, nearly half of the respondents attached their priorities to strengthen the existing embankment network. In particular, 56.92%, 40%, 46.97% and 61.19% of the respondents from blocks of Gosaba, Sandeshkhali II, Joynagar II and Kultali respectively prioritized the task of strengthening existing embankment network. On an average, 10% of the communities assigned this particular task as their highest priority.

(v) <u>Task 11 (CZM-2): Conservation, Protection and Restoration of Mangroves</u>

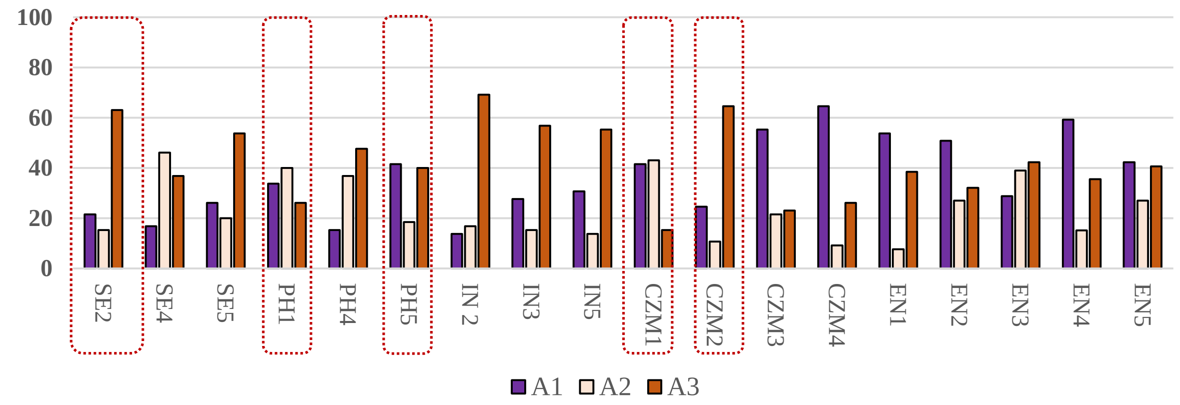
Despite hosting the largest single block mangrove forests in the world, the majority of the human occupied Indian delta is void of mangrove cover. As identified in several contemporary literatures, conservation, restoration and protection of the existing mangroves remain imperative form the perspectives of sediment accumulation, protection from tidal and storm surges, enhancing rural resource based livelihood and a plethora of other social and environmental benefits. However, in number of cases, such benefits are undervalued and not very well perceived by the local communities. What is fascinating about the outcome of the existing survey is that, in general, communities are well aware of the benefits provided by the mangroves which is perhaps the result of the traditional knowledge as well as the activity of several environmental NGOs. On an average, nearly 45% of the communities have assigned their priorities to promote conservation and restoration of mangroves. In particular, an overwhelming majority of the blocks, which are bit distantly located from the existing mangrove protected areas have strongly envisaged the urgency of protecting and/or regenerating the mangrove forests. For example, as high as 57.14% and 68.18% of the respondents from Sandeshkhali II and Joynagar II block assigned their priorities to the particular task, whereas, in case of other blocks such as Gosaba and Kultali 24.62% and 49.25% of the communities did the same. However, what is interesting is that less than 10% of the communities mentioned this particular task as their first or foremost priority. This, in turn, establishes the magnanimity of the other problems. In addition, this observation also establishes that mangroves are essentially as common pool resource rather than individual priority.

Apart from the above mentioned five major tasks, some of the other tasks were also trivially prioritized in the above survey. For example, on an average nearly 20% of the respondents also assigned some sort of priorities in Task 3 (SE-5) which is ‘enhancing disaster and environmental awareness of the communities’. In addition, closely to 25% of the respondents urged to develop quick and effective response mechanism in case of a disaster [i.e. Task 8 (IN-3)]. In case of both the low resilient blocks i.e. Gosaba and Sandeshkhali II, Task 16 (EN-3) which is reducing the frequency of flood events was prioritized by more than 30% of the respondents.

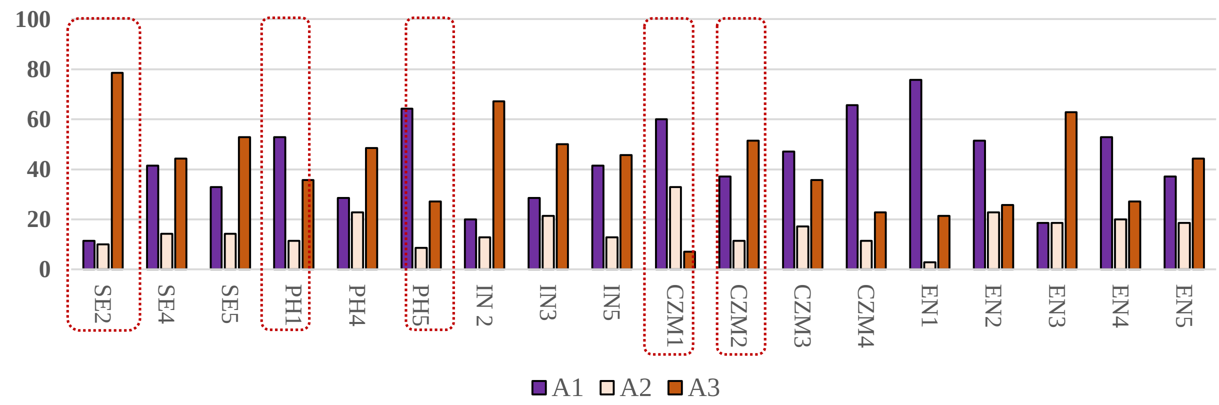
(c) Prioritization of Actions

As mentioned earlier, the questionnaire survey also intended the the prioritization of actions defined under each tasks **(see Table 4.4.).** The results of the four surveyed blocks is summarized in **Figure 4.11.** However, it remains imperative to discuss the prioritized actions in the lights of the above mentioned tasks (highlighted in red boxes). For example, an overwhelming majority (nearly 60%) of the respondents hypothesized the Action 3 (Improve existing livelihood and local business/markets) under the Task 1 (SE-2) in comparison with Action 1 (Development of Alternative Livelihood) or Action 2 (Implementation of Rural Employment Guarantee Action). This can be referred to the potential limitations for developing alternative livelihood such as lack of financial capital, adequate training and markets. On the other hand, despite of strong potential of alleviating rural poverty, the federal government MGNREGA scheme (popularly known as 100 days’ job for rural poor) have been largely criticized for untimely payment, lack of continuity of jobs and political bias.

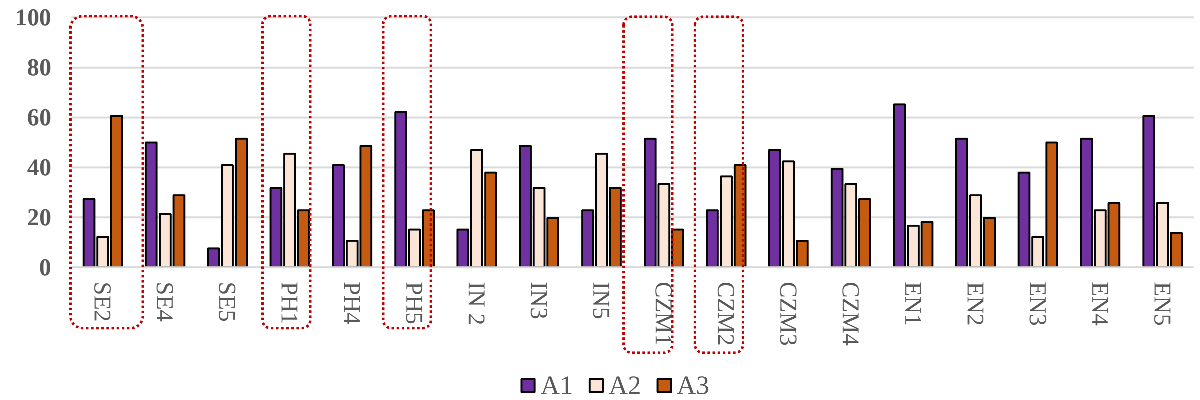
Prioritized Actions for Gosaba Block
(in % respondents)



Prioritized Action for Sandeshkhali II Block
(in % respondents)



Prioritized Actions for Joynagar II Block
(in % respondents)



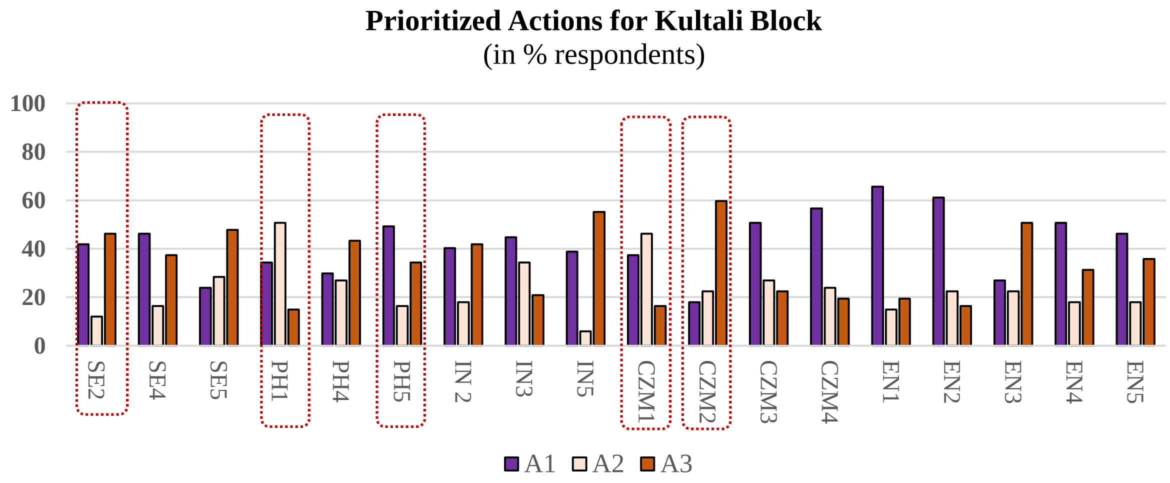


Figure 4.11.: Prioritization of Intended Actions [Sample Size: Gosaba (65), Sandeshkhali II (70), Joynagar II (66), Kultali (67)]

In case of task 4 (PH-1), i.e. to enhance safe mobility through land and water, a scattered response is obtained among the four surveyed blocks which closely corresponds to distinct topographical feature of the blocks. For example, in case of Gosaba, the first two actions, i.e. (A-1) improvement of jetties and boat condition as well as (A-2) increase of local transports is prioritized by more than 70% of the respondents. On the contrary, responses from Sandeshkhali II block prioritized Action 1 and Action 3. In case of Joynagar II and Kultali Block Action-2 (i.e. improvement of transport frequencies) has been prioritized by nearly half of the respondents. In summary, the prioritized actions under the Task 4 strongly corresponds to the local issues, e.g. since the first two blocks can only be accessed through water ways, respondents' priority largely focuses on the improvement of jetties and boat safety conditions, whereas in cases of Joynagar and Kultali, transport frequency is relatively prioritized.

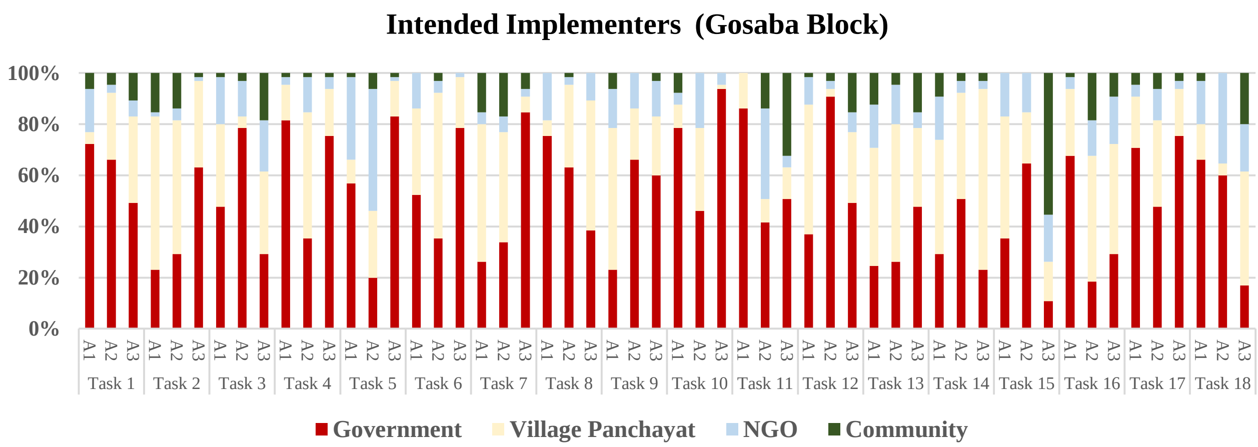
Similar observations can also be stated for Task 6 (PH-5) i.e. 'Develop Improved Source of Drinking water facilities'. Responses for these also remain scattered and all the three proposed actions can probably be justified against the local context. For example, blocks such as Gosaba and Kultali highlighted the need of more numbers of deep and safe tube wells (A-1) and at the same time, they also wished to have supplied piped water (A-3). However, in case of Sandeshkhali II and Joynagar II, nearly 65% of the respondents assigned their priority to only A-1, which seems to be more realistic considering the limited capacity of local government to purify and supply piped water. However, a small section of the Joynagar II block has been covered under the piped water supply scheme.

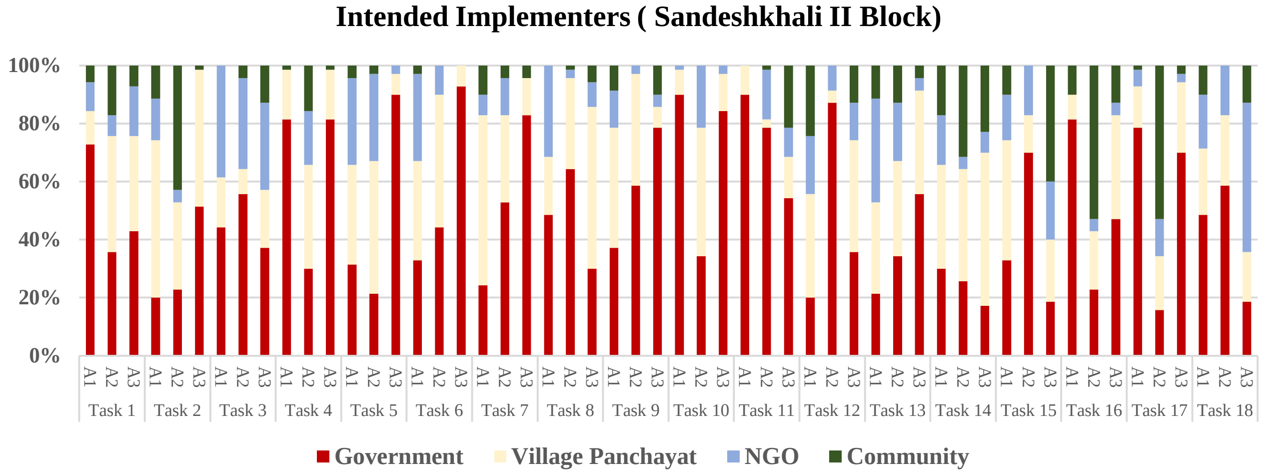
In case of the Task 10 (CZM-1), i.e. strengthen the existing embankment network, an overwhelming majority of the respondents prioritized the Action 1(increase the existing height of the embankment) and Action 2 (Develop barrier plantation). Out of these, respondents from blocks Sandeshkhali II and Joynagar II primarily focused on raising the height of the embankment. This observation intently corresponds to several overtopping incidents reported from these blocks. However, as evident from the other two blocks, both of these actions (A1 and A2) remain imperative for strengthening the existing earthen embankment network.

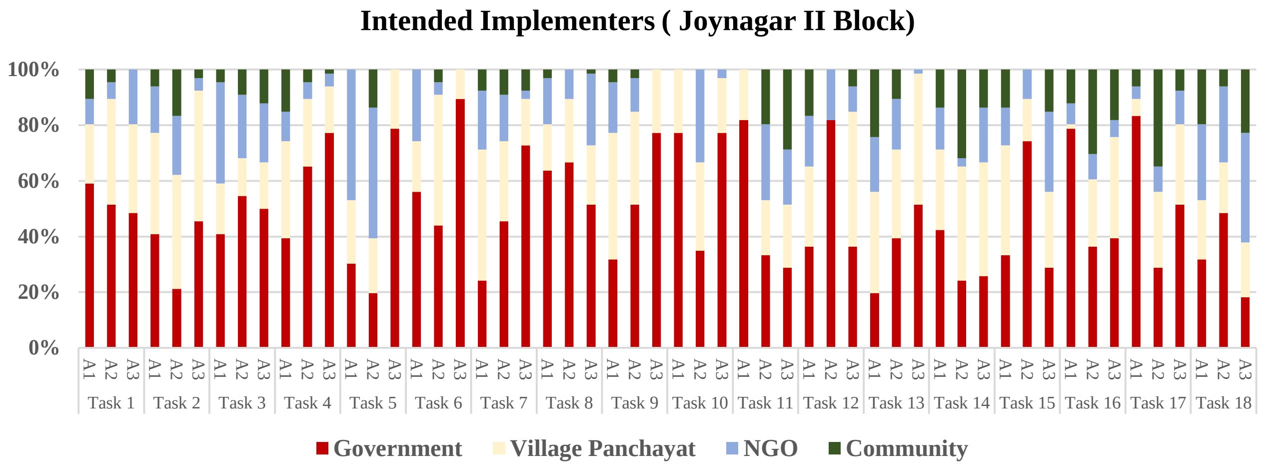
Regarding the protection, conservation and restoration of mangroves i.e. Task 11 (CZM-11), on an average more than half of the respondents prioritized the action 3, i.e. enhancing the Joint Forest Management (JFM) mechanism in mangrove forest management. JFM is a federal government initiated participatory forest management strategy that envisages community participation through judicial uses of forest resources, therefore, serves as an institutional platform for community based mangrove management. However, in case of Joynagar II Block, Action-2 i.e. protected area based mangrove conservation has been equally prioritized. This result is somewhat interesting, since it is indicative of community's dependency on the mangroves. Communities living in blocks such as Gosaba, Kultali, Sandeshkhali II are more dependent on mangroves and are in strong contradiction to enforce 'protected areas' as a mean for mangrove conservation. On the contrary, communities living in Joynagar II are lesser dependent on mangroves, and therefore, this result can be characteristically justified.

(d) Identification of Potential Implementers

The last objective of the questionnaire survey was to identify the potential implementers for each of the proposed actions against the 18 mentioned 'tasks'. The respondents were asked to choose among the four potential implementers, i.e. the Government (mostly interpreted as the local government, in particular, the block offices), Village Panchayats (the local self governance), NGOs and community itself. The results obtained from the survey is summarized in **Figure 4.12.** The results unanimously established the 'local government' as the most favored implementers compared to the other three. In all the four surveyed blocks, major responsibilities have been assigned to the 'government' with particular references to actions that require some capital investments or meticulous policy implementation. For example, in case of Task 1 (SE-2), more than 65% of the respondents believe that the prime responsibility lies with the Government in case of all the three proposed actions. The same is applicable for Task 4 (PH-1), Task 5 (PH-4), Task 10 (CZM-1) and Task 11 (CZM-2). The scenario is representative of the existence of strong local governance, in particular, the Block Development Offices (BDO). This is followed by the Village Panchayats, which can also be considered as an extension of the existing local governance mechanism. In general, the village panchayats are identified as potential implementers in cases where specific local actions or mass mobilization is required. For example, in case of Task 2 (SE-4), on an average, nearly 50% of the respondents identified Village Panchayat as potential implementers of Action-2, i.e. formation of community groups such youth and women. This also indicates the high coordination capacities of the local institutions. Similarly, village panchayats along with NGOs are also identified as potential implementers in case of monitoring and maintenance of the existing tube wells (i.e. Action-2) under the Task 6 (PH-5). Here it is imperative to mention that many Village Panchayats and NGOs have already taken special initiatives to repair the damaged tube wells after the cyclone Aila and the survey results is well indicative of that fact. However, compared to the Bangladesh counterpart of Sundarban, existence of international NGOs and scope of developmental funding from international agencies are much limited in the study area. For example, more than 40,000 NGOs work in coastal areas of Bangladesh and majority of which are developmental NGOs. However, in case of Indian Sundarban, this numbers are limited. Based on author’s work experience in both the Sundarban, it can be said, that the Indian side mostly relies of the performance of the local government, i.e. the Block offices and the panchayat system for developmental assistance. In addition, village panchayats are also considered as strong motivators of the communities. For example, nearly half of the respondents marked the potential role of the village panchayats to control unscientific fish catch and prawn seed collection under the Task 12. Needless to say, this action requires consensus building among the villagers, for which the role and potential of the village panchayat are enormous.







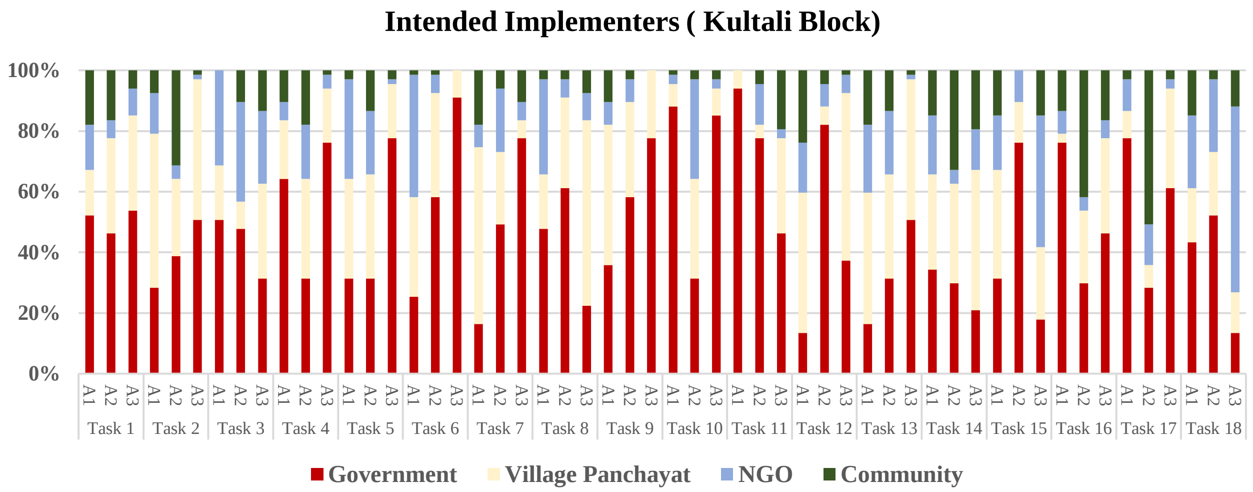


Figure 4.12. Identification of Potential Implementers [Sample Size: Gosaba (65), Sandeshkhali II (70), Joynagar II (66), Kultali (67)]

On the other hand, apart from some specific actions, the respondents did not attach major responsibility to the NGOs. This is probably due to very localized and time-bound operation of the existing NGOs in the Indian Sundarban delta. Nevertheless, the respondents identified the role of local NGOs for some specific actions, e.g. Developing Community Charging Points (Action -2 under Task 5), stakeholder's consultation of environmental actions (Action -3 under Task 18) etc. This can be presumably derived from some of the existing initiatives taken up by the local NGOs. Lastly, except only a few cases (e.g. adjust individual practices according to changes, i.e. Action-3 under Task-15), respondents did not assign any major responsibilities to the communities itself, which may be attributed to the existing lack of coordination, mutual trust and economic capacity of the communities.

4.4. Conclusion and Way Forward

As argued by Shepard et al. 2015, community-based assessments underpin the importance of long-term disaster resilience planning and remain imperative for bridging the existing policy gaps and challenges. In line with the above, the main objective of this chapter was to identify the specific indicators, appropriate tasks and broad actions that the community consider to be relevant from their own perspectives. In order to achieve the above mentioned objectives, this particular research has been conducted in two phases. Firstly, the four FGDs were instrumental for the identification of 18 specific indicators. Furthermore, 18 corresponding tasks and 54 broad actions (18 x 3) were also developed as the main outcome of the FGDs. In the second step, a questionnaire survey (*n=268*) was conducted to prioritize the 18 relevant tasks and their corresponding 54 actions in 3-point Likert scale. In lieu with that, it also identified the potential implementers for each of the proposed actions. Based on these extensive PRA exercises, the following research finding can be summarized with special reference to the overall community resilience in the Indian Sundarban Delta.

(a) Firstly, as mentioned by a number of researchers, this participatory research exercise also confirms that 'resilience' is essentially 'place-based'. For example, it was observed that community's apprehension for a specific tasks and/or actions is largely shaped by local issues rather the overall regional problems. Therefore, it is wrong to propose a uniform policy response for the entire delta, and local level planning remains much imperative. However, at the same time, some commonly prioritized tasks, i.e. Task 1 (Enhancing **Livelihood** opportunities), Task 4 (Enhancing safe mobility i.e. **Transportation**), Task 6 (Develop improved source of drinking **water**), Task 10 (strengthen the **embankment** network) and Task 11 (Conservation, Protection and Restoration of **Mangroves**) could also be identified from the same ranking process. This can be essentially referred to the scale and magnitude of the problems, and as a consequence, the corresponding tasks remain pertinent across the delta. Therefore, with specific focus to long term disaster resilience planning, it remains imperative to include these commonly prioritized tasks in order foster disaster and climate resilient communities.

(b) With regards to the specific ‘actions’ that were prioritized under the above mentioned tasks, the study also observed distinct variation as well as some similarities among the surveyed blocks. For example, in case of Task 1 (Enhancing **Livelihood** opportunities), majority of the respondents favored the Action-3, i.e. improvement of existing livelihood and local business. As mentioned earlier, despite of sufficient scopes for the development of alternative livelihood (A-1), there are several social and economic constraints that essentially restricts thesescopes. This includes physical isolation, lack of economic capacity, training and lack of potential markets; which is perceived by majority of the respondents irrespective of their ‘place’. Therefore, in general, this indicates to a common developmental deficit that prevails almost all across the delta. On the contrary, in case of Task 4 (Enhancing safe mobility across the delta), prioritized actions mostly refer to the local pertaining issues, and, therefore, all the three actions remain equally prioritized. In particular, the prioritized actions are more indicative of local issues than the regional issues. For example, Action-1(Improvement of Jetties and Boat conditions) has been prioritized by Gosaba and Sandeshkhali II which largely reflects the dependence of the communities on water transport since both of these block can only be accessed through waterways. Conversely, Kultali and Joynagar II block, which can be accessed through land, have mostly opted for higher frequencies for public transports (A-2) compared to the rest two actions.

In case of Task 6 (Develop improved source of drinking water), the respondents from all the four blocks have mostly opted for action-1 (i.e. more number of deep and safe tube wells) with a smaller extent of communities opted for A-3 (Piped supply water). At the outset, this defines the extent and regional nature of the problem. In particular, drowning and disruption of tube wells aftermath the cyclone Aila posed a critical challenge for community’s access to safe drinking water. Although, official reports mentioned that, close to 80% of the communities from these above mentioned blocks are fully or partially covered by rural water supply scheme (District Human Development Report, 2009), the need for revitalizing and risk proofing the 'rural drinking water supply schemes' remain highly imperative.

In case of Task 10 (strengthen the **embankment** network), both the Action-1 (heightening of the embankments) and Action-2 (Promote barrier plantation) have been prioritized by the entire population, although, marginal variations have been observed among the blocks. For example, respondents of Sandeshkhali II clearly favored Action-1 over the others; while respondents from Joynagar II assigned their priority to action-2. This is a decent reflection of the local understanding or risks, while, in reality both of the actions seems equally desirable.

In case of Task 11 (Conservation, Protection and Restoration of Mangroves), an overwhelming majority of the respondents have opted for Action-3 i.e. enhancing the activities of JFM. As mentioned earlier, participatory forest management model has been hypothesized as an ameliorative model for mangrove conservation through active community participation. Therefore, this particular observation can be justified, especially in the backdrop of the rural resource dependent communities of the delta. Nevertheless, it is also important to mention that the respondents showed some agony over the existing participatory forest management mechanism that are in place since late nineties. Therefore, considering the regional perspective of the problem of mangrove degradation, it remains imperative to carefully examine the existing forest management mechanism and to enhance the performance of the current JFM arrangements.

(c) The results from the entire participatory action planning process also suggest that the communities, in general, are highly aware of the benefits of the mangrove forests. This was widely reflected from their affiliation to mangrove based corrective actions such as barrier plantation in front of embankments (Task 10/A-2), mangrove plantation for flood risk reduction (Task 14/A-1) and mangrove plantation for erosion control (Task 16/A-3). However, what is important to note that awareness itself does not lead to actions for mangrove conservation since a section of community are also involved in mangrove forest degradation for various economic reasons such as development of aquaculture pond, brickfields etc. Hence, an 'ecosystem based management approach', which considers human being as an integral component of the ecosystems, remains imperative in the backdrop of the Indian Sundarban.

(d) Another interesting observation from the prioritized tasks is the <u>nexus between livelihood, mangroves and embankments.</u> Despite of the fact that 'access to safe drinking water' and ‘transportation’ are also identified as major problems, this can be referred as an adverse consequence of general developmental deficits and are fairly identical to many other rural settlements across the state of West Bengal as well as in India. Furthermore, it can be argued that once the basic developmental deficits are fulfilled, these problems are most likely to minimize. On the contrary, livelihood (especially coastal agriculture and fishing), mangroves and embankments are the three components that are not only the unique features of the delta, but also are characteristically interlinked with each other, and therefore, forms a close nexus. Arguably, these three component remains the most prominent regional issues that were particularly evident from the consequence of cyclone Aila, and therefore, may be considered as the pillars of community resilience within the regional perspective. As depicted in **Figure 4.13**, this nexus begins with the antecedent conditions that poor agricultural output (agriculture being the primary livelihood of the delta) essentially leads to extreme pressure on the mangroves (marked in red arrows in **Figure 4.13**). However, this is often triggered by failure of embankments and pro-longed flooding of the agricultural lands which results in low agricultural productivity and loss of livelihood (as in the case of Cyclone Aila). Conversely, ‘Loss of livelihood’ is a major factor for illegal

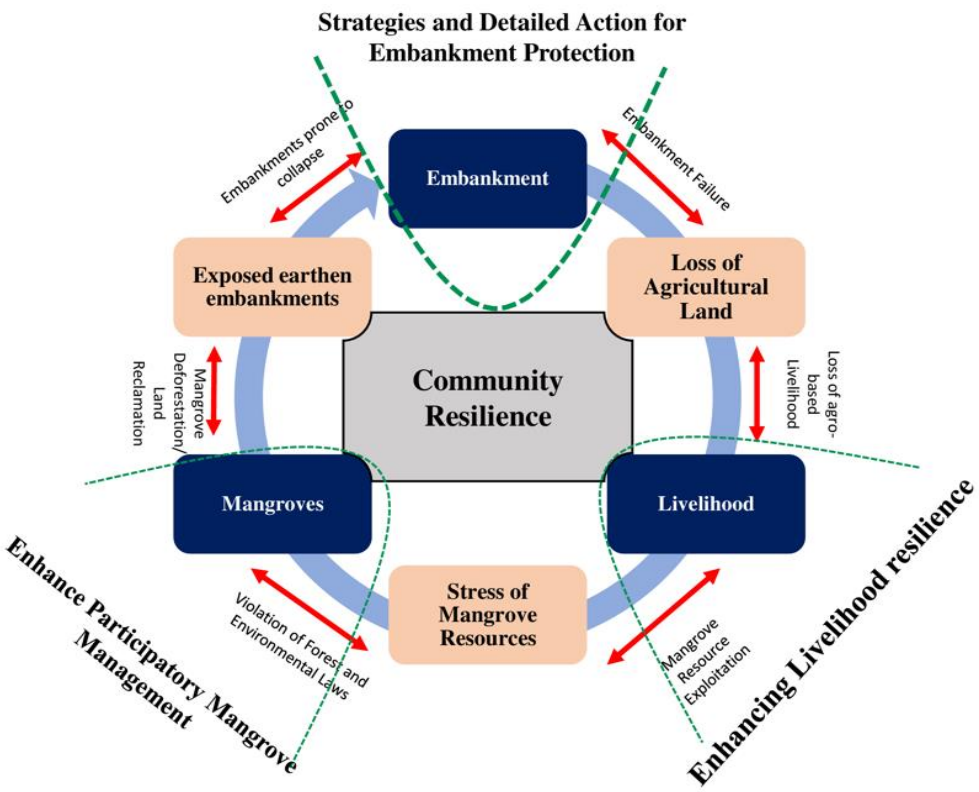


Figure 4.13. The Livelihood-Mangrove-Embankment Nexus in the Backdrop of Indian Sundarban

deforestation or land reclamation for development of brickfields, aquaculture ponds etc. Needless to say, loss of mangroves leads to lesser protection of the fragile earthen embankments to extreme storm and tidal surges. This relationship is marked with red arrows in **Figure 4.13**. Interestingly, the reverse relationship will essentially enhance the resilience of the communities. For example, if the agricultural productivity is enhanced by the means of adaptation and ameliorative agricultural practices, this will certainly lead to lesser stress on the mangroves. However, apart from the agricultural communities, there are certain other mangrove dependent livelihoods that operates within the scope of existing Joint Forest Management (JFM). Hence, it also remains imperative to enhance the performance of the existing JFM arrangements with two specific objectives, firstly, to promote community based ecological conservation and restoration, and secondly, to enhance the economic capacity of the forest dependent communities. Nonetheless, this model is only possible when the existing 3500 km long network of embankments are made resilient through the appropriate combination of social and technical measures, of which, barrier plantation and heightening of the dykes remain crucial.

The above discussion can be taken up for a further detailed study on this particular nexus as any regional development plan that are aimed towards fostering resilient communities in the Indian Sundarban delta need to encompass a detailed investigation of these three components. Considering this, a detailed research has been conducted for three of the above mentioned components. The chapter 5 encompasses detailed actions and policy recommendation to enhance livelihood resilience of the communities and especially focuses on the available adaptation options for coastal agriculture and estuarine fishing. The chapter 6 critically examines the performance of the existing Joint forest management in the Indian Sundarban with special references to incentive design and active community participation. Lastly, the chapter 7 describes in details an evaluation of the existing management practices of the vulnerable earthen embankments and formulates an ameliorative management strategy which adheres to the key ideas of social mobilization and ecosystem based disaster risk reduction.

References

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global environmental change*, *18*(4), 598-606.

Hamdi, N., & Goethert, R. (1997). Action planning for cities: a guide to community practice (p. 264). Chichester, UK: John Wiley.

Prashar S, Sharma A, Shaw R (2011) From action planning to community-based adaptation. In: Shaw R, Sharma A (eds) Climate and disaster resilience in cities. Community, environment and disaster riskmanagement, vol 6. Emerald Group, UK, pp 163–182

Prashar, S., Shaw, R., & Takeuchi, Y. (2013). Community action planning in East Delhi: a participatory approach to build urban disaster resilience. *Mitigation and Adaptation Strategies for Global Change*, 18(4), 429-448.

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in human geography,* 24(3): 347-364.

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science*, 309(5737), 1036-1039.

Haldar, A., & Debnath, A. (2014). Assessment of Climate Induced Soil Salinity Conditions of Gosaba Island, West Bengal and Its Influence on Local Livelihood. In Climate Change and Biodiversity (pp. 27-44). Springer Japan.

Henly-Shepard, S., Anderson, C., Burnett, K., Cox, L. J., Kittinger, J. N., & Ka'aumoana, M. A. (2015). Quantifying household social resilience: a place-based approach in a rapidly transforming community. *Natural Hazards*, 75(1), 343-363.

Chevalier, J. M., & Buckles, D. J. (2013). Handbook for participatory action research, planning and evaluation. SAS2 Dialogue: www. participatory action research. net.

Government of West Bengal (2009): District Human Development Report (South 24 Parganas)

CHAPTER 5: Enhancing Livelihood Resilience

"Our livelihood is intimately tied to the food we eat, water we drink and places we recreate. That's why we have to promote responsibility and conservation when it comes to our Natural resources".

Mark Udall, Former US Senator

CHAPTER 5: Enhancing Livelihood Resilience

As have been recognized in the previous chapter, on a regional perspective, enhancing livelihood resilience occupies the central theme for community's disaster and climate resilience. Under this backdrop, this chapter narrates the existing livelihood scenarios of Indian Sundarban delta and its vulnerability against natural hazards, including its future susceptibility against climate change and climate induced hazards. In particular, the chapter characteristically describes the livelihood vulnerability of the communities involved in agriculture and inland/estuarine fisheries; the two most practiced livelihood in the delta. Identifying the key factors that restrict communities to achieve a sustainable livelihood that is resilient to disasters and/or climate change, the chapter principally attempts to describe the results of several participatory adaptation planning exercises conducted with local farmers and fishermen. Based on the research findings, the chapter identifies the most favored and potential adaptation options and concludes with some key recommendations to facilitate the adaptation process.

Outline of the Chapter 5

5.1. Introduction

Livelihood occupies the central theme of socio-economic sustainability and have been traditionally considered as the chief indicator of human development. There are no doubts that disasters affect livelihood, directly or indirectly, and that, fostering disaster resilient communities is incomplete without appropriate planning for livelihood resilience. While at one hand, massive technological advancement has largely restricted the loss of human life from hydro-meteorological disasters in coastal areas, community livelihood still continues to remain vulnerable against a variety of coastal hazards, especially across the natural resource dependent coastal rural communities. For example, during the Cyclone Phailin in 2013, the local government of Orissa were largely acclaimed by the international communities due to their massive evacuative responses which saved precious lives. The same area, when hit by the notorious Orissa cyclone in 1999, suffered more than 10,000 casualties. Yet, what went relatively unnoticed is that the cyclone Phailin damaged crops over 500,000 hectares of agricultural land throughout the state of Orissa, significantly higher than the Orissa cyclone in 1999. In addition, partial salinization of coastal agricultural lands poised identical challenges that the communities confronted during Orissa Cyclone in 1999. Therefore, even if the precious human lives were saved, it is highly imperative that the local government spends significant efforts and resources on community livelihood in order to achieve an inclusive resilience against coastal hazards.

As have been mentioned in Chapter 4, communities living in Indian Sundarban delta are no exception and major livelihood disruption after the Cyclone Aila in 2009 and exceptionally slow recovery since the last five years has been identified as one of the principal concern of the local communities. Further, dire poverty and geographical isolation continues to play a significant role impairing livelihood sustainability of the entire region. The perilous condition of the community livelihood can be further justified by the fact that, on an average, 43.5% of communities live under the nationally designated poverty line which is merely INR 32 (0.5 USD) per capita per day (in rural areas) (Census 2011). Therefore, the situation implies that a proper plan needs to be developed considering the major livelihood of the region, by understanding the inherent vulnerabilities and adopting technology and innovation driven solutions towards fostering resilient livelihoods. Considering the above, this chapter narrates the specific research exercises that are aimed to enhance the resilience of two of the most practiced livelihood of the delta, i.e. agriculture and inland fisheries.

5.1.1. Livelihood Profile of the Indian Sundarban Delta

Communities in the Indian Sundarban Delta are primarily agro-riparian communities, which theoretically means that, agriculture and fisheries consists the two major livelihood of the region. Among these two, agriculture, by a considerable margin, serves as the primary livelihood of the communities. As per the official records, nearly 60-65% of the people are directly involved in agriculture, while indirect dependency may reach up to 95% (District Human Development Report, 2009). However, about 54% of the communities are landless, which implies a considerable high number of 'agricultural labors' with no land holding. Important cash crop involves rice, chili, cotton, water melon, cucumber, betel leaves etc. **Table 5.1.** summarizes the crop calendar of the Indian Sundarban. As per the official estimates, Indian Sundarban consists of nearly 2482.33 sq. km. of agricultural land, mainly producing rice as the major harvest (SBR, 2008).

Table 5.1. Crop Calendar for Indian Sundarban Delta with Reference to Irrigation Facilities

Pre Kharif [a]	Kharif [b]	Rabi [c]	Land Characteristics [d]
No crop	Aman paddy	No crop	Land having no irrigation facility (nearly 50% of the land)
Sunflower/Cotton	Aman paddy	No crop	Land having moderate irrigation facility. (nearly 20% of the land)
Summer Mung	Aman paddy	No crop /Rabi pulses/mustard	Land having moderate irrigation facility (nearly 30% of the land)
No crop	Aman paddy	Boro paddy	Land having good irrigation facility (nearly 20% of the land)
Vegetables	Aman paddy	Vegetables	Land having good irrigation facility. (nearly 20% of the land)

[a] Pre Kharif season continues from March to May and harvesting in June to October. [b] Kharif is the main rice growing season in India which depends largely on Southwest monsoon. Sowing of the crop is done between June and October and harvesting is between November and April. [c] Rabi is the second cropping season in India. Sowing of crop is done between November to February and harvesting is between March to June. [d] Crop production in Indian Sundarban Delta extensively varies with the available irrigation facilities. In general, nearly 80% of the land is non-irrigated or locally irrigated. Only, 20% of land receives sufficient irrigation throughout the year.

Source: Personal Communication with Dr. Joydip Mukhopadhyay, Asst. Director of Agriculture, Joynagar, South 24 Parganas, Government of West Bengal

Nevertheless, it is important to mention that the Indian Sundarban delta have largely missed out the benefits of 'Green revolution' in India, therefore, rice cultivation still follows primitive technologies, lack of mechanized farms, and majority (approximately 80%) of the agricultural land being 'non-irrigated'. Therefore, except the northern interior blocks, mono-crop rice cultivation, particularly the Aman Rice *(Monsoonal Rice, grown during the monsoon and harvested in the post monsoon season),* predominates the agricultural production of the delta. In addition, due to the existence of unfavorable soil salinity and lack of irrigation facilities, crop yield is substantially lower than the rest of the country. Needless to say, poverty being another determinant behind lack of crop diversification and farm mechanization. Despite of all the adversities, rice cultivation continues to serve as the sole livelihood of the communities, having profound impact on the local food security and employment generation.

Sundarban being the nursery ground for nearly 90% of the aquatic species available in the eastern coast of India, serves also a potential fishing hub (Chandra and Sagar, 2003). Therefore, both estuarine and deep sea fishing are prevalent in the extreme coastal blocks. It has been estimated that the estuarine water of Sundarban host nearly 120 commercially important fish species (Gopal & Chauhan, 2006). In addition, it also harbors 20 identified species of prawns and 44 species of crabs, although majority of them are not used for human consumption. The rich nutrient supply from the mangrove litter fall and warm brackish water serves as the perfect background of the observed rich aquatic diversity. Fishing, therefore, serves as an auxiliary livelihood involving nearly 25-30% of the existing population. In addition to this, a good number of fishermen are involved in deep sea fishing. Estuarine fishing is officially allowed throughout the year, except the designated breeding period of 90 days (April to June). However, this is vastly controlled by the local forest offices through many designated '*go*' and '*no go'* areas within the estuary. Despite of its potential, one would argue that the prosperity of fishers is largely hindered by lack of markets, cold storages and primitive transportation facilities.

In addition to these two major livelihood, communities of Indian Sundarban Delta are also involved in supplementary livelihood such as forest product (honey and wax) collection, tourism (especially boat drivers), tour guides etc. However, only a small segment of communities, mostly living beside the mangrove protected areas are, at present, involved in these kind of activities. Importantly, most of the above mentioned livelihood are dependent of the mangrove ecosystem services and functions under the administrative supervision of the local forest department. A detailed discussion on these particular livelihoods which operate under the existing Joint Forest Management (JFM) mechanism have been furnished in Chapter 6.

5.2. Impact of Coastal Disasters on Community Livelihood

5.2.1. Impact on Agriculture

Livelihood vulnerability of the coastal communities in Indian Sundarban against hydro-meteorological disasters are nothing new, but a historical reality. Ever since the communities started living in these reclaimed islands, they had to live with saline water, tidal surges and a host of other coastal hazards. In fact, the local saying '*nodir dhare bas, chinta baro mas'* [*When you live by the river, you need to worry throughout the year*] translates the long-standing vulnerability of the communities, both in terms of lives and livelihood. However, for the ease of the discussion, this study chooses to narrate the livelihood scenario in the post Cyclone Aila (2009), as the storm triggered massive disruption of community livelihood almost in every pockets of the delta. While the damage was far more severe in the extreme

Figure 5.1. (A) & (B) Aerial Photographs of Flooded Agricultural Land after Cyclone Aila in Patharpratima Block (C) & (D): Flooded agricultural lands in the aftermath of Cyclone Aila in Patharpratima Islands

Source: (A) & (B): Indian Air Force,2009
(C) & (D): District Disaster Management Authority, South 24 Parganas

coastal blocks such as Pathar Pratima, Sagar, Namkhana and Gosaba, where practically the entire blocks were flooded, interior blocks such as Sandeshkhali I & II, Kultali, Joynagar II, Kakdwip were also significantly affected due to the breaching of the earthen embankments. As per the author's interview with district disaster management authority, direct loss of agricultural products and revenue was estimated as 1472 ha of rice cultivation, 748 ha of betel leaves cultivation and 2151 ha of vegetable cultivation costing nearly INR 12 crores (approximately 20 million USD); while indirect loss due to salinization of agricultural plots, loss of freshwater ponds may reach up to INR. 125 crores (US$26.3 million). Importantly, since the 'Aila' occurred in late May, there were no particular damage to rice cultivation itself, however, it completely destroyed the crop potential for the next couple of years by extensive salinization of fertile agricultural lands.

Internal report from the district administration suggests that nearly 1390 sq. km of agricultural land was flooded and were salinized due to the cyclone Aila (Office of the District Magistrate, South 24 Parganas 2010). In the post Aila scenario, most of these agricultural land could not be cultivated due to the occurrence of excessive salinity, although the official report suggests that in some areas 20% of the regular agriculture was possible with the help of extensive irrigation. Due to the process of salinization, an estimated 2,26,345 number of families were without employment for next couple of years. Not surprisingly, it also led to massive outward migration and deterioration of local law and order situation. In addition, Cyclone Aila also caused vital damage to the rural agricultural facilities, particularly, the freshwater ponds. The same report suggests that nearly 160,000 ponds were affected by saline water, while the local government could retrieve some 60000 ponds in the following year. On the contrary, the cultivable fields could not be desalinated and the situation became even worse because of paucity of rain in June, 2009. As revealed by the local farmers, the salinity scenario lasted till 2012 with crop production reduced to less than half of the normal yield.

In particular, the massive discontinuation of agriculture due to salinization of agricultural lands leads to the apprehension of a greater threat which arises from the current trend of sea level rise (+5.14mm/year) in the Indian Sundarban Delta. It is expected that the unfavorable soil and water salinity scenario will continue to rise under the influence of persisting sea level rise, leading to further loss of agricultural productivity in near future. For example, Abedin et al. 2012 mentioned from the neighboring Bangladesh, that the country is already loosing 0.2 Million metric ton of rice every year due to salinity intrusion in its coastal areas. While the problem of unfavorable salinity received significant attention in neighboring Bangladesh, empirical studies on the long term salinity impacts is limited in case of the Indian Sundarban.

5.2.2. Impact on Fisheries

The damage in fisheries, especially, to the estuarine fishermen were mostly limited to the damage of boats and nets leading to discontinuation of fishing in the aftermath of 'Aila'. However, there is no available statistical account of the economic loss to fisheries incurred to such damages. As per the available official reports, it is mentioned that the fishing communities also suffered discontinuation of livelihood, although for a lesser period of time. In particular, saline water flooding over the freshwater and aquaculture ponds led to the discontinuation of nearly 100,000 people's livelihood. In this regard, it is important to mention that during the interviews with estuarine fishermen, it was revealed that fishermen observe an adverse ecological change of the river water and relates this with the mixing of pollutants in the river water. Majority of the fishermen also expressed their concern over the depleting fish resources and consequently lesser catch since the Cyclone 'Aila'. However, there is no proper scientific data available in support of their claim.

5.3. Coastal Disaster, Climate Change and Need for Livelihood Adaptation

As mentioned previously, the impacts of coastal hazards are most likely to aggravate with the onset of climate change as scientists expect more intense storms, frequent flooding and sea level rise induced erosion in the low-lying coastal areas (Nicholls et al. 2007; Mcgranahan et al. 2007; Knutson et al. 2010) (*See* Chapter 1). Needless to say, the entire Indian Sundarban Delta are also expected to undergo major geomorphological alterations within the next 30 years (INCAA 2010; Krishnamurthy et al. 2015). The possible adverse climate change consequences in the Sundarban Delta have been hypothesized by severe coastal erosion, intensified cyclones, changes in hydrodynamic regime with probable rise in water temperature and salinity (e.g. Rahman et al. 2011; Rabbani et al. 2013; Dasgupta 2014) [*see chapter 1 for more details on the regional exposure to climate change*]. As have been postulated by a number of researchers, climate change will adversely affect community livelihood in this region, and in particular, changes in inland water salinity have been identified as one of the major determinant that can jeopardize the traditional rice cultivation of the Sundarban Delta (e.g. Abedin et al., 2012; Rabbani et al., 2013; Dasgupta 2014). Despite rice being a moderately salt tolerant crop, empirical studies have indicated that each unit (dS/ml) rise of salinity roughly corresponds to 12% reduction in rice yields (Hanson et al. 1999; Redfern et al. 2012). In addition, salinity also causes several structural damages to rice production such as rolling of leaves, white tips and grain sterility leading to acute disruption of coastal agricultural systems and loss of market compatibility (Redfern et al.

2012). Although, specific thematic studies from the Indian side of Sundarban is rare, case studies from the Bangladesh counterpart have strongly indicated the possibility of a serious disruption of coastal agriculture in near future (e.g. Rahman et al., 2011, Rabbani et al., 2013, Dasgupta, 2014). For example, Dasgupta, 2014 mentioned that Bangladesh many loose up to 2% of its current national rice yield in 2050 under the existing trend of salinization of coastal agricultural land, accounting for a net loss of 0.5 Million metric ton of rice every year. This prediction remains equally applicable for the Indian counter part, since, the farming methods and physical environment are quite similar to coastal Bangladesh. Hence, it will not be incorrect to consider that the existing methods and practices of coastal agriculture in the Indian Sundarban, like its counterpart in Bangladesh, will eventually meet the same fate. In addition, climate change may also adversely impact the estuarine fishers as the productivity of the estuarine waters might decease under the various environmental factors. It is mentioned, that in case of the Sundarban Delta, the changes in the hydrodynamic regime may led to the diversion of commercially important migratory fish species. However, as argued by Roessig et al. 2004 significant knowledge gap exists on how the complex estuarine systems will respond to the ongoing changes; and they suggested that in some cases, fish production may also increase, while majority of the existing estuarine system will perhaps loose their productivity. Consequently, with respect to the fishermen of the Indian Sundarban Delta, future livelihood sustainability is burdened with high amount of uncertainties.

Since the realization of the climate change adversity and its possible impacts on community livelihood, adaptation occupied the central theme of livelihood resilience, especially in the backdrop of rural resource dependent communities. As mentioned, considering the high amount of future uncertainly, it becomes rather imperative to pursue an anticipatory adaptation strategy to enhance the livelihood sustainability of the coastal communities living in the Indian Sundarban Delta. In simpler term, livelihood adaptation denotes to the methods and practices that are aimed to maintain the specific livelihood objectives such as productivity, price and market sustainability under external stresses such as disaster and/or climate change. Smit & Skinner 2002 argued that with appropriate adaptation measures, future and existing vulnerability can be significantly reduced and there are numerous opportunities that can be realized throughout the adaptation process. In conjugation with their arguments, several other researchers highlighted the need of adaptation planning against natural disasters and climate change stressors. Thus, the present research primarily attempts to conduct a detailed adaptation planning for the two main livelihood sectors of the Indian Sundarban delta, i.e. agriculture (with main focus to rice cultivation) and inland fisheries, by conducting participatory exercises with the local farmers and fishermen. The principal aim of the study is to identify the key livelihood stressors, coping and adaptive responses aftermath the cyclone Aila, and to understand communities' intention and ability to adapt. The study also provides a series of recommendation that are imperative for a planned/anticipatory adaptation strategy in the agriculture and fisheries sector, which can serve as the foundation for enhancing livelihood resilience of the communities.

5.4. Research Objectives

As mentioned, the main objective of this present research is to plan for an ameliorative adaptive mechanism in the two of the most practiced livelihood, i.e. agriculture and inland fisheries against the backdrop of high disaster and climate vulnerability of the community livelihood. As in previous cases, the author preferred to adopt a bottom-up approach for adaptation planning and the study was principally conducted through the intervention of local block offices and Ramakrishna Mission Krishi Vigyan Kendra, Neempith, Joynagar (an NGO). The research serves the following steps to attain the above mentioned objectives.

- **Identification of Livelihood Stressors**, i.e. disaster loss and threats perception of individual farmer or fisher men, particularly in the aftermath of Cyclone Aila.
- **Practiced/Planned Coping and Adaptation Strategy,** i.e. to identify the available coping or adaptive mechanism.
- **Understanding individual intention to adaptation** (choice of coping or adaptation, i.e. which adaption suits whom)
- **Provide specific recommendations to overcome the existing livelihood vulnerability of the communities.**

For the ease of the discussion, the study has been divided into two sections, namely, adaptation planning for coastal agriculture and adaptation planning for estuarine/inland fishermen.

5.5. Adaptation Planning for Coastal Agriculture

5.5.1. Materials and Methods

As the **Table 5.1**. and the above discussion suggests, rice is unanimously the major crop of Indian Sundarban delta, and in general, an overwhelming majority of the farmers are exclusively involved in rice cultivation. Therefore, in order to understand existing rice cultivation scenario, six Focus Group Discussions (FGDs) were conducted with the rice farmers and agricultural labors involved in paddy cultivation. Participation preference were given to those who had suffered livelihood discontinuation in the Cyclone 'Aila' and are capable of narrating their agricultural experiences. Hence, site selection for the FGDs were chosen from the villages of Gosaba, Pathar Pratima, Kultali and Sagar Blocks, which were reported to have sustained massive disruption of coastal agriculture. In the same process, an enquiry was made over the farmer's coping/adaptive methods in response to high soil salinity in the post Aila period. The discussion also summarized a number adaptive/coping actions that the farmers proposed based on their individual experiences, learning from the local NGOs and agricultural research agencies such as Central Soil Salinity Research Institute (CSSRI) in Canning, Ramakrishna Mission Krishi Vigyan Kendra in Joynagar etc.

Figure 5.2. (A) FGDs with Farmers at Gosaba Blocks (B) FGDs with Farmers in Sagar Block (C) FGDs in Pathar pratima Block (D) FGDs with famers in Kultali Block

Thereafter, a list of agricultural coping/adaptive actions was finalized from the above discussions. In the second stage of the research, 126 farmers were surveyed in Gosaba, Sagar, Kultali and Pathar Pratima block through a questionnaire designed on the outcome of the above mentioned FGDs. The sample population of farmers was later classified based on their landholding. i.e. **Agricultural labors** (*n=35*) (no landholding or landholding of less than a bigha), **Marginal Farmers** (possess land measuring within 1 to 3 Bighas or 1 acre) (*n=41*), and **Small farmers** (*n =50*), (land holding greater than 3 Bighas but less than 10 Bighas) Note1,2. The questionnaire survey was typically intended to identify the variation between threat perception, incurred agricultural damages and choices of adaptive actions among these three groups of farmers.

The questionnaire survey essentially relied on a five point Likert scale based prioritization technique, where '1' denotes least priority and '5' denotes highest priority. Depending on this classification system, farmers were asked to classify each of the identified threats and adaptive actions based on their individual perception (**Annexure 4**). In this regard, it is important mention that agriculture being a multi-layered system, requires adaptive intervention at various level of operation (e.g. farm level, institutional level etc.). However, at the farm level, individual adapt based on their own perception of threat, whereas various other factors such as economic and social capital, cultural factors, institutional and political circumstances are also hypothesized to influence adaptation intentions (Adger et al. 2009; Dang et al. 2014). Considering the above, it becomes crucial to identify the adaptation intentions of these three existing groups of farmers.

The data obtained from the questionnaire survey were firstly converted into frequencies and thereafter, statistical hypothesis testing were conducted over the observed frequencies for each of the threats and adaptive actions. The Null hypothesis (H_0) for this study was formulated as that there is no statistically significant difference in threat perception and adaptation intentions among this three groups, and conversely the alternative hypothesis was

***Note 1*:** *As per the prevailing definition of the provincial government of West Bengal, farmers having less than 1 ha of land are broadly defined as marginal farmers, whereas farmer cultivating land measuring between 1-2 ha are defined as small farmers [Adhikari et al. (n.a.)]. However, as per this definition, classification of farmers in the study area and interpreting their perception would be gross generalization under the existing socio-economic scenario. The reasons are- Firstly, the local unit of land is Bigha (1 Bigha equals one third of an acre or 0.1338 hectare) and farmers having one acre of land are considered to be significantly dependent on agriculture, whereas, the definition does not mention about agricultural labors who often are landless or cultivate tiny portion of land. Official figure suggests that nearly 85% of the farmers in the Indian Sundarban delta are considered as marginal or small farmers which does not allow the proper data representation for a micro-level perception analysis. Considering the above, these classifications were made to capture the micro-level scenario of agricultural adaptation intensions in the Sundarban Delta.*

Note 2: *The study did not consider of semi-medium (landholding 2-4 ha), Medium (4 to 10 ha) or Large (>10 ha) farmers due to very limited or non-existence population in the surveyed areas.*

farmed. In majority of the cases, χ^2 test were conducted for hypothesis testing, however, in some cases, due to the non-fulfillment of the test conditions, Freeman Halton Extension of Fisher Exact Test were adopted (*p<0.05*) *(for test results, see **Annexure 5**).* The observed *p* values were used to accept or discard the null hypothesis. For diagrammatic representation of data, standard bar and charts were used in this study.

5.5.2. Results and Discussions

➢ **Agricultural Damage Incurred in the Cyclone Aila**

During the FGDs, local farmers mentioned that since the landfall of Aila coincided with no-crop season, direct damage to agriculture was much limited, therefore, not affecting investments at large. However, as mentioned earlier, the main problem identified by the farmers is the post-Aila unfavorable soil and inland water salinity scenario and heavy yield loss in consecutive years, which eventually led to a major livelihood crisis. In general, the identified issues during and after the cyclone Aila revolves around crop yield loss, permanent land loss, high residual salinity in agricultural land, loss of livestock, financial loss and loss of life.

In the follow up questionnaire survey, 100% of the agricultural labors and nearly 90% of marginal and small farmers reported high yield loss, while more than 70% mentioned the occurrence of high residual soil salinity in their agricultural land in the following years. Consequently, an overwhelming majority of farmers also mentioned to have suffered financial losses that continued for nearly two years **(marked in red in Figure 5.3).** However, as evident from Figure 5.3., loss of lives as well as livestock were much restricted within the surveyed population.

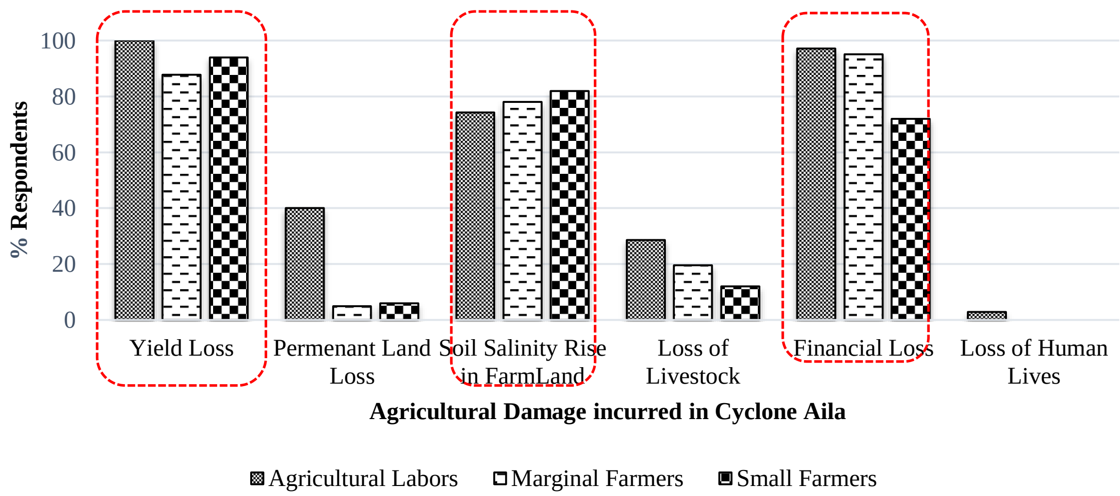


Figure 5.3. Agricultural Damage Incurred in the Cyclone Aila

The questionnaire survey typically enquired about the chronological crop yield since 2008, and it was revealed that during 2008-09 (before the occurrence of cyclone Aila), the average crop yield (*for Aman Paddy*) was nearly 5 quintal/bigha (approximately 37000kg/ha) for the small farmers, 3.64 quintal/bigha (approx.27200 kg/ha) and 3.15 quintal/bigha (approx. 23500 kg/ha) for marginal farmers and agricultural labors respectively **(Figure 5.4).** However, in 2009-2010, due to extensive salinization of agricultural lands, virtually no crop could be grown. Since 2010-2012, the scenario improved slowly, although, as the **figure 5.4.**

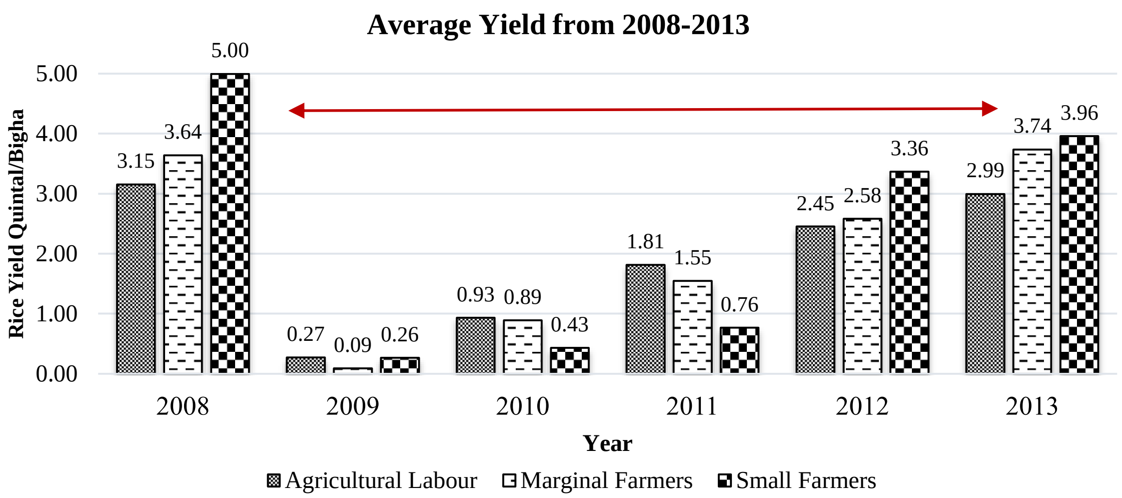


Figure 5.4. Reported Rice Yields in Quintal/Bigha from 2008-2013

suggests, crop yield has not yet been recovered to its earlier extent. However, one interesting feature coming out of this survey is that the marginal farmers and agricultural labors could recover bit faster than the small farmers, probably due to lesser requirements of financial and human capital to restore their agricultural facilities.

➢ ***Farmer's Perception of Threats against Agricultural Sustainability***

Perception of threats regulate farmer's decision to act or restrain, and therefore, has been considered as the key component of adaptation decision making (Alessa et. al. 2008). The FGDs with the farmers mostly highlighted six major factors related to the future sustainability of agriculture in the Indian Sundarban Delta. Firstly, as evident from the post Aila recovery period, farmers believed that increasing soil salinity is building an adverse scenario, in which, rice could probably no longer be cultivated. In the follow up questionnaire survey, when asked to prioritize the salinity threat, nearly 60% of the small farmers believed that soil salinity will have very high impact on their production, while the number of marginal farmers/agricultural labors perceiving the same is about 40% respectively **(Figure 5.5).** However, in general, more than 85% of the surveyed farmers perceived that increased soil salinity will have high to very high impact in their agricultural productivity. This observation also aligns well with Banerjee, 2013 which claims an unprecedented salinity increase (about 2.8 psu/decade) in the estuarine waters of Indian Sundarban and consequent renormalization of salinity in the soil-aquifer systems. Hypothesis testing in this regard, did not show statistically significant differences among these three farmers groups and therefore it can be concluded that the threat of increasing soil salinity is uniformly perceived and believed to have significant future impact in agricultural sustainability.

The second issue which came out from the FGDs is the lack of fresh water availability. As mentioned earlier, this particular threat originated from the salinization of inland water reservoirs such ponds and tanks, which resulted in severe shortage of irrigation water. More than 90% of the small and marginal farmers recognized it as high or very high impact threat whereas the perception of agricultural labors remains scattered over this issue (**Figure 5.5).** This is probably due to leaser requirement of water since the landholding of the agricultural labors are significantly small. Further, hypothesis testing also indicated statistically significant differences over the opinion in fresh water availability among the three farmers' groups and it is found that small and marginal farmers generally perceive the lack of freshwater as a more significant threat compared to agricultural labors.

The third issue was the threats of natural disasters, particularly cyclones and surge/tidal flooding. During the FGDs, farmers revealed that in recent years, intensity of tidal surges has become more severe than the previous years and the direct risk of crop damage from the disasters are also rising simultaneously. In addition, they also mentioned that even with their historical experience with cyclones and floods, the rampage caused by the 'Aila' was unique and unprecedented in the delta's history. Therefore, in general, a uniform response has been observed among the surveyed population as the majority perceived the impact of cyclones and flood will continue to have high to very high impact on the coastal agricultural sustainability. Hypothesis testing in this regard did not show any statistically significant difference among the three groups of farmers leading to the conclusion that all the person associated with agriculture perceive cyclones and tidal flooding as a serious threat to their agricultural sustainability.

Climate variability, such as temperature and rainfall are two important factors that heavily influence agriculture. Since rice cultivation of Indian Sundarban is particularly dependent on the monsoon, therefore understanding farmer's perception about the rainfall and temperature variability is highly imperative. During the FGD process, farmers mentioned about inconsistent

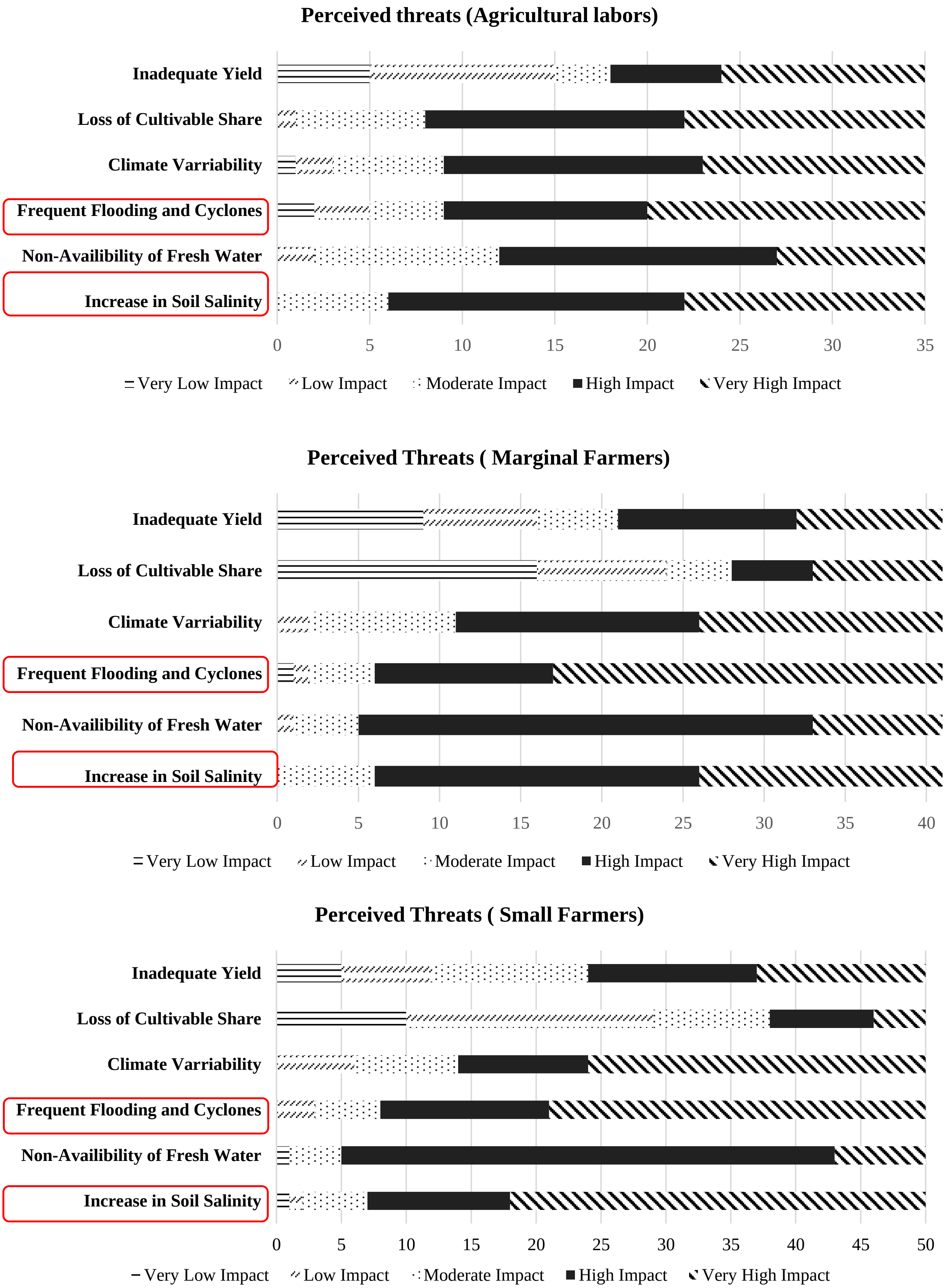


Figure 5.5: Threat Perception of Three Groups of Surveyed Farmers

rainfall and rising temperature in recent years, particularly, a delay in arrival of monsoon was highlighted. Although, this observation may have been heavily influenced by lack of rainfall in June, 2009 (*just after the cyclone Aila, when a good monsoon was desperately needed*), chronological rainfall trend analysis (1905-2004) for nearly a century revealed a non-significant decreasing trend of rainfall during the monsoon season (*See* Chapter 1.). In a recent study, Mondal et al. 2010 revealed, based on their study of climate variability for nearly three decades (1982-2010), that cumulative rainfall during monsoon and post monsoon season (main *crop growing season*) has a non-significant decreasing trend at the rate of 3.84–4.42 mm per year. As argued in chapter 1, although statistically non-significant, the present trend is indicative of shifting of monsoon rainfall, with reduction in cumulative rainfall in June and increase in September. However, the average monsoonal rainfall does not show any significant trend. In case of the temperature, Mondal et al. (2010) revealed a significant rising trend of maximum surface temperature for all the seasons with an annual average rise of 0.065°C, while, on the contrary, minimum temperature has declined at the rate of 0.03°C year per year.

Despite of the fact, the above observations are based on a single point data source (Sagar Islands) which might not be representative for the entire delta, farmer's perception of climate variability, mostly, aligns well with the available scientific observation. When asked about how climate variability would impact their agricultural productivity in near future, general perception of farmers, including that of small, marginal and agricultural labors were mostly found between moderate to high impact. Nevertheless, it was also found that small framers tend to put more priorities on climate variability in contrast with marginal farmers or agricultural labors. Hypothesis testing, however, could not reveal any statistically significant difference among the three groups.

<u>Loss of cultivable share</u> has been traditionally a social problem associated with agriculture in Indian Sundarban. As reveled by the farmers, ancestral inheritance leads to fragmentation of agricultural lands between two or more recipients, and therefore, individual share turns insignificant that are incapable of producing enough yield for a sustainable agricultural living. However, loss of cultivable share may also have been borne by permanent land damage (by submergence), government acquisition (for creating new embankments, roads or other infrastructure), political conflicts and distress sell. During the questionnaire survey, it was observed that although it remains a fear factor for all the farmers, only agricultural labors perceive a potent threat from it. Nearly 80% of the agricultural labor fear to lose their small to

little available land in future from reasons mentioned above. Particularly, their perception is largely derived from the recent land acquisition drive for creating new embankments that have resulted in some conflicts of interests in the surveyed areas. As expected from the observation, hypothesis testing also provides statistical evidences of bifurcation of opinion on this issue.

As mentioned the existence of high soil and inland water salinity since the Cyclone Aila has been the single largest cause of the massive disruption of agriculture, however, the more visible outcome of soil and inland water salinity (or even lack of fresh water availability) is the reduction in crop yields. The historical yield of rice in Indian Sundarban is less than that of the inland cultivation, yet could sustain the local markets and catered to local food demands. However, inadequate and poor quality yield is an emerging concern for local farmers. For example, farmers revealed about white grains, grain sterility, high insect damage (disease) in the post Aila period which not only hindered the average yield of rice, but also affected in price in local markets. However, in the questionnaire survey, most of the farmers remain scattered in their perception of inadequate or poor quality yield as a potential threat, while many believed that the situation will largely depend on the available seed quality and the available irrigation facility in future. Hypothesis testing also affirmed a uniform scattering of opinions and there are no statistically significant differences among the three groups.

- ***Farmer's Adaptation Intensions against perceived threats***

In view of adverse agricultural scenarios like high soil salinity, lack of fresh water and low crop yield, it is imperative that the farmers' uptake suitable measures that meets the requirements of crop production, demand for food and income generation for the dependent communities. Since the Cyclone Aila, there has been a growing interest among the local communities to cope or adapt to such extreme environmental scenarios, and as a result, communities have undergone several small scale agricultural transformations to sustain normal livings from their limited land, water and economic resources. In particular, local and research NGOs have also supported the communities by developing several pilot studies of ameliorative agricultural practices. However, in most cases, it has been done with only a segment of population in pockets of the Indian Sundarban delta. Therefore, neither these measures have been tested on a broader scale, nor it could be generalized with respect to the three types of farmers as mentioned above. While on the other hand, the local agricultural offices also attempted to promote some alternative livelihood, yet, their approach has been largely made in a piecemeal manner without a proper scenario assessment. In order to bridge this gap, the study principally aims to conduct a micro-level perception analysis to identify and prioritize the existing agricultural adaptation/coping options (i.e. *which options suits to whom*) and thereby, attempts to develop a sectorial guideline, by which, adaptive practices can be systematically infused within the existing social and economic scenario.

From the Focus Group Discussions and following transect walks, the study could identify a total of eleven potential adaptive/coping mechanism, which, the farmers believed to have some sort of local applicability or have practiced aftermath the Aila. As mentioned, some of these adaptive/coping mechanism are essentially being promoted by the NGO led initiatives, while some of them has been recommended or being supported by the local agriculture research institutes. **Table 5.2.** provides a detailed analysis of the identified adaptive measures with subsequent illustrations on the specific advantages and disadvantages. However, it was observed that, among these 11 adaptive actions, farmers characteristically emphasized five specific adaptive measures (marked in red boxes in the table 5.2). The author also conducted transect walk in order to observe the potentials of the identified adaptation options. These five actions are cultivation of salinity resilient paddy species, crop/flood insurance, development of local irrigation, soil and water conservation structure, diversification of livelihood and outward migration for better opportunities. It is, however, imperative to understand that each of the adaptive actions have specific relevance in order to achieve agricultural sustainability the study area, yet, the choice of adaptation is largely influenced by the availability of technical resources, knowledge, awareness of the farmers, training, landholdings and financial capacity. Therefore, in the follow up questionnaire survey, an attempt was made to understand individual's intensions to adapt. Similar to the threat perception, a Likert scale of 1 to 5 were used to prioritize each of the adaptation actions. The summary of the analysis is provided in **Figure 5.7** and in the following paragraphs.

Out of the 11 mentioned adaptation/coping actions (Table 5.2.), eight shows statistically significant variation among the three groups of famers, while, adaptation intension for the rest three adaptive measures do not show any significant difference in perception among the three groups of farmers (see ***Annexure 5***). Difference in perception has been observed for the following adaptation options, namely, 'changing cropping pattern', 'intercropping', 'crop and flood insurance', 'dual use of agricultural land', 'construction of irrigation facilities', 'soil and water conservation structure', 'diversification of livelihood' and 'migration to other places'

Table 5.2. Agricultural Adaptation Options and their applicability in Indian Sundarban

Adaptation Options	Description	Adaptation Type	Advantages	Disadvantages	Requirements
Change of Seed Sowing Time	This is the most common agricultural adaptation action that intend to marginally reschedule the traditional agricultural calendar based on the new weather patterns. This particular adaptation option is principally useful for monsoon variability or consistent late arrival of monsoon. However, this is often not a full proof adaptation option since it encompasses several weather uncertainties.	Behavioral Adaptation (Farm Level)	No major investments are required.	Weather uncertainties increases the margin of error, and most importantly, the process is not irreversible.	• Requires close monitoring of local weather and weather information dissemination among the farmers. • Technical guidance is also required for the farmers. • Market compatibility is always an issues with this particular adaptation option. Late arrival of crop in the market may loss prices or vice versa.
Change of Cropping Pattern	Change in cropping pattern refers to the change in proportion of area under different crops at two different points of time. In Sundarban, majority of the agricultural field are used for mono crop cultivation. It is possible to cultivate other crops, especially cash crops during the existing no-crop seasons which are not very water intensive.	Technical Adaptation (Farm Level)	Economic advantages for local farmers, especially from cultivating two crops.	Major investments required with provision for local irrigation, soil development etc.	• Farm mechanization is the primary requirement, however, in order to do this, farmers also require significant financial capital. • Agricultural loan and lean season crop incentives by the local government can be a suitable way to promote this adaptation.
Salinity Resistance Paddy Species	Salinity Resistant rice species are specially engineered variety of rice that can grow under high salinity scenario. For example, while normal variety grows under salinity level less than 6 dS/meter, moderate and high salt tolerant species can grow within 6-8 dS/m or more salinity level.	Technical Adaptation (Farm Level)	Comparatively higher yield in the existing salinity scenario.	Non-availability of good quality seeds in the local market and lack of market demand	• Salinity resistant rice variety has significant potential in Indian Sundarban. However, the major requirements are the quality of seeds, seeds storage facilities that the farmers don't have right now. Major local experimental varieties include *Luneshree, Bhutnath and Sumati* which showed promising results.
Home Stead Gardening	Home stead garnering is an auxiliary income opportunity especially aimed at securing individual food security in case of complete discontinuation of farm level agriculture.	Behavioral Adaptation (Individual Level)	Auxiliary support, especially securing individual food security	No profitability and commercial production	No specific requirements

Adaptation Options	Description	Adaptation Type	Advantages	Disadvantages	Requirements
Inter Cropping Pattern	Intercropping is a multiple cropping practice involving growing two or more crops in close proximity. This type of adaptation is especially applicable when yield from a particular crop is unsatisfactory. Especially, in case of Indian Sundarban, rice cultivation can be combined with other crops/vegetables which does not compete with rice on the physical resources.	Technical Adaptation (Farm Level)	Substantially increase yield, better pest control and profitability.	Requires scientific monitoring and assessment such as soil testing etc.	• Technical guidance to local farmers is a prerequisite since the two varieties than can be grown together should not compete on the resources. • Farmers also requires some capital to conduct intercropping practices in their filed.
Crop and Flood Insurance	Crop and flood insurance is a risk transfer mechanism adopted by farmers and others to protect themselves against either the loss of their crops due to flood and cyclones. At present, there are some group insurance mechanism existing in the Indian Sundarban, however, this are not for individuals and he determination of loss and damage is based on institutional assessment of village level crop loss, which might not represent individual loss of crops.	Economic Adaptation (Institutional Level)	Financial Compensation in case of a disaster damage.	This measure is sole aimed to manage economic loss, however, it does not have anything to deal with production. Also, this is not applicable for slow onset coastal disasters such as salinity.	• Local governments on financial institutions such as Cooperative Banks need to develop some scheme to protect farmer's financial interests. • Requires awareness camps to share the benefits of crop and flood insurance.
Dual Use of Agricultural Land	Dual Use of agricultural land is a special intercropping pattern when rice and fish are cultivated in tandem. Cultivation of fish is done by deepening the rice filed (sometimes with impermeable layering) and the excavated soil is used to heighten the agricultural land. This process can suitably manage the water demand for rice cultivation as well as use the water for pisiculture.	Technical Adaptation (Farm Level)	Diversification of income, especially the major protein demand of the local communities are served through fishes.	Massive one-time investment which majority of the farmers may not bear.	• This adaptation measure is applicable only when the farmers have significant land. • This measure also requires technological guidance from the agricultural agencies.

Adaptation Options	Description	Adaptation Type	Advantages	Disadvantages	Requirements
Construction of Irrigation Facility	Since majority of the agricultural land in the Indian Sundarban are void of formal irrigation facilities, construction of canal system for irrigation is seems to be imperative for enhancing agricultural productivity. Particularly, this measure can promote two-crop cultivation in the Indian Sundarban delta.	Infrastructural Adaptation (Institutional Level)	Possibilities for two –crop cultivation	Considering the lack of freshwater availability any centralized irrigation facilities may lead to massive ground water pumping in coastal areas.	Irrigation water budgeting for coastal areas and development of irrigation facilities. However, considering the local hydrological and topographical scenario, centralized irrigation may attract huge budget.
Soil and Water Conservation Structure	This is mostly an agricultural adaptation option attached to farm level portion. Farmers with significant landholding sacrifice a small portion to collect rainwater by creating ponds or tanks.	Infrastructural Adaptation (Farm Level)	Decentralized irrigation with generally higher productivity.	Loss of fertile land	• No specific requirements, although availability of land is a major constraint.
Diversification of Livelihood from Agriculture	Under the local context, it typically includes the horticulture, ornamental fisheries, goatery, duck etc. The local government provides several schemes to promote the alternative livelihood in the Delta.	Behavioral Adaptation (Individual Level)	Diversification of income generation	No proper markets within the proximity	• Technical guidance from the local agricultural authorities • Existence of local markets and demands
Migration to Other Place	Migration is one of the extreme adaptation which have been extensively practiced after the cyclone Aila. Many young farmers/agricultural labors, capable of delivering physical labor, migrated to cities all across India. Although, to a major extent, it helped their families to survive under adverse economic scenario, it can be classified as an extreme adaptation measures which has little role to play in agricultural sustainability.	Behavioral Adaptation (Individual Level)	Economic Support to family members	Gradual Depopulation of the Delta	• No specific requirements

Figure 5.6. (A) A community weather station especially intended for farmers and fishermen (in Kultali Block), (B) Dual Use of agricultural land for rice and fish, developed by an NGO (in Kultali Block), (C) Intercropping with rice and Vegetables (in Patharpratima Block) (D) Localized irrigation facilities by sacrificial of a portion (25%) of agriculture land (in Gosaba Block).

Source: Author, 2012-13

while, on the contrary, the results indicate a uniform perception over the adaptive actions such as ‘changes in seed sowing time’, ‘salinity resistant paddy cultivation’ and ‘homestead gardening’. Of which, all the three groups of farmers favored the ‘cultivation of salinity resistance paddy species’ (marked in red dashed lines in Figure 5.7).

Importantly, as mentioned earlier, all the three groups of farmer uniformly perceived the threat of climate variability, particularly the late arrival of monsoon in the recent years. Therefore, it can be justified that all the three groups of farmers feel it necessary to marginally readjust their cropping calendar. Community led weather station and weather information dissemination system, as shown in the **Figure 5.6 (A),** is, therefore a significant measure to promote this type of behavioral adaptation. Similarly, the threats of soil salinity are also homogeneously perceived among the farmers. Not surprisingly, majority of the surveyed farmers put 'cultivation of salinity tolerant rice species' as the most favored adaptation option. During the FGDs, many of them, particularly the small farmers, mentioned to have cultivated salinity resistant species. Further, they mentioned about six local indigenous, salt tolerant rice species which were long lost due to introduction of high yielding varieties over the previous years. Therefore, the farmers now have to depend on external sources for salt tolerant varieties. However, the major hindrances to cultivate such varieties is the unavailability of good quality seeds and lack of seed storage facilities. In addition, they mentioned that the lack of seed certification which essentially lead to poor yield and financial loss.

Homestead gardening, as mentioned earlier, is a common adaptation (arguably coping method) to live in the adversities when agricultural system completely fails to cater the local demand. Although, this particular adaptation option does not seem to be very significant among the marginal farmers or agricultural labors, small farmers mentioned to have practiced homestead gardening in lieu with their regular agricultural activities. As the **Figure 5.7** suggests (highlighted in red boxes) that the most favored adaptations for small farmers is construction of irrigation facilities, soil and water conservation structures and cultivation of salinity resilient rice varieties. Understandably, the combination of these three would make agricultural yield sustainable while other provisions such as *Boro crop* can also be planned. However, as mentioned, given the complex topography of the Indian Sundarban delta, centralized irrigation facilities are virtually impossible. Decentralized zone based irrigation is probably the best option under the existing circumstances, however, that may also lead to massive pumping of ground water since the river water is essentially saline. Therefore, although provisioning of irrigation facilities is a suitable adaptive option to increase productivity, it remains unlikely under the mentioned adversities. In order to cope with this situation, soil and water conservation structures through augmentation of rainwater, such as small ponds or tanks have strong potentials. As depicted in **Figure 5.6 (B)** farmers develop small water conservation structure (water storage pit) within their agricultural land by sacrificing a portion (25%) of land. Hence, many small farmers favored in this particular adaptation. Similar to the small farmers, marginal farmers also mentioned about construction of irrigation facilities and salinity tolerant rice varieties, however, also put additional priority on dual use of agricultural land, probably due to the apprehension of increasing income from the combination of rice and fish from limited land. On the other hand, most of the agricultural labors prioritized cultivation of salt tolerant species, dual use of agricultural land and migration to different places. Here it is

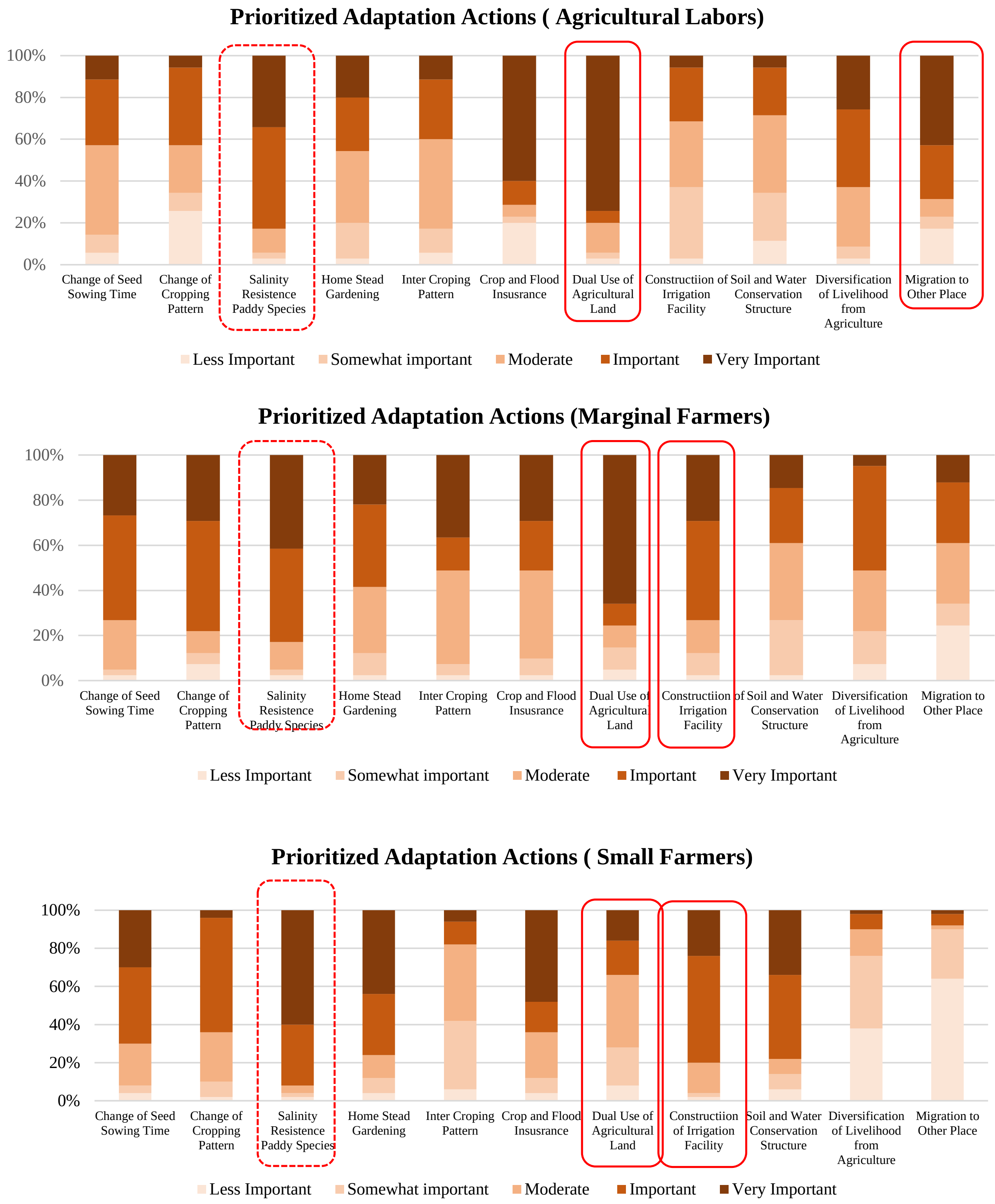


Figure 5.7. Prioritized Adaptation Actions (Represented in % of respondents). Sample Size: Agricultural Labors (n=35), Marginal Farmers (n=41) and Small Farmers (n=50)

important to mention, that following the cyclone Aila, almost 65% of the agricultural labors migrated to different parts of the country leaving their families behind. While this can be argued as a suitable agricultural adaptation measure, in order to survive under the extreme adversity, possibilities of mass outward migration of agricultural labors cannot be ruled out under the present circumstances.

In addition to the above discussion, crop and flood insurance is also a desired adaptive action that the farmers mentioned and prioritized. In this regard, it is imperative to mention that, at present, the government insurance scheme for disasters is aimed at the village *panchayat* level. What it theoretically means is that, if the local administrators, based on their stipulated guidelines, declare a *panchayat* as disaster affected, dwelling villagers including farmers can be compensated for the loss of crop under the National Agriculture Insurance Scheme (NAIS) or '*Rashtriya Krishi Bima Yojana (RKBY)'.*The scheme is a nationwide plan to support farmers against adverse natural calamities and each state is required to reach to the level of *Gram Panchayat* as the unit of insurance in a maximum period of 3 years. The premium has been designated as 1.5 percent to 3.5 percent of sum assured on food crops. However, it can be argued that special cases such as Sundarban, where cyclones/flood affect more on individual basis, this needs to done more on the individual levels rather the Village *panchayat* level.

As discussed earlier, diversification of livelihood (especially development of the alternative livelihood) is one of the pressing agendas of the local governments. A number of alternative livelihood schemes such as ornamental fisheries, horticulture, sericulture, goatery, piggery etc. have been promoted by the local government. However, considering the population size, these measures are inadequate. Further, lack of marketing provisions for the end products coupled with lack of demand in the local/rural markets (e.g. ornamental fishes or even horticulture products) is in clear contradiction with the general objective of adopted livelihood diversification schemes. Hence as mentioned in Chapter 4, despite of a strong potential, the existing scope of alternative livelihood development has been vastly restricted.

Technological measures such as crop diversification, intercropping or dual use of agricultural land has significant potential in Indian Sundarban. Nevertheless, these measures also require capital investments and technical guidance for the farmers. Hence, the scope of these options are largely restricted under the current socio-economic scenarios of the farmers. Although, NGO lead adaptive approaches have been well accepted by the communities, transformation of technical knowhow is vastly confined into small pockets hindering the large scale implementation of adaptive action. On an institutional side, lack of agricultural facilities, such as soil testing laboratories, crop variety selection guidance, seed storage facilities, poor quality seeds, pest control kits are also among the denying factors behind adopting technological adaptation measures.

As have been identified in Chapter 4, the communities, in general, look up to the local government as the main implementer, and, therefore, the block offices, especially the agricultural extension offices need to execute bulk of the above mentioned activities along with other concerned government departments. However, this requires, at least, under the present circumstances, significant mobilization of human, technical and financial resources at the block level. In particular, creation of an adaptation support cell under the local block offices would largely facilitate local level actions, from which farmers can immensely benefit. Hence, the recommendation furnished in this chapter are aimed to facilitate a supportive local environment to promote the desired adaptation actions keeping the local government at the central.

5.6. Adaptation Planning for Estuarine Fishermen

5.6.1. Materials and Methods

In lieu with agricultural activities, estuarine and inland fishing also serves as the primary and traditional livelihood of the Indian Sundarban delta. As mentioned earlier, the existing fishing scenario of the Indian Sundarban delta is diverse, since the fishing communities are involved in several types of fishing, such as, deep sea fishing, pisiculture, aquaculture (mostly prawns) and fishing within the estuarine water. While aquaculture and deep sea fishing is mostly conducted in large groups and requires substantial capital investments, estuarine fishing is mostly conducted by individuals or in small groups, therefore, remain largely unorganized. Moreover, estuarine fishing is also strictly governed by a number of forest rules applicable over the entire delta (see Chapter 6). As per the official data collected from the Assistant Director of Fisheries (ADF), total fish production for the previous years are estimated as 172041 MT (2011-12), 164030 MT (2012-13) and 158251 MT (2013-14); of which, roughly 30-35% come from marine sources, whereas 60% comes from inland and estuarine waters. Therefore, in this particular research, the study characteristically focuses on the estuarine and inland (freshwater) fishing, since, this type of fishing involves a larger population with limited financial capacity and contribute to higher production.

Research methodology deployed for this study is similar to that of the agriculture. In order to identify specific issues related to sustainability of this particular group of fishermen, a total of six FGDs were conducted with estuarine/inland fishermen in Gosaba, Pathar Pratima, Kultali and Sagar Blocks. As like in the previous cases, preferences were given to participants who suffered loss of livelihood following the cyclone Aila. During the FGDs, the target population of fishermen were typically enquired about the existing fishing scenario, profitability, perception of threats and coping/adaptation mechanism to perceived threats. In the second step of the research, coping and/or adaptation strategies were prioritized through a questionnaire survey of 46 estuarine/inland fishermen (including 13 inland fishermen) by using a five point Likert scale. As like the previous cases, simple graphs and charts were generated for data visualization. It is important to mention that, although, the sample size is considerably small and the results might not replicate over the large fishing population of the delta, however, issues identified during the FGDs and the follow up questionnaire survey, is representative and worth considering for the enhancement of fishing communities' economic resilience from the long-term perspective.

Figure 5.8. A) FGDs with Fishermen at Gosaba Blocks (B) FGDs with Farmers in Patharpratima Block (C) FGDs with Fishermen in Joynagar II Block (D) FGDs with famers in Kultali Block.

5.7.2. Results and Discussions

- ***Damage Incurred during the Cyclone Aila***

FGDs with the fishing communities, in general, mentioned about the loss of boats and fishing nets following the Cyclone Aila. In addition, some of the participants also mentioned about financial losses, damage of inland fishing facilities and mixing of pollutants in the inland pisiculture ponds. In particular, salinization of pond water was also mentioned as one of the major cause for reduction in inland fish production. In the follow up questionnaire survey, majority of the fishermen indicated loss and damage of fishing boats (67%) and damage of equipment's (71.74%) such as fishing nets and gears etc. during and just after the cyclone event **(Figure 5.9).** Nearly 65% of fishermen mentioned to have suffered from significant financial loss due to loss of equipment. In addition to this, approximately 40% fishermen also mentioned to have sustained significant damage from mixing of pollutants and structural damage to fish cultivation ponds. As mentioned earlier, freshwater ponds flooded during the cyclone Aila, largely resulted in salinity contamination that remained for nearly two years.

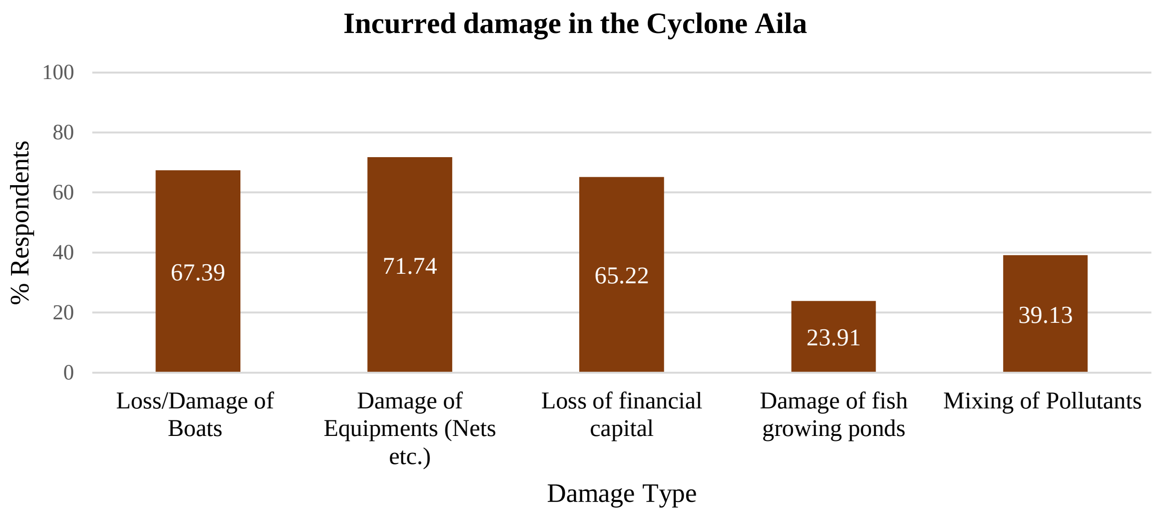


Figure 5.9. Incurred Damage in Cyclone Aila (n=46)

➢ *Fishermen's Perception of Threat*

During the FGDs and the follow up questionnaire survey, an overwhelming majority (93.5%) of the estuarine and inland fishermen mentioned about significant loss of fish catch in last five years. Although, it is not directly linked to disaster and/or climate change, according to the participants, this represents the single most concern of the local fishermen. Individual perception, as revealed during the FGDs, ranges from 30 to 50% reduction in fish in estuarine water and the fishermen also mentioned about partial annihilation of some of the commercially important fish species such as *Boal (Wallago attu), Bhetki (Lates calcarifer), Ilish (Hilsa hilsa*). In addition, inland fishermen also mentioned of prevalence of diseases and small sizes of fishes that are inconsistent to the time and resources invested. However, as mentioned by the participants, lack of available fish has resulted in a price hike in the local fish markets which actually helped the local fishermen to survive in financially difficult times. While this has been the traditional coping method of the fishermen, they mentioned about tough competition from cheap, exported fish from nearby provinces, especially Orissa and Andhra Pradesh.

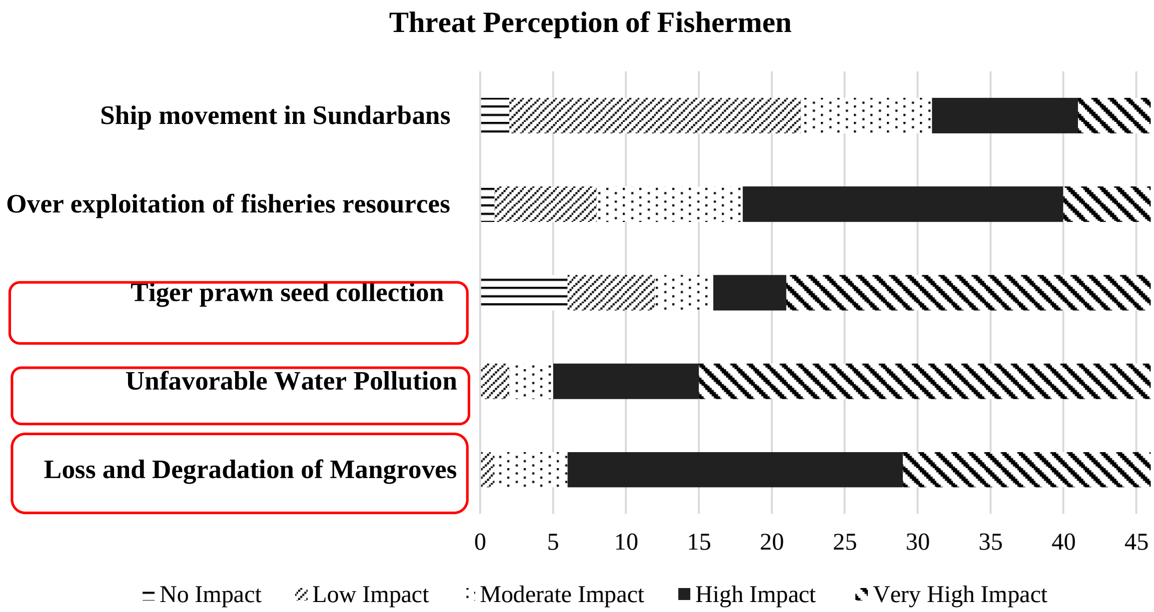


Figure 5.10. Fishermen Perception of threat against their livelihood (Loss of fish catch)

When enquired about the possible causes that are associated with reduction of fish catch or future disruption of fishing activities, nearly 90% of the surveyed fishermen pointed out the ecological degradation of mangrove forests and consequent deterioration of water quality as the principal cause (high to very high impact) of loss of fishing population **(Figure 5.10).** In addition, majority of them highlighted the unsustainable ways of prawn seed (*locally known as Bagda meen*) collection (using the mosquito nets) which destroys the larva of other fish species. Approximately, 75% of the surveyed fisher further considered the overexploitation of resources due to the increase in fisher population in the delta. Here it is important to mention that, as per the fish production trend, it was observed a general decreasing trend of fish catches over the last three years, although several factors can be associated with this observation. However, at the local level, the present apprehension is largely shaped by the reduction of individual fish catch due to increase in fisher population. Particularly, after Cyclone Aila, as a result of discontinuation of agriculture, a considerable population engaged themselves in estuarine fishing. In addition to this, fishermen also mentioned about the movement of large commercial ships to have impacted the estuarine waters in adverse way, particularly resulting in fish flock migration to other places.

- ***Fishermen Intended (Adaptive) Actions for Livelihood Sustainability***

As discussed earlier, the main livelihood issue for the estuarine and inland fishermen is the gradual depletion of fishing resources and consequent lesser amount of fish catch in the estuarine water. In case of inland water, fishermen mentioned about poor breed that are fast losing commercial values in comparison with fishes imported from nearby provinces. In general, based on the discussions with the fishermen, a total of six adaptive (or corrective) actions could be identified to overcome the current situation and to promote long-term sustainability. Arguably, the first problem arises from overfishing in the estuarine waters. This is particularly relevant since estuarine fishing is largely conducted in an unorganized and haphazard manner. For example, participants of FGDs characteristically mentioned about the unscientific ways of fish catch, specifically with nets of fine meshes, as the potential human cause for gradual degradation of fish population in the estuarine water. These fine nets damage a large number of other larva that results in poor aquatic diversity of the estuarine water and annihilation of commercially important fish species. In addition, the potential fishing area being restricted due to several territorial restrictions, large number of fishermen occupies the same area leading to poor individual catch. Therefore, more than 90% of the surveyed fishermen attached high to very high importance to implement a mutually agreed control mechanism within the mangrove water. Secondly, considering the depleting resources and relatively high time and risks associated with estuarine fishing, an overwhelming majority (nearly 80%) of fishermen expressed their willingness to practice freshwater fish cultivation with locally consumable fish species. However, this option is vastly restricted due to small or no land availability to individual fishermen. Among the other adaptive actions, fishermen also mentioned about mangrove regeneration along the river side through barrier plantation. They typically discussed about the role of mangroves in leaf litter fall and its ability to control the river water quality by sediment trapping.

During the FGDs, two particularly important adaptive measures were revealed by the fishermen, especially who practice inland pond based fishing. Firstly, they mentioned the potential of *Tilapia* cultivation (common name for nearly a hundred species of cichlid fish) as an alternative to the traditional cultivated fishes. These species, which is relatively new in the Indian Sundarban Delta, can survive in harsh environmental conditions and undergo rapid growth. Since it can live on omnivorous diets, this also requires lesser investment and can be

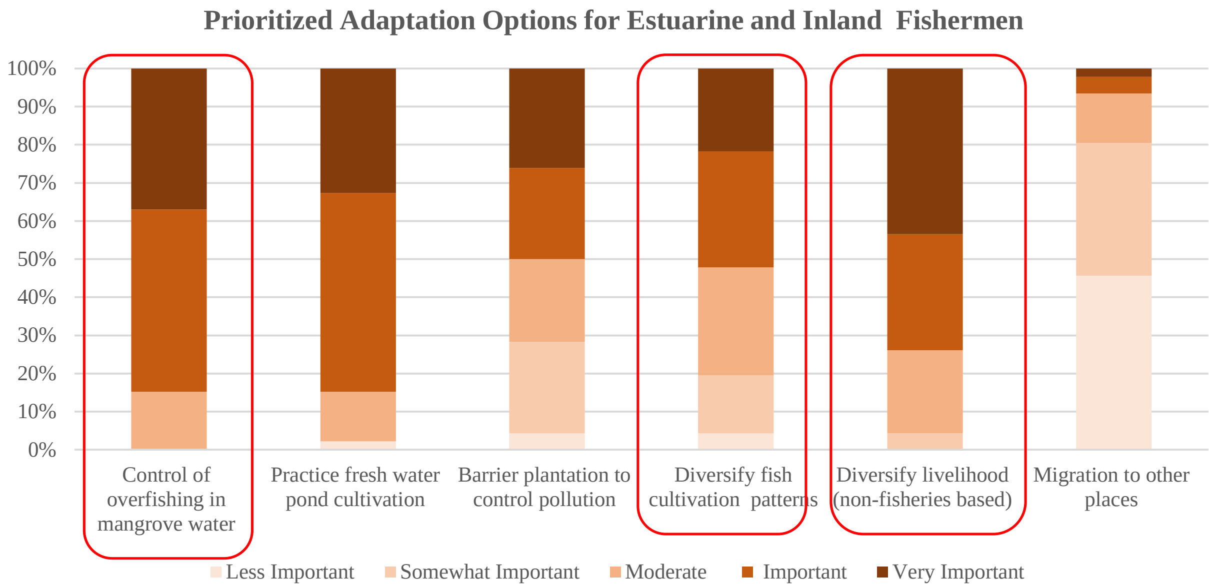


Figure 5.11. Prioritized Adaptation Actions for Estuarine and Inland Fishermen

grown in large numbers. In addition, being rich in protein, this has also high demand in the local and nearby urban markets. However, due to several financial and technical obstacles, it is difficult for the local fishermen to execute such potential adaptive actions. Therefore, most of the fishermen have expressed to diversify their income through non-fisheries based sources such as goatery, ornamental fishing etc., and particularly by physical labor under the MGNREGA scheme of 100 days' job. Although, some of them did migrate to nearby cities after the cyclone Aila, an overwhelming majority of fishermen did not express their willingness to migrate, which is in complete contrast with the agricultural labors or marginal farmers who share similar socio-economic scenario and have suffered from discontinuation of livelihood. The probable explanation may indicate the non-static nature of the livelihood and emotional attachment of the fishermen with the estuarine waters, which make fishing the oldest from of traditional livelihood of the Indian Sundarban Delta.

5.7. Key Recommendations

The study attempted to address the key challenges of livelihood sustainability in two of the most practiced livelihood sectors of Indian Sundarban. i.e. agriculture and estuarine/inland fishing. In addition, it also attempted to identify and prioritize specific adaptive actions that are aimed to increase livelihood resilience of the farming and fishing communities. The following key recommendations are developed based on the feedbacks received in the FGDs, follow up questionnaire surveys and a comprehensive scenario analysis. Here it is imperative to mention that livelihood resilience is a broader concept that includes several sub-components such as human resources, financial resources, production landscapes, infrastructure and governance etc. Hence, achieving livelihood resilience, therefore, requires methodical technical, economic, social and behavioral interventions in each of the components.

The recommendations presented in this study are especially aimed at the local government and targets developing favorable policy and physical environment to foster disaster resilient livelihood in the delta. As have been mentioned, communities consider the local government as the most important stakeholder for implementing such adaptive actions. Therefore, it remains imperative that the local government, and in particular, the block level administration should be made capable in terms endorsing the following adaptive interventions to enhance the resilience of the local communities. Precisely, the Block agricultural officer and fisheries officer can be the typical nodal adaptation agents, who would be responsible for infusing the suggested actions within the community level. Needless to say, this requires significant strengthening of the blocks offices and allocation of resources from the provincial government. As have been identified during the above participatory exercises, following interventions remain highly imperative to enhance livelihood resilience of the communities living in the Indian Sundarban Delta.

a) Economic Interventions

- ***Creation of an adaptation fund at District Level***

As discussed in this chapter, Indian Sundarban require substantial adaptive interventions in agriculture as well as fishing activities. Despite of willingness of the farmers and fishermen, infusion of adaptive practices into traditional agricultural or fishing activities requires significant financial investments. For example, development of agriculture through rainwater harvesting and canal irrigation facilities can improve agricultural productivity to a great extent. Similarly, dual uses of agricultural land, intercropping also have strong potentials, yet, attracts necessary capital investments. The major constraint, as observed in this study, revolves around the limited of financial capacity of the communities. Therefore, despite of willingness, communities are unable to inculcate adaptive measures into their traditional practices. Considering the above, creation of a dedicated adaptation fund at the district or sub-district level and arrangement of specific loans/grants to farmers/fishermen for crop enhancement or taking up sector specific adaptation measures is imperative for promoting livelihood resilience. Here it is important to mention, that provision of adaptation fund has already been discussed under the 'State Action Plan for Climate Change', however, it does not specifically mention the implementation plans, in particular, how this fund can be effectively utilized. In view of this, the local government should particularly work in close collaboration with the village financial institutions such as cooperative or nationalized banks. In lieu with this, the substantial amount of fund is also required for capacity development, training and developing pilot studies and dissemination of adaptive knowledge in the study area.

b) Technical Interventions

- ***Training and Capacity Development***

There is also a general requirement of the capacity development of the local farmers and fishers. It is highly imperative that the local farmers/fishers are trained to assimilate market led expansion strategies. Similarly, fishing communities needs to be trained in scientific ways of fishing so that biological diversity of Indian Sundarban remains unaffected. In this regard, it is important to mention that several national and international NGOs work in the Indian Sundarban in training and capacity development, however, works in isolation. Therefore, even if they promote some innovative technologies or training, communities at large, are deprived to gaining substantial experience from such initiatives. The local agriculture and fisheries extension offices, therefore, needs to be well equipped to share the good practices through experience based learning. In addition, a social business model can be adopted to methodical intervention of the NGOs.

- ***Water Resource Development***

Despite of the provincial government's continuous advocacy and efforts to increase irrigated areas through rainwater harvesting under the flagship project of *Jol dhoro, jol bhoro* (Preserve Water, Reserve Water), Sundarban continues to remain one of the freshwater scarce area. Although there have been some efforts to create new ponds and small reservoirs, it failed to address the community concern of reliable irrigation facilities. In particular, as per the author's interview with the Deputy Director of Agriculture in the South 24 Parganas, it was revealed that excavation of pond more than 8 feet's have been unsuccessful due to the presence of saline water aquifers. Therefore, water resource development remains particularly challenging. One suitable alternative is the shallow, canal based irrigation facilities from the upstream and augmenting rain water. This model has been used in parts of Irrawaddy delta during the British occupation in Myanmar (Burma) to sustain high yielding agriculture. However, feasibility check is required for replication of such model. Above all, continued investment with sound technical foundation for developing small water harvesting structures (with some protective lining), canal based irrigation system should be given significant priority.

- ***Research and Development***

The fragility of Indian Sundarban delta demands continuous research and development in both the agriculture and fishing sector. In case of agriculture, development of locally applicable high yielding, salt resistant varieties of paddy is extremely crucial. Other than this, research should also focus on developing plant species that can control soil salinity and/or reduce soil erosion. For example, cultivation of jackfruit, cotton, sunflower has been successful on experimentation basis, and therefore, feasibility study needs to be conducted to upscale this measures. Conversely, determination of maximum sustainable yields for estuarine fishing is the basic requirement to attain the ecological sustainability. In case of inland fishing, significant research is required on fisheries management such as breed selection, selection of non-competitive breeds, disease control etc. In this regard, the local government needs to create or collaborate with laboratories and research facilities within the delta region. Further, significant research is also required in the field of product and market management such as study of market behavior, reasons for variation in prices, determination of best time to sell products etc. The enhancing the scopes of existing ATMA (Agricultural Technology Management Agency) is highly important in this regard.

c) Social and Behavioral Intervention

Creation of Farmer's / Fishermen Cooperatives

In case of Indian Sundarban, the scopes of farm mechanization and increasing agricultural productivity with technological /behavioral adaptation measures is heavily restricted due to lack of landholding of the farmers/fishermen. As mentioned, nearly 85% of the farmers are having landholding less than 1 ha. Similarly, farm mechanization for inland pisiculture is also limited due to small size of tanks. Hence, individual capacity is largely restricted. In view of the above, farmer and fishermen cooperative needs to be developed. Although, some cooperatives are currently existing, the region lacks severely in terms of farmer's cooperatives compared to other parts of West Bengal. In addition, it is also imperative to strengthen the institutional relationship with the existing cooperatives. The local government and the village level self governance can play a significant role in facilitating such cooperatives by providing small scale incentives such as loan for buying a tractor, development of localized irrigation facilities, group insurance etc.

d) Overcoming the Infrastructural Gaps

In general, Indian Sundarban delta suffers from high developmental deficit and livelihood sector is no exception. Lack of supportive infrastructure have been impairing the productivity as well as market sustainability of agriculture and fisheries products. It is very often that due to shortage of adequate storage facilities, farmers or fishermen are forced to sell their products at lesser price. In addition, they are also unable to dispatch or export cash crops in the neighboring states or even outside the country. The combination of these factors is a clear determinant for the lack of motivation among the farmers to diversify their agriculture. As mentioned by the communities during the FGD process, deficiency of livelihood supporting infrastructures such as good transportation network, absence of proper market facilities, cold storages, seed conservation centers, rice mills, soil testing laboratories etc. serves as crucial factors that inhibit infusion of suitable adaptation measures, both in agriculture and estuarine/inland fisheries sectors. For example, in the entire Sundarban region, there is only one soil testing laboratory and unless that farmers are aware of their soil quality, it is extremely difficult to promote adaptation options such as intercropping, dual use of agricultural land or cultivation of the high yielding varieties. In lieu with this, non-availability of high yield and salt tolerant varieties is also a major concern for farmers. There are only few seed collection and conservation center in the delta region. In addition, the existing seed certification mechanism is not robust enough. Further, the network of agricultural extension agencies is also week with limited number of field staffs. As a consequence of these factors, farmers or fishermen of the Indian Sundarban delta has failed to develop a sustainable relationship between rural producers and urban consumers in the vicinity. It is highly imperative, in order to sustain community livelihood in this eco-fragile delta, that the rural farmers and fishermen get the maximum benefits for their efforts and attempts to get hold of the nearby urban markets. Undoubtedly, significant investments (development) are required form the local or provincial government to reduce the infrastructural gap, not only by creating markets but also linking rural producers to the urban markets. Further, the local government should create a strong network of agricultural facilities including seed collection and conservation centers, soil testing laboratories, provide quality fertilizers etc. National and international NGOs can particularly collaborate with the local government and a Public-Private Partnership (PPP) model can be adopted in this regard. In addition, federal and local government research agencies such as Central Soil Salinity Research Institute, extension centers of Bidhan Roy Agricultural University need to disseminate their research findings in a more proactive way, so that theoretical findings from the laboratory is properly implemented in the agricultural lands.

References

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., ... & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic change*, *93*(3-4), 335-354.

Adhikari. B., Bag M. K., Bhowmick M. K. and Kundu C. (n.a.): Status Paper on Rice in West Bengal , Rice Research Station, Govt. of West Bengal

Alessa, L., Kliskey, A., Williams, P., Barton, M., (2008): Perception of change in freshwater in remote resource-dependent Arctic communities. *Glob. Environ. Change* 18, 153-164.

Banerjee, K. (2013). Decadal Change in the Surface Water Salinity Profile of Indian Sundarbans: A Potential Indicator of Climate Change. J Marine Sci Res Development S11: 002. doi: 10.4172/2155-9910. S11-002 Page 2 of 7 J Marine Sci Res Development Climate Change ISSN: 2155-9910 JMSRD an open access journal Figure 1: The Ganges delta and the Sundarbans location the GBM River catchment. *J Marine Sci Res Development* S, 2, 3.

Census (2011): Unpublished official reports of South 24 Parganas and North 24 Parganas

Chandra, G., & Sagar, R. L. (2003). Fisheries in Sundarbans: Problems and Prospects. Available at SSRN 2084014.

Dasgupta, S., Kamal, F. A., Khan, Z. H., Choudhury, S., & Nishat, A. (2014). River salinity and climate change: evidence from coastal Bangladesh. World Bank.

District Disaster Management Authority (2009): A brief report on ‘AILA’ and Review on Disaster Risk Management Programme (Unpublished Internal report)

District Human Development Report, 2009: Government of West Bengal, South 24 Parganas District Human Development Report

Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, 68(3), 338-354.

Hanson, B., Grattan, S. R., & Fulton, A. (1999). Agricultural salinity and drainage. University of California Irrigation Program, University of California, Davis.

INCAA (2010): Climate Change and India: A 4 x 4 Assessment published by Indian Network for Climate Change Assessment (INCCA), Ministry of Environment and Forests, Government of India.

Knutson TR, Mcbride JL, Chan J, Emanuel K, Holland G, Landsea C, Held I, Kossin JP, Srivastava AK, SugiM (2010): Tropical Cyclones and Climate Change. *Nat Geosci* 3:157–163

Krishnamurthy, R. R., DasGupta, R., Chatterjee, R., & Shaw, R. (2014). Managing the Indian coast in the face of disasters & climate change: a review and analysis of India’s coastal zone management policies. *Journal of Coastal Conservation*, 18(6), 657-672.

Mandal, S., Choudhury, B. U., Mondal, M., & Bej, S. (2013). Trend analysis of weather variables in Sagar Island, West Bengal, India: a long-term perspective (1982–2010). *Curr Sci*, 105(7), 947-953.

McGranahan G, Balk D, Anderson B (2007) The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environ Urban* 19(1):17–37

Nicholls RJ,Wong PP, Burkett VR, Codignotto JO, Hay JE,McLean RF, Ragoonaden S, Woodroffe CD (2007): Coastal systems and lowlying areas. Climate Change 2007. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 315–356

Office of the District Magistrate, South 24 Parganas (2010): Internal Report on the Damage and response of Cyclone Aila (unpublished)

Rabbani, G., Rahman, A., & Mainuddin, K. (2013). Salinity-induced loss and damage to farming households in coastal Bangladesh. *International Journal of Global Warming*, 5(4), 400-415.

Rahman, M. H., Lund, T., & Bryceson, I. (2011). Salinity impacts on agro-biodiversity in three coastal, rural villages of Bangladesh. *Ocean & Coastal Management*, 54(6), 455-468.

Redfern, S. K., Azzu, N., & Binamira, J. S. (2012). Rice in Southeast Asia: facing risks and vulnerabilities to respond to climate change. Building resilience for adaptation to climate change in the agriculture sector, 23, 295.

Roessig, J. M., Woodley, C. M., Cech Jr, J. J., & Hansen, L. J. (2004). Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries*, 14(2), 251-275.

SBR (2008): Sundarban Atlas, Sundarban Biosphere Reserve.

Smit, B., & Skinner, M. W. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change*, 7(1), 85-114.

CHAPTER 6: Enhancing Participatory Mangrove Management for Coastal Resilience

"The axe forgets what the trees remember…", African Proverb

CHAPTER 6: Enhancing Participatory Mangrove Management for Coastal Resilience

This chapter provides an in-depth review and research findings on the effectiveness of the existing institutional mechanism (both forest and civil government) of mangrove management in the Indian Sundarban delta and identifies the key achievements, gaps, and challenges towards the conservation, protection and restoration of mangroves. In particular, the chapter provides a detailed analysis of the sustainability and effectiveness of the participatory conservation model executed under the Joint Forest Management (JFM) guidelines of the Government of India. The research exercises principally aim at two board objectives, i.e. to evaluate the current incentive mechanism used under the existing JFM arrangements and secondly, to identify the effectiveness of the current incentive mechanism to motivate the five distinct forest user groups. A three tiered survey methodology was adopted to attain the above mentioned objectives. The chapter concludes with specific recommendations and corrective actions that are pivotal to enhance the performance of the existing co-cooperative (JFM) management of mangroves.

Outline of the Chapter 6

6.1. Introduction

The name of Sundarban is synonymous to the mangrove species of *Heritiera fomes*, locally known as *Sundari* tree. The name also suggests, in the local language of Bengali, the existence of a beautiful (sundar) forest (ban). In addition, historians argue that the name 'Sundarban' was originally derived from *Samudraban*, which literally means *forest by the sea*. Despite of several semantic differences, the saga of Sundarban revolves around its vast exuberant mangroves, its impeccable biodiversity, and human struggle to conquer the hostile nature. The documented history of Sundarban, on the contrary, predominantly narrates the transformation of mangroves into agricultural lands, thereby, facilitating human habitation over the passage of time. Earliest available revenue records reveal that the Mughal Emperors were the first to established a 'Parganas' (*small revenue generating unit*), named as Ambarabad (presently in Noakhali District of Bangladesh) in 1734 (Barlow 2009). Prior to that, Sundarban were virtually uninhabited and appeared to many as 'horrid jungle' (Beveridge 1876). Human settlement in the Sundarban region started soon after 1757 when Nawab Mirzafar handed over *24 Parganas* to the East India Company (Government of West Bengal 2009). Yet, the proliferation of human settlement was vastly restricted due to the topographical hostility of the region (Das 2006). During the colonial era in India, the British expanded into former Mughal provinces and retained the '*Pargana* System' until Lord Cornwallis enacted the Permanent Settlement of 1793. The Permanent Settlement allowed long-term land leasing with the creation of local landlords known as *Zaminders*. Under the permanent settlement, reclamation of Sundarban mangrove forests were initiated by bringing in the hardworking labors from nearby places and constructing earthen embankments to contain tidal flooding (Das, 2006). At the same time, around 1800 A.D., a large number of poverty and famine stricken people took shelter in Sundarban as the British government officially directed the commencement of agriculture in the low-lying plains of Sundarban. By that time, the fate of the Sundarban mangroves was decided. Large-scale conversion prevailed almost all across the delta until the economics of exploitation changed in due course of time. During the mid of 19^{th} century, forest products became more valuable than the agricultural revenue, which compelled the British Government to change its erstwhile policy. During 1875-1876, British government decided to stop further leasing forestlands for agriculture and placed them under the jurisdiction of the newly formed forest department (DasGupta and Shaw 2013). The process saved the unexploited mangroves of Sundarban, and the present extent of mangroves largely owes to it.

6.2. Historical Extent of Mangrove Forests in Indian Sundarban

In a survey conducted in 1829-1830, two British officials, Mr. William Dampier and Lt. Hodges demarcated the northern boundary of the Sundarban mangroves by an imaginary line (later named as Dampier and Hodge line, **see Figure 6.3**.) which translates the historical extent of mangrove cover in Indian Sundarban. While the entire mangrove cover of Sundarban delta was estimated to be 25500 sq.km., the line roughly corresponds to nearly 10,000 sq.km. (approximately 39%) of mangroves within the present Indian Territory. However, by 1873, the mangroves of Indian Sundarban experienced a net loss of 5100 sq. km because of the 'permanent settlement' arrangement (DasGupta and Shaw, 2013). By the end of nineteenth century, mangroves of Indian Sundarban further shrunk to 5000 sq. km., nearly half of its original extent. However, as mentioned earlier, the enactment of Indian Forest Act, 1927 by the British Government halted further degradation of Sundarban mangroves. Despite of it, mangroves of Indian Sundarban received conservational priority only after India's independence. In 1987, the National Mangrove Committee (NMC) recommended strict conservation for 2584.77 sq. km. of mangroves in Indian Sundarban (ENVIS, 2002). It is, however, important to mention that this figure actually represents the green cover area excluding the tidal creeks and rivers flowing through the mangroves. As per the Sundarban Biosphere Reserve, the present extent of forested area, including tidal creeks and mudflats, is about 4700 sq.km. Since 1987, Forest Survey of India keeps track of the mangroves with an assessment frequency of every two years. Officials estimations of mangrove cover in Indian Sundarban since 1987 is furnished in **Figure 6.1.**

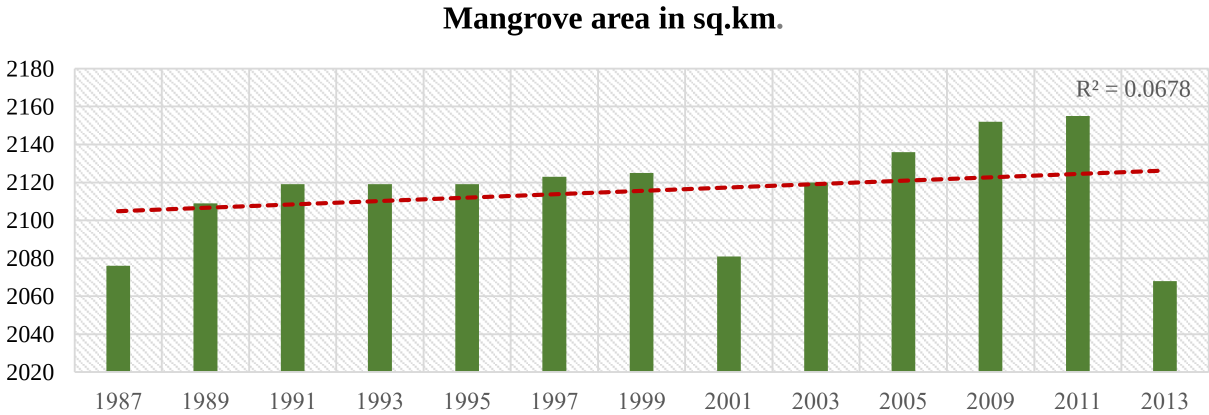


Figure 6.1. Mangrove Cover (excluding tidal creeks) in Indian Sundarban from 1987-2013
Source: Forest Survey of India,2013

Historical time line data reveals a generally constant mangrove cover since 1987. The observed marginal fluctuation is regarded to the inconsistency of monitoring methodology, better approximation of remotely sensed data and tidal fluctuation in the delta (State Forest Report 2013). **Figure 6.1** corresponds well to unofficial research reports, especially, Giri et al. 2007 assessment of mangrove cover in the Sundarban delta. Giri et al. 2007 mentioned that the net mangrove loss over the Indian Sundarban since 1970 to 2005 is negligible and regarded Sundarban as one of the best-preserved mangroves in the world. Nevertheless, they also argued that the non-protected buffer areas significantly differ from the protected areas and underwent substantial degradation over the years. Recent study based on satellite remote sensing, conversely, revealed that mangrove cover has decreased approximately by 5% from 1999 to 2010 (Giri, et al. 2014). The study, however, focused on the species diversity of mangroves, where mangrove associates are at present replacing the true mangroves species originally abundant in the Indian Sundarban. Irrespective of the fact that the gross mangrove area was generally retained, official report also reveals thinning of dense forests and increment of open forests within the forested areas of Indian Sundarban (State Forest Report 2013).

There is no denying of the fact that despite of the large underprivileged population in the vicinity, the mangroves of Indian Sundarban is comparatively well preserved (Giri et al. 2007). However, only an uninhabited segment of the Indian Sundarban delta is forested, whereas the large inhabited areas in the western and central part of the delta is void of mangrove cover. As have been prioritized by the community (*see Chapter 4*), the need of extending the mangrove cover in the settlement areas has been vastly recognized, particularly in the backdrop of seaward hazards and climate change. Therefore, it remains imperative that the Indian Sundarban is restored to its old glory, to an extent which is reasonably possible.

6.3. Mangroves of Indian Sundarban and Its Role in Disaster Risk Reduction

As discussed in Chapter 2, mangroves offer invaluable services of coastal protection to millions of people all across the world, and Indian Sundarban is no exception. In case of the Indian Sundarban, mangroves occur in a zone of cyclonic storms and tidal bores that originate in the Bay of Bengal and periodically devastate coastal areas (Giri et al. 2007), therefore, act as a natural shock absorber reducing the intensity of storms and surges (*for details on role of mangroves in Disaster Risk Reduction see Chapter 2*). Unfortunately, the importance of mangroves in disaster risk reduction were largely ignored during the development of Sundarban delta, both by the British and the following Indian government. For example, during 1853, Henry Piddington, who coined the term ‘cyclone’ for tropical storms originating in the

North Indian Ocean, wrote an open letter to the then Viceroy Lord Dalhousie, opposing the construction of port Canning within the Sundarban region. In his letter, he clearly mentioned-

> "*Everyone must be prepared to see the day when in the midst of horrors of a hurricane they will find a terrific mass of water rolling in or rising upon them with such rapidity that in a few minutes the whole settlement will be inundated to a depth from five to eighteen feet of water."*
>
> (Cited in Parker 2010)

Port Canning was subsequently built by the British Government ignoring his warnings, reclaiming the mangroves by the river Matla, only to get completely destroyed by a cyclone on November 2, 1867 (Parker 2010). Five years down the lane, Port Canning was abandoned. In his book 'A Statistical Account of Bengal', W.W. Hunter mentioned that during 1870, Port Canning and the auxiliary township was the only town in the Sundarban region with a population size of 714 persons. He continued, that by the end of 1873, the town was completely deserted with a few government officials left to complete the decommissioning of the Port Canning (Hunter 1875).

Tropical cyclones and associated storm surges are not new to Sundarban, neither the tidal surges and occasional inundation (for detailed discussion of disaster and climate vulnerability of Sundarban Delta, see Chapter 1). Nevertheless, in the remembered history of the present dwelling communities, impacts of Cyclone 'Aila' in 2009 has been the worst and the scars are still very much alive. As mentioned in Chapter 4 and 5, the dominant signature of the cyclone Aila was the breaching of earthen embankments, thereby, instantly flooding the low lying villages for months. Over 400 km of earthen embankment were completely or partially collapsed by the sheer force of the 5-meter storm surges (*see Chapter 7*). Mitra 2013 mentioned that the existence of mangroves as coastal buffer greatly reduced the damage in certain pockets of Indian Sundarban during the landfall of Cyclone Aila. Visual evidences are also available that mangrove shielding played a crucial role in saving the earthen embankments from catastrophic failure **(Figure 6.2).** During the FGDs in Participatory Action Planning process, communities also revealed that the presence of mangroves largely reduced the damage of embankments, thereby, saving lives and properties. Moreover, the problem of coastal flooding and long term inundation is getting further complicated in the reclaimed areas due to absence of mangroves. In a personal interview with Prof. Kalyan Rudra, eminent scientist and river expert of Government of West Bengal, the author was stated about distinct elevation difference between the reclaimed and unaltered islands (of about 4-5 meters) in Indian Sundarban. Rudra

Figure 6.2 (A) Coastal erosion aftermath the Aila a major environmental problem in Sagar Islands. Over the past few decades, the island is constantly losing its shores exposing the population and agricultural fields to the open sea. (B) A thick mangrove plantation helped to minimize the erosion loss of Henry's Island. It not only protected from erosion but helped to foster bio-diversity and recreation of the tourist and local communities (C) Damaged embankment in the Aftermath of Cyclone 'Aila' (near Pakhiralaya, Goasaba Block). The village was instantly flooded due to embankment failure. (D) Mangrove shielding of earthen embankments. The embankment survived the Cyclone Aila and the adjacent villages were saved (Near Kaikhali, Kultali Block).

Photo Source: Author/2012

mentioned that the reclaimed inhabited islands rapidly losing its elevation due to the occurrence of massive embankment network. Consequently, the natural accretion process is largely restricted. The average elevation of the reclaimed islands is approximately 2 meters below the high tide line; whereas due to the accretion capacity of the mangroves, the non-reclaimed islands are observed to be around 2-4 meters higher than the high tideline. This implies a net difference of 4-6 meters between the reclaimed and unaltered islands (Rudra, 2014). Considering the threats of relative sea level rise and intensified surges in this region, these elevation difference may prove to be extremely critical in near future.

6.4. Management of Mangroves in the Indian Sundarban

The above discussion leads to an inference that the mangroves of Indian Sundarban needs to be further conserved as well as restored, especially considering the high disaster and climate vulnerability of the delta. This has been also time and again highlighted by several NGO reports, national policies (e.g. in Green India mission under the National Action Plan on Climate Change), provincial government's action plans etc. Therefore, it demands a careful and minute investigation of the existing management scenario of mangroves and identification of potential scopes to improve the existing arrangements. Following sections demonstrates the existing mangrove management scenarios of Indian Sundarban.

6.4.1. Mangroves Governed by Forest Administration

Two government forest agencies, based on their demarcated territorial area, are primarily responsible for the management of the Indian Sundarban mangroves. These are Sundarban Tiger Reserve (STR) and State Forest Department (SFD). STR is responsible for the management of core and immediate buffer areas designated under the 'Project Tiger', whereas, SFD is primarily responsible for the management of the reserve forests in the buffer areas. In the reclaimed human inhabited areas, especially along the embankments, there is no clear authority for the management of the mangroves. Civil administration, especially the *Gram Panchayat* (Village Council) and Block Development Offices (BDOs) as well as some local NGOs sporadically monitor these mangroves. As discussed, the main forested areas of Indian Sundarban enjoys a good amount of legislative conservation since the NMC recommendations were put into place. In order to conserve this unique mangrove forest and its associated bio-diversity, especially the Royal Bengal Tiger, Sundarban Tiger Reserve (STR) was established as early in 1973 (under the Project Tiger of Government of India), followed by three Wild Life Sanctuaries in 1976 **(Figure 6.3).** During 1984, the core areas of STR were further designated as Sundarban National Park. Additionally, the entire region of Indian Sundarban was demarcated under the UNESCO Man & Biosphere Program as a 'Biosphere Reserve' and received a 'World Heritage' status in 1989. **Table 6.1** summarizes the chronological conservation initiatives taken so far to protect the existing mangroves and its associated bio-diversity.

Table 6.1:Historical Timeline for Conservation Initiatives in Indian Sundarban

Year	Conservational Initiatives	Description
1973	Sundarban Tiger Reserve (2,585 sq.km)	Due to the occurrence of the Royal Bengal Tiger, the large section of the forests was put under the 'Project Tiger'; a national government's initiative to conserve the remaining tigers in India.

1976	Sajnekhali Wildlife Sanctuary (~362 sq.km)	This includes the buffer area of the Sundarban Tiger Reserve (designated as **IUCN Category IV** Protected Area). All sort of hunting and fishing is prohibited by the Forest Department; however, the area is open for tourists with special permission.
1976	Lothian Island (38 sq. km) declared as an Wildlife Sanctuary	Lothian island is located at the center of the Indian Sundarban delta. Considering the existence of unique flora and fauna, this island has been declared as a Wildlife Sanctuary in the year 1976.
1976	Haliday Islands (6 sq. km.) declared as an Wildlife Sanctuary	This small island at the confluence of river Malta and the Bay of Bengal was declared Wildlife Sanctuary due to its unique wildlife such as Spotted Deer, Wild Boar, Barking deer and Rhesus macaque. The island is especially famous for its migratory birds.
1984	Declaration of Sundarban National Park (initially 1330.10 sq.km, later extended to 1699.62 sq. km in 2007)	This consist the core area of Sundarban Tiger Reserve protected under the **IUCN category II**. All sort of human activity is prohibited in this area. The area is completely restricted and governed by the Sundarban Tiger Reserve (STR) authority.
1989	Sundarban Biosphere reserve (9630 sq. km)	As part of the Man and Biosphere Program (MAB) adopted by the UNESCO in 1971, the entire delta of the Indian Sundarban was declared as Sundarban Biosphere Reserve. This includes the core area (1700 sq.km), buffer areas including mangrove reserve forests adjoining core zone. The Transition Zone covers the balance of the Biosphere Reserve area, which comprises mangrove areas, reclaimed lands for agricultural areas and human settlement.
1989	World Heritage site in 1989	The Sundarban National Park received the status of UNESCO World Heritage Site as a part of the largest contiguous mangrove forests and the habitat of Royal Bengal Tigers; the only tigers living in a saline environment.
1993-2004	Formation of 14 Eco-Development Committees and 51 Forest Protection Committee	This initiative was taken after the JFM notification came into existence. The aim of forming these communities based organizations was to protect the buffer areas from illegal deforestation, poaching and to facilitate wildlife conservation.
2012	Sundarban West Wildlife Sanctuary (462 sq.km.) (***Proposed***)	Sundarban West Wildlife Sanctuary is a newly proposed sanctuary between the river Matla and Thakuran. However, this is not yet implemented. The intended goal is to restrict illegal approach to the conserved areas of Sundarban.

6.4.2. Joint Forest Management (JFM) in Indian Sundarban

Responding to the global consensus of decentralization of forest governance, Joint Forest Management (JFM) was a new doctrine introduced by the Government of India in early 1990's to facilitate participatory conservation of forest resources (*see chapter 2* for more details). Importantly, JFM operates on an incentive based co-management mechanism and the process involves sharing of forest products and revenues with the local communities. Forest users and fringing communities, in turn, protect the forests from illegal exploitation. Despite of several arguments whether or not, JFM has actually contributed in the economic wellbeing of the communities, it has, to a considerable extent, halted the massive forest degradation in India (Behera & Engel 2006; Bhattacharya et al. 2010). However, as an incentive based forest management mechanism, JFM arrangements has also faced critical challenges over the last two decades. Particularly, the use of forest resource based incentives to motivate the fringing communities still remains a critical design of it. Additionally, Datta et al. 2012 argued that participatory mangrove management significantly differs from other cooperative resource management because of the uniqueness of mangroves, it associated services and occurrence of diverse stakeholders. Community involvement in participatory forest management is primarily linked to the adequacy of forest ecosystem services, incentive designs and delivery mechanism which collectively derive an economic model more lucrative than the alternative use of the forests. Despite of irreversible damage to the environment, alternative uses of mangroves such as conversion to aquaculture ponds are often economically rewarding and therefore, serves as strong motivation for the poverty stricken communities.

Nevertheless, JFM was formally introduced in Indian Sundarban during 1993 through the formation of village level committees (also known as Joint Forest Management Committees) and it peaked somewhere in between 1997-98. At present (as of 2014), a total of 64 JFMCs including 14 Eco-Development Committees (EDCs) and 51 Forest Protection Committees (FPCs) are responsible for the management of nearly 632.17 sq.km of mangrove forest in Indian Sundarban (for locations of JFMCs, see **Figure 6.3**). Involving 35079 local villagers in this region, the scale of the JFM arrangement is unique as the average per capita forest availability (PCFA) reaches approximately 1.80 ha/person, significantly higher than the estimated average per capita forest availability in other JFM arrangement in eastern India (0.5 to 1.5 ha/person) (Bhattacharya et al, 2010).

It is important to mention that nowhere is the world, mangroves exist with such a population density in the vicinity as in the case of the Indian Sundarban delta. Moreover, topographical

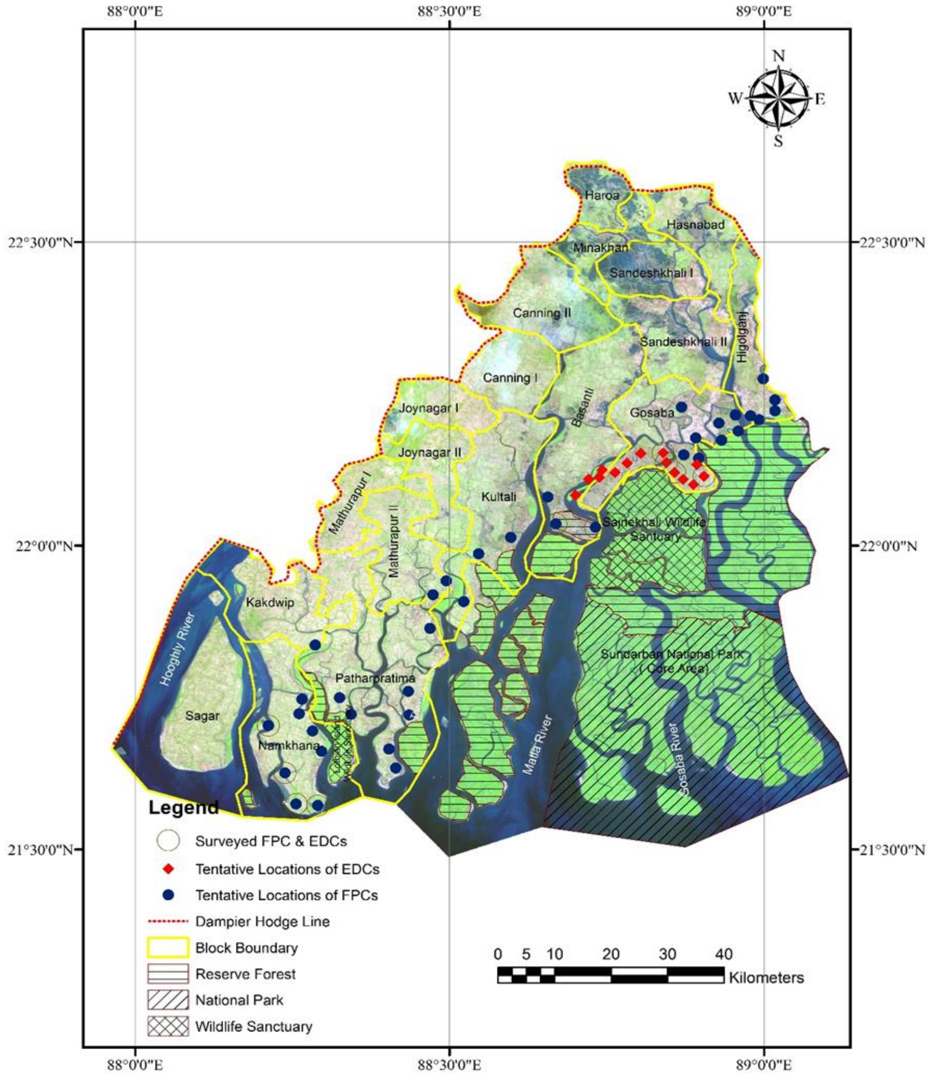


Figure 6.3. IRS AWIFS Satellite Image of the Indian Sundarban with demarcation of Forest Boundaries (Year of Acquisition: 2010), Raw Data Source: ISRO/Bhuvan, Geo-rectified and Processed by Author.

hostility largely limits the employment and developmental opportunities of the region leading to the exclusive dependence on mangroves and its ecosystem services. Therefore, despite of strong legal protection, reports of wildlife poaching or illegal logging were plenty even during the late nineties. Since then, both the managing agencies looked up to the local communities as a useful mean of restricting forest and wildlife loss through the induction of ‘community policing’. There are two discrete reasons for it; firstly, due to the inaccessible terrain and inadequate infrastructure, the forest departments were fairly unable to patrol the vast tract of forests and secondly, a favorable change of federal government’s forest management perspectives. However, mere implementation of JFM arrangement is no guarantee of its success. Although partly effective in halting bio-diversity poaching, as have been mentioned during the participatory action planning, sustainability of existing JFM arrangement in Indian

Sundarban is questionable. Further, Giri et al. 2007 highlighted that the non-protected buffer areas are undergoing considerable degradation which translates the malfunctioning of the existing JFM arrangement in the region. In addition, in a study conducted to examine the performance of the 14 EDCs, Datta et al. 2010 revealed that only half of it are potentially active. As prioritized by the community, enhancing the existing participatory mangrove management mechanism therefore remain highly imperative (see Chapter 4).

6.4.3. Mangroves Governed by Civil Administration

Sporadic mangroves also exist in the reclaimed and inhabited islands of Indian Sundarban and these mangroves are crucial for disaster risk reduction purposes. Several NGOs and CBOs also occasionally conduct plantation programs to facilitate mangrove restoration. However, as mentioned earlier, these mangroves are not covered under any formal management system, rather monitored by the communities and the civil administration. Therefore, the civil government, especially, the *Gram Panchayats* are also an important stakeholder for mangrove management in the non-forested areas. This discussion demands a special mention of the 'Green Sundarban' project which was initiated by the district government in 2012 in response to the recovery efforts from Cyclone Aila. Acknowledging the grave scenario of the mangroves in the reclaimed areas, the District administration of South 24 Parganas developed an innovative way of mangrove restoration through income generation**.** A fiver yearlong (2012-17) mangrove restoration drive were introduced in this project. The project represents a 'win-win' situation both for the community and the government. Local communities were involved in mangrove plantation under the national government initiatives of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), which ensures 100 days job for unskilled rural communities. Mangroves has been planted in the government land mostly adjacent to the embankments. Key features of this project is listed below-

- Identification and demarcation of 2485 hectare of land (in the reclaimed area) for mangrove plantation involving 64 Gram Panchayats in 8 Community Development Blocks.
- Plantation of 11.7 million mangrove seedlings in reclaimed areas of Indian Sundarban over a period of five years.
- Protection of 2,500 km of river Embankment & Earthen Dam.
- Generation of total 0.33 million person-days of job opportunities including 0.268 Women Person-days.

Figure 6.4. (A) Mangrove Plantation at Namkhana (B) Trench Cutting for Mangrove Plantation at Indranarayanpur, Patharpratima Block (C) Mangrove Nursery at Jharkhali (D) Basanti Block Mangrove Nursery

Photo Courtesy: Office of the District Magistrate, South 24 Parganas, 2012

- In addition, the project also allotted some funds for monitoring and maintenance of the mangroves, development of nurseries and capacity building of the local communities.

Green Sundarban project is indeed a contemporary project with immense potential for development of local livelihood, women empowerment and mangrove restoration. However, the project is presently challenged by lack of funds (partial discontinuation of MGNREGA scheme), technical incapacity, poor survival rates of mangroves seedlings and lack of actually available land for plantation.

6.5. Evaluation of Participatory Mangrove Management in Indian Sundarban

The existing scenario of mangrove conservation in the Indian Sundarban broadly follows the three pathways discussed in the section 6.4. Importantly, despite that majority of the mangroves are covered within strong legislative protection, the most significant among these three pathways is the performance of the existing JFM arrangement in the buffer areas. There are three main reasons associated with this - firstly, majority of the protected area enjoys default protection because of the topographical complexity and human intervention in the protected region is negligible. Secondly, as argued by Giri et al. 2007, the problem of mangrove degradation in Indian Sundarban is mainly observed in the buffer areas. Characteristically, these areas are principally governed by the forest fringing communities under the JFM arrangement. Moreover, JFM involves institutionalized, long-term and mainstream participatory management of mangroves which has direct linkages with community livelihood and well-being. Thirdly, during the Participatory Action Planning process, respondents prioritized that the conservation of mangroves needs to be facilitated by the JFM activities (see Chapter 4). Therefore, the performance of the JFM arrangement is a determining factor for mangrove conservation as well as an inclusive ecosystem based disaster risk reduction strategy for the Indian Sundarban delta. In view of the above, the study focused on a detailed investigation of the existing JFM arrangements, thereby, identifying its opportunities, challenges and effectivity in mangrove conservation. Based on this evaluation, the study provides some key recommendations to improve the effectiveness of the current JFM arrangement in Indian Sundarban.

6.5.1. Research Objectives

As argued by Melana et al. 2005 and Datta et al. 2012, sustainability of participatory mangrove management primarily revolves around the effective participation of communities which is ensured by fulfilling community self-interest or economic wellbeing. Needless to say, community perception about the participatory arrangement is the key factor behind the long term sustainability of such arrangements, and according to Melana et al., (2005), community perception is largely shaped by the economic outcome of the participatory arrangements such as derived economic benefits. Suich 2013, additionally argued that communities will eventually withdraw if the derived incentives are not properly designed or insufficient to their economic aspirations, and that, no participatory forest management can have long-term sustainability without rigorous incentive design. Therefore, the objective of this research was to conduct a critical assessment over the existing incentive design, and to examine the perception of the village communities (mangrove users) about the derived incentives. However, as depicted in the **Figure 6.5,** both the incentive design and community perception depends on a series of social, economic, institutional as well as environmental factors which needs to be carefully examined to arrive at a distinct conclusion. Therefore, the study characteristically examines a series of dependent variables under the socio-economic, institutional and environmental sustainability component which in fundamental to an effective incentive design, that is capable of catering to the communities' need and well-being.

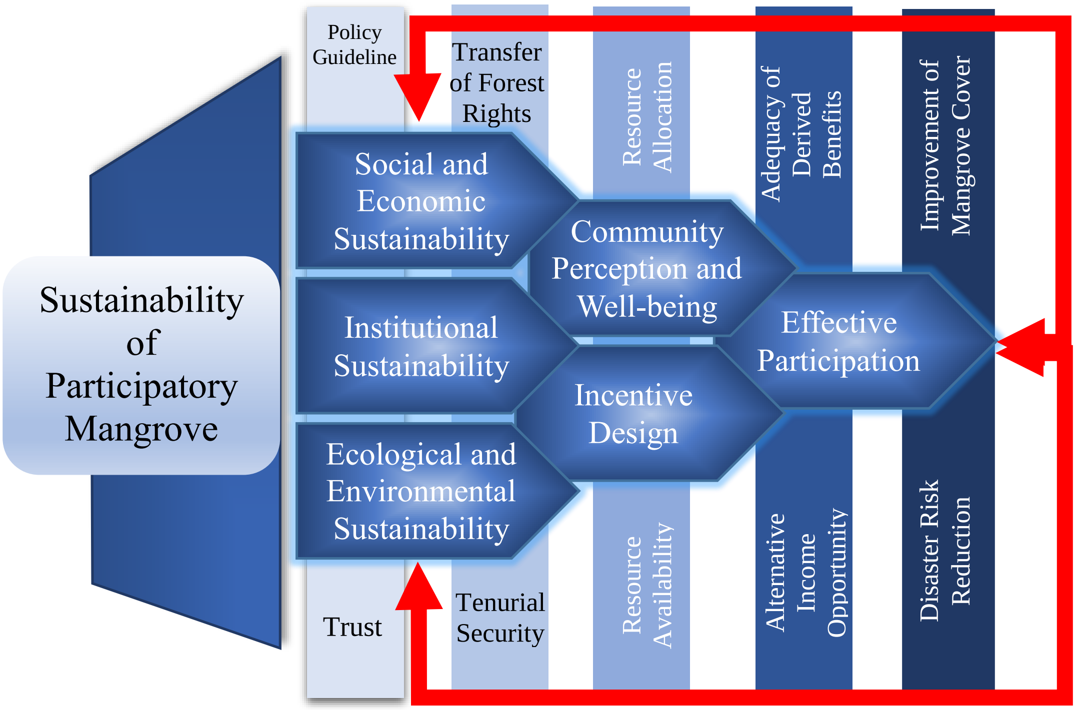


Figure 6.5. Conceptual Framework for Sustainability of Participatory Mangrove Management

6.5.2 Methodology

➢ **Research Design**

In achieving the above mentioned objectives, research methods for this study deploy a qualitative, in-depth, thematic analysis of the entire JFM arrangement of Indian Sundarban. The study is essentially based on a three tiered analysis of the participatory arrangement, namely (a) Structured Interviews with higher forest officials (**Tier 1**) (b) Focus Group Discussions (FGDs) with 10 sample JFMCs (**Tier 2**) (c) Semi structured interviews with 119 forest user group (from 5 distinct occupational groups) (**Tier3**). During the three tiered survey process, a theoretical framework was used to design the key questions relevant to each level of governance. This framework involves several factors and variables that are argued by a number of researchers to have played an important role in shaping community perception and an effective incentive design (**Table 6.2**). Structured Interview and FGD questions were designed based on the combination of these factors (**Annexure 5**). In addition, a set of interview questions were designed to understand the end user's perception which includes key questions such as opinion on the incentives from JFM arrangement, percentage of household income derived from the existing JFM arrangement etc.

Table 6.2: Factors Affecting Incentive Design and User's Perception in Participatory Forest Management

Component	Factors Influencing Sustainability of Participatory Forest Management
Social & Economic Factors	• Community Size & Structure, Population depending on direct or indirect forest resources (Kumar 2002; Pagdee et al. 2006; Paul & Chakrabarti, 2011; Datta et al. 2012) • Adequacy of Incentives (Suich, 2013; Adhikari et al. 2014), Livelihood dependence, % of Household income generated from JFM arrangement, Poverty reduction (Pagdee et al. 2006; Datta et al. 2012) • Communication & Relation with Forest Officials (Rishi, 2007; Andersson 2004), Democratic control of forest resources/Equity (Paul & Chakrabarti 2011; Pagdee et al. 2006) • Political and/or external interferences on JFMC functioning (Pagdee et al. 2006; DasGupta & Shaw 2013)
Institutional Factors	• Structural representation of community in the JFMC (women, vulnerable groups etc.) (Singh 2001) • Degree of Property Right transfer (Pagdee et al. 2006; Behera & Engel 2006); Management & withdrawal rights, tenurial rights, (Behera & Engel, 2006; DasGupta & Shaw 2013) • Marketing and Pricing of Forest Products (DasGupta & Shaw 2014)
Environmental & Ecological Factors	• Forest Cover and Ecosystem services (Pagdee et al. 2006) • Monitoring & Control of Forest Crimes/Community Policing (Garcia & Lescuyer, 2008) • Environmental & Ecological Awareness of the community (Pagdee et al. 2006).

➢ **Data Collection and Analysis**

As mentioned, the study includes a three tiered analysis of the existing JFM arrangements according to the level of governance. Tier 1 deploys the survey of the higher forest officials (policy planners and project implementers), while Tier 2 and Tier 3 deploy the survey of JFMCs (Mediators) and JFM beneficiaries (mangrove users).

- ***Survey of Higher Forest Officials***

At the beginning, higher forest officials (both from STR and SFD) were interviewed in order to understand their perception of the existing JFM arrangement, resource availability and uses. The author principally interviewed the DFO, South 24 Parganas and Dy. Field Director of Sundarban Tiger Reserve. Through their mediation, a number of rangers were also interviewed. In the interviews, officials were mainly asked about the local level policy amendments (in lieu to the federally administered JFM notification) and institutional aspects of the participatory governance. Key questions such as the legally permitted exploitable mangrove resources, benefit sharing mechanism, adequacy of ecosystem services to fulfill community needs, opportunities and hindrances of the existing JFM arrangements were asked during the interview. Further, chronological data of resource exploitation and usage, forest crimes were also collected from the concerned officials.

- ***Survey of the Joint Forest Management Committees***

In the second stage of the study, FGDs were conducted with 10 representative JFMCs in order to understand the current policy implementation mechanism, incentive delivery systems and other institutional factors such as tenurial security, transfer of property rights etc. (*see Annexure 6 for FGD questions*). In particular, an attempt was made to explore about the collective negotiation arrangements and community participation in the management of Indian Sundarban mangroves. The ten surveyed JFMCs include four Eco-Development Committees (EDCs) namely, Jamespur EDC, Dayapur EDC, Pakhiralaya EDC Bally EDC and 6 FPCs namely, Jharkhali-3, Jharkhali 4, North Bhakkhali, South Bhakkhali, Patibunia & Maushuni (for location see Figure 6.3., see JFMC details Table 6.3). These surveyed JFMCs encompass distinctive variation in terms of managed forest areas as well as PCFA along with the proximity from the core protected areas. The author intentionally chose both the EDCs and FPCs in recognition to slight structural and administrative differences among them. Hence, it can be argued that the surveyed population is fairly representative of the 65 operational JFMCs. Importantly, all the JFMCs include the local forest administrator (Beat Officer) as the convener

Table 6.3. Details of the Surveyed JFMCs in Indian Sundarban

Name of the JFMC (Governing Agency)	Range/Beat	Year	Members	Protected Area (in Ha)	Per Capita Forest Availability (ha/person)
Jamespur EDC (STR)	SWLS/Sajnekhali	1998	347	960	2.76
Dayapur EDC (STR)	SWLS/Sajnekhali	1998	326	650	1.99
Pakhiralaya EDC (STR)	SWLS/Sajnekhali	1998	517	480	0.93
Bally EDC (STR)	NP(W)/Bidya	1998	258	770	2.98
Jharkhali-3 FPC (SFD)	Matla/Herobhanga	2004	1496	638	0.42
Jharkhali-4 FPC (SFD)	Matla/Herobhanga	2004	578	586	1.013
North Bhakkhali FPC (SFD)	Bhakkhali/ Bhakkhali	2004	5400	300	0.05
South Bhakkhali FPC (SFD)	Bhakkhali/ Bhakkhali	1994	1593	244	0.15
Patibunia FPC (SFD)	Bhakkhali/ Bhakkhali	1997	1033	550	0.53
Maushuni FPC (SFD)	Bhakkhali/ Bhakkhali	2004	640	1950	3.04

of its seven to nine-member committee, hence the FGDs were also presided by the relevant Beat officers.

- ***Survey of JFM Beneficiaries / forest user groups***

The third and final step involved individual and group interviews with five different forest user groups namely farmer, fishermen, forest product (honey & wax) collectors, prawn seed collectors and groups involved in tourism. A Semi-structured, opened ended response sheet was used for the survey. In general, enquires were made related to their expectations, adequacy of derived benefits and perception about the existing JFM arrangements were made through semi-structured group and individual interviews over a sample size of 119 forest users. Distribution of sample size involves the survey of 52 farmers (including agricultural labors), 37 estuarine fishermen, 8 Prawn seed collectors, 9 honey and wax product collector and 13 boatman/tourist guides. Key questions such as share of household income, opinion on the economic outcome, perceived benefits and threats from JFM were asked during the course of the interviews.

Figure 6.6. (A) Forest Protection Committee (FPC) in Jharkhali 3 (B) Forest Protection Committee (FPC) in North Bakkhali (C) Notice for hiring charges for forest guides (D) Eco-Development Committee (EDC) members of Dayapur EDC.

The two types of data, i.e. qualitative and quantitative data were later analyzed using conventional data analysis techniques. For quantitative data, such as trend of resource exploitation, share of household income from the forest resources were analyzed using simple arithmetic functions such as ‘sum’ and ‘average’. Microsoft excel were used to conduct these operations and generate the final bar diagrams. In case of the qualitative data, the documented information and the transcripts were firstly transformed into thematic reports containing specific issues, key statements and observations. As suggested by Berg 2001, this is one of the standard data reduction techniques that can be applied to summarize large amount of qualitative information. The summary reports were further subjected to either summative (in case of forest officials) or directed content analysis (for stakeholder’s perception). The aim of directed content analysis, as suggested by Hsieh and Shannon 2005, was to identify key observations from each FGDs and interview sessions, and to categorize them under a defined codes or labels. Thereafter, the author conducted a manual frequency/repetition search in order to identify the relevance of an identified issue. The information was later summarized in a stakeholders’ and a SWOT (Strength, Weakness, Opportunities and Threat) analysis pertaining to their impression and sustainability of the existing JFM arrangements. It is important to mention that despite performing extreme precautions during the above mentioned PRA exercises, the results might have some systematic bias due to the inherent limitations of these tools and small sample sizes, although the author executed extreme precaution during the deployment of these tools.

6.6. Results

The result of this three tiered survey is summarized under two broad dimensions i.e. ‘incentive design’ and ‘community perception’ about the existing Joint Forest Management. Associated socio-economic, institutional and environmental factors are integrated within these above mentioned dimensions.

6.6.1. Incentive Design and Delivery Mechanism

As argued by Adhikari et al.2014, incentive mechanism is the principal variable that affects an individual’s or communities’ behavior in the participatory forest management. In principle, incentive design evolves from the ideas of sustainable resource consumption where program implementers adopt a series of control mechanism (often through mediators) over the available commercially exploitable ecosystem services. Two primary factors that affect the incentive design is the availability of exploitable ecosystem services (environmental factor) and the demands from the forest fringing communities (socio-economic factor). In addition, the collection and delivery mechanism of ecosystem based incentives remains at the central of participatory forest management mechanism (institutional factor). Therefore, incentive design requires a careful integration and a practical balance among these three factors.

In case of the existing Joint Forest Management of Indian Sundarban, the study identified three direct incentives which are, at present, shared with the fringing communities. These are (a) honey and wax collection (b) fishing rights within and around the mangroves and (c) tourism benefits. In addition, interviews with forest officials and FGDs with JFMC members also revealed some additional opportunities such as training, seasonal jobs (e.g. plantation, land development etc.) which are also shared with the local communities registered under the JFMCs. Unlike the inland JFM arrangements where a percentage of revenue is shared with the communities because of rotational felling, the most critical design of existing management of Indian Sundarban is the complete prohibition on collection of wood based resources. For example, Golapata (*Nypa sp*.) and Hental (*Phoenix sp.*) which were collected earlier by the fringing villages was discontinued since 1978 & 1991, while controlled felling has been completely stopped since 2001 (Vyas & Sengupta 2012). In addition, fishing communities are only allowed to exploit a very small portion (<25%) of the potential fishing areas due to several territorial restrictions within and around the mangroves (Patel & Rajagopalan 2009). An additional complexity led by the ban on the collection of dry leaves and shredded branches clearly impedes the community to obtain a sustainable living out of the forest products. This evidently shows that the mangrove provisioning services are party used for incentives due to an enhanced 'safety-margin based design' approach adopted by the local forest department. In general, it leads to a conclusion that the exploitation is well within the carrying capacity of the mangroves.

An enquiry made over the existing trend of exploitable Non-Wood Forest Products (NWFP) revealed that there is no significant variation of resource exploitation over the past decade. As depicted in **Figure 6.7. and 6.8**., time series data obtained from the forest offices reveals a generally constant rate of resource exploitation (Honey and Wax). A sharp decline during 2009-2011, however, relates to the loss of lives and assets during cyclone 'Aila' and are not indicative of the declining forest health. Since 2010, both honey and wax production is gradually rising to its earlier extent. In this context, it is important to mention, in case of honey, all the collected products need to be sold to the local forest offices in a stipulated price, who further sells it to the West Bengal Forest Development Corporation (WBFDC). This is, however, not applicable to wax production as the communities can directly sell it an open market. This is again a critical design of the incentive delivery and distribution mechanism; where marketing rights is partially restricted.

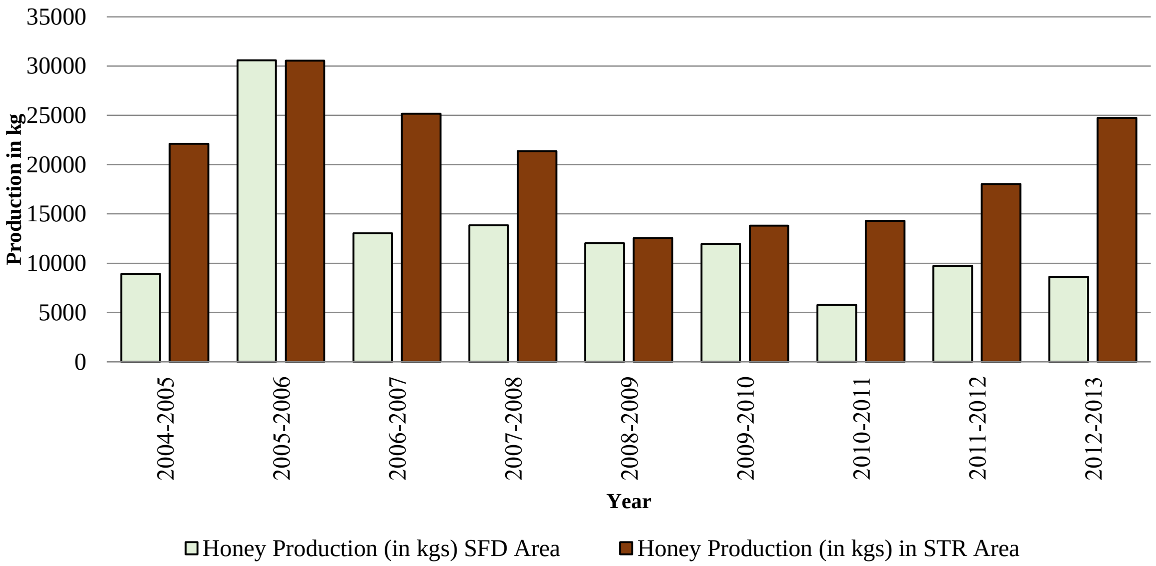


Figure 6.7. Trend of Honey Collection in Indian Sundarban

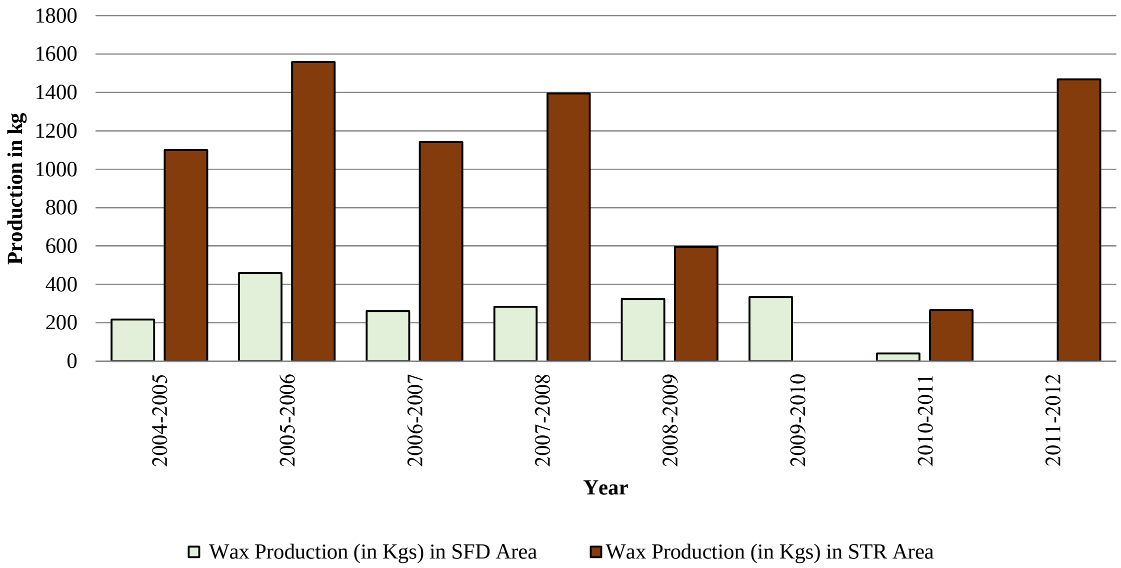


Figure 6.8. Trend of Wax Collection in Indian Sundarban

Unlike the provisioning services of the mangroves, cultural services such as tourists frequenting the mangroves have increased by nearly 400% since the last decade (**Figure 6.9**). Officials revealed that on an average, 25% of the revenue collected from eco-tourism spots are shared with the communities. In this regard, it is important to mention that JFM guidelines does not specify the amount to be shared with the communities and enables the provincial forest departments to make decision on this. For example, in case of the Indian Sundarban, EDCs receive around INR 100,000 per year as their share of tourism revenue collected from different tourist spots under STR, however, such provisions are nonexistent for FPCs operating under SFD.

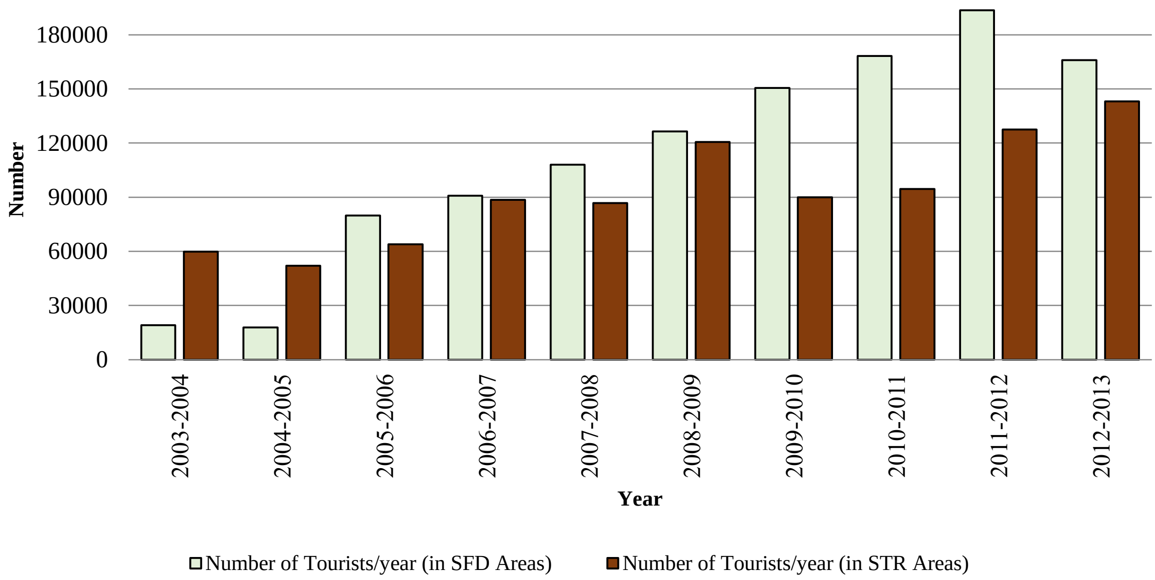


Figure 6.9: Observed Trend of Tourists Frequenting in Indian Sundarban

Incentive design also demands a careful investigation into the participatory control and monitoring mechanism which ensures that the resources are not illegally exploited and/or exploited within the carrying capacities. Being at the core of participatory forest management, JFMCs provide an interface between the forest administration and the user groups, thereby executing the bulk of responsibilities in monitoring and distribution of incentives. In addition, given the finite available resources, the role of JFMCs as a local authority is crucial for the equity of distribution. Representation of different occupational groups, relationship with the forest officials, management rights, legal and tenurial security are additionally the key determinants for active and impartial functioning of the committees (Singh, 2001; Pagdee et al. 2006; Behera & Engel 2006; DasGupta & Shaw 2014). FGDs with the JFMCs, however reveal that, in the existing case of Indian Sundarban, JFMCs have little role to play as their major functioning is restricted only to 'community policing', in which they are partly successful. **Figure 6.10.** depicts the chronological trend of forest crimes as obtained from the forest officials. Importantly, cognizable forest crimes, such as illegal penetration into protected areas, logging, poaching etc. have drastically increased in recent years. While the officials and JFMC members argue that the figure depicts the efficiency of community based monitoring mechanism, counter arguments are also provided by the end users. Accordingly, to them, tendency to disobey the local forest rules in gradually rising among the users which questions the future sustainability of participatory mangrove management in Indian Sundarban.

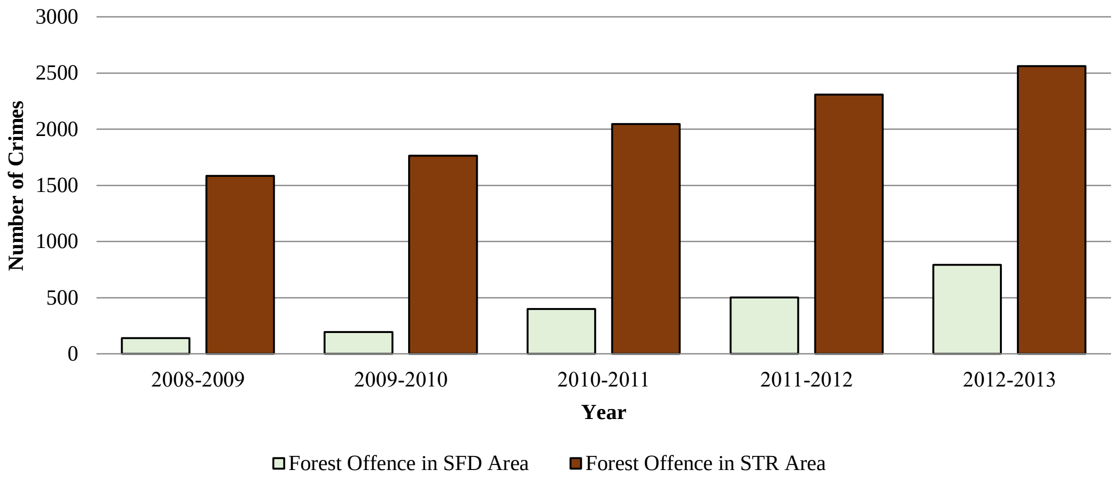


Figure 6.10. Reported Forest Crimes in Indian Sundarban

However, apart from monitoring forest crimes, none of the surveyed JFMCs are involved in the broader decision making (such as micro-planning, pricing and marketing of forest products etc.) and the legal awareness of the committee members are also severely limited. From the FGDs, it was observed the existing mediator’s role of the JFMCs are currently restricted nothing beyond than a community based monitoring institution, and, their participation in decision making and incentive delivery mechanism is largely restricted. For example, the committees itself are formed only for one year (i.e. lack of tenurial security) and can be abandoned or extended at the sole discrimination of the local forest department. In addition, they have no significant role in resource allocation since, in order to obtain forest exploration rights, community members need to apply directly to the concerned forest offices. Allocation of resources such as fishing rights and honey collectors’ pass to enter protected areas are, at present, strictly governed by the local forest administrators. Except some plantation based job opportunities through the JFMCs, the existing resource allocation mechanism, as reveled during the FGDs, seems to be heavily skewed towards the local forest offices.

On the other hand, despite of the fact, that some of the surveyed JFMCs, e.g. Mausuni, Jahrkhali 3 & 4, Patibunia receive support from national and international NGOs, majority the JFMCs depend on the local forest department for financial assistance for their own survival. Hence, majority of the committee members feel that their responsibilities are confined to forest protection and to help local forest guards, while, incentives or rights to exploitation is a subject of the local forest administration. This is a clear contradiction of the intended decentralization of forest management, since, the decision making capacity of the JFMCs, as reveled during the FGDs, have been restricted by the local forest offices. This, in lieu with poor legal awareness has led to improper functioning of the JFMCs. For example, in all the surveyed JFMCs, members are not aware of the micro-planning and other necessary legal and technical process. When enquired with the local forest officials about the intentional depowering of the JFMCs, they unanimously highlighted that political influences are the major determinants for sharing such rights. As have been found during the FGDs, predominance of political leaders and local elites rather than the forest users and high politicization of the committees, indeed, a major problem for the local forest officials to share substantial forest rights. Therefore, as explained by the local officials, a ‘high safety margin based incentive design’ remains the only alternative.

6.6.2. Community Perception of existing JFM arrangement

Despite of a preemptive safety margin based incentive design, it is important to know that how the JFM beneficences perceive about the existing JFM arrangement. Therefore, this section narrates the perception of JFM beneficiaries about the derived benefits, expectation and perceived threats from the existing JFM arrangement. A synoptic summary of the observation is also furnished in the stakeholder analysis (**Table 6.4**).

- ***Farmer’s Perception of existing JFM arrangements***

Despite the fact that the agricultural workers have no direct stake in the existing participatory management, they consist the largest occupational group under the JFMCs. As mentioned in the chapter 5, agriculture in Indian Sundarban, despite being the primary livelihood of the communities, are characterized by non-irrigated mono crop rice cultivation and low productivity. In addition, storm and tidal flooding often impel them to exploit the mangroves as an auxiliary livelihood option. Among the surveyed population of 52 farmers, 31 mentioned that they depend on a secondary source of income, such as seasonal job opportunities under the MGNREGA. When asked about the major benefits derived from the JFM arrangement, farmers revealed sporadic job opportunities such as plantation programs executed under the JFM arrangements. In this study, the sample population perceived that these benefits roughly correspond to approximately 10% of their overall monthly income. Although, not specific to their occupation, farmers revealed three main reasons hindering their active participation. These are (a) Prohibition of fuel wood collection in absence of any alternative fuel (b) Political interference and favoritism in the JFMCs and (c) lack of institutional and administrative support for improvement of agricultural productivity. For example, one farmer mentioned that -

> *"We are badly in need of a sluice gate to prevent saline water to come in.... we want the forest department to provide one. If we get it, we will more actively participate in forest protection"*

(Interview with a Farmer in Jharkhali III FPC)

However, over 90% of the surveyed farmers recognizes the importance of mangroves, especially its role in disaster risk reduction, and mentioned that they are willing to actively cooperate within the existing participatory mechanism.

- ***Fishermen's Perceptions of existing JFM Arrangements***

Communities involved in fishing represents nearly one third of the JFM beneficiaries. However, the scenario of fishing in the tide dominated creeks and river systems is extremely complicated since the designated fishing area in and around the mangroves are divided into several '*go*' and '*no go*' areas. Forest offices issue each fisherman an identity card and an accidental life insurance plan which needs to be renewed on a temporal basis. Additionally, non-transferable boat licenses are also allotted to each fishing group. Fishing is legally permitted only when the fishermen are equipped with a valid boat and fish trading license.

Out of the sample population of 37 fishermen, 23 fishermen mentioned that they are involved in secondary occupation, mostly during the designated breeding season (April to June) when fishing is prohibited. They further revealed that approximately 70-75% of their household income are derived from estuarine fishing. This economic dependence is a crucial factor that determines their perception and participation about the JFM arrangement. The study identified three main constraints behind the active participation of fishing communities i.e. (a) Due to the increased number of fishermen, the individual benefits are decreasing (lower per capita fish catch) (b) about 30 to 50% reduction of commercially important fish catch and (c) due to poor catch, more fishermen try to penetrate the protected areas. Unlike the farmers group, fishermen own completely different perception about the JFM arrangement. According to them, the existing arrangements are forcefully restrictive and cannot support a sustainable living. Three major demands, which were mentioned by the overwhelming majority of the interviewed fishermen are- (a) permission of fishing in core and otherwise restricted areas (b) access to the leaves and shredded woods and (c) permission to carry country swords/weapons while fishing. For example, a fishermen mentioned-

> *"Maunds (traditional unit of mass used in British India) of fallen woods, tree branches every day floats on the rivers. Yet, if we try to collect those, we are unnecessarily penalized. Our boats are seized and we are physically harassed".*

(Interview with a Fishermen in Pakhiralaya EDC)

Another fisherman stated -

> "*We don't carry country swords to chop the trees but to protect ourselves from pirates or sudden tiger attacks. However, forest guards feel differently and penalize us."*

(Interview with a Fishermen in Dayapur EDC)

The statements clearly translate the lack of motivation and trust of the fishing communities on the existing JFM arrangement. Additionally, fishermen also mentioned about the necessity of appropriate markets to sell their products. Consequently, growing mutual distrust between the forest officials and the fishing communities emerges as a clear threat to the future sustainability.

- ***Prawn Seed Collector's Perceptions of existing JFM Arrangements***

Prawn seed collector is a very small group of marginalized women (dominated by widows or separated women) who collect seeds and larvae of crustaceans from intertidal areas of estuarine rivers and creeks. The seeds are typically sold to middlemen who further sell it to the aquaculture farms. The process of prawn seed collection is harmful for both human and the aquatic ecosystems. STR officials mentioned that collection of each prawn seeds, on an average, destroys 40 other larva of fish, crustaceans and other aquatic species. Besides it is also poorly rewarding. The collected seeds are sold at a mere price of INR 40-50 per 1000 samples. Considering its long term adverse ecological impacts, regulations stipulated by STR advocated for complete ban of these activities (Patel & Rajagopalan 2009). Yet, both the forest officials and the JFMC members ignore these activities citing humanitarian reasons. As argued by many, the process is a serious threat to continual ecosystem services and environmental sustainability of the region. The entire sample size of 8 prawn seed collectors mentioned that they are solely dependent on this activity and does not possess any additional skills or agricultural land for an alternative livelihood. None of them, so far, received any voluntary aids from the JFMCs. In addition, we found majority of the surveyed population to be socially isolated and poorly represented in the JFM arrangement, despite of being the most vulnerable members. Unable to identify any tangible benefits from the existing JFM arrangements, majority of our sample population feared about strict implementation of forest laws might adversely affect their livelihood.

Figure 6.11. (A) An estuarine fishermen fishing along the creeks (B) Prawn Seed Collectors in the tidal areas (c) A volunteer (tourist guide) appointed by STR (D) Group Interviews with Prawn Seed Collectors *Source: Author/2013*

- ***Honey and Wax Collector's Perceptions of existing JFM Arrangements***

Honey and bee-wax are the minor forest products collected during the month of April and May. The entire collection process is closely supervised, monitored and documented by the relevant forest offices. Each year, license are issued for conducting such activity. Out of sample

Table 6.4: Stakeholder's Perception about the Existing JFM arrangements in Indian Sundarban

	Farmers and Agricultural Labors	Onshore/Estuarine Fishermen	Prawn Seed Collectors	Forest Product (Honey /Wax) Collectors	Individuals involved in Tourism
User Group	Distant	Direct	Direct	Direct	Direct
Composition of the Community	50-60%	25-30%	1-3%	3-5%	2-5%
Main Interest	Leaves & Timber	Fish, Crabs and NTFPs	Prawn Seeds	Honey and Bee-wax	Tourist/Commissions of travel guide
Territorial Distribution of Operation	Buffer and Non-forested Areas	Buffer Areas	Buffer Areas	Core & Buffer Areas	Buffer Areas
Ecological influence	Low	Moderate	High	Moderate	High
Average Monthly Income	INR 2000-5000	INR 3000-5000	INR 800-1200	INR 2500-4000	INR 3000-5000
Whether involved in a secondary occupation (% respondents)	~60%	~52%	Nil	100%	~31%
% share of monthly income from Mangrove or allied resources	<10%	70-75%	100%	50-60%	60-70%
Perceived Benefits from JFM arrangements	Small scale plantation program executed by JFMCs	Organized fishing activities, insurance and government identity cards	Nil	Organized exploitation, provision for sale	Sharing of Revenue, increment in tourist activities
Perceived Threats from JFM arrangements	No opinion	Restriction of fishing into core & designated areas	Strict enforcement of laws	Loss of marketing rights	Nil
Key Issues related to occupation	Rise of salinity & flooding incident, loss of agricultural productivity	Rights for fishing in core and restricted areas	Alternative Livelihood/ Rehabilitation	Price of Honey , Marketing rights etc.	Increment in revenue sharing and competitors outside the JFM arrangement

population of 9 forest product collectors, all of them use this opportunity for additional income. When enquired of their perception about the benefits derived out of the forest products, majority of them revealed satisfaction over the entire arrangements. However, some issues, especially related to marketing and distribution rights of the collected forest products were identified by the interviewed forest product collectors. The issues are (a) in case of honey, all the collected products need to be sold to the local forest offices, (b) Selling price of each unit of honey has been traditionally poor (INR 75-100/kg), while open market price are almost double and (c) Revision of prices of collected forest products are rare. Some of the honey collectors find it objectionable as depicted in the following statement-

> *"Despite of our hard work, we get only half of the existing market value. We lose a good amount of money."*

(Interview with a Honey Collector in Bally EDC)

However, the study also encountered contradictory statements such as-

> "*Since we don't have an access to the distantly urban markets in Kolkata, it would have been difficult to sell all our products in domestic market. There is very little demand. It is good that forest department is taking all of it"*

(Interview with a Honey Collector in Pakiralaya EDC)

Importantly, these issues are not relevant to wax and it can be directly sold to an open market. In general, the surveyed forest product collectors appreciate the overall arrangements and are satisfied with the derived incentives.

- ***Tourist Guide's Perspectives of existing JFM Arrangements***

As depicted in **Figure 6.9,** tourists visiting Indian Sundarban have increased significantly over the previous year creating larger opportunities for communities involved in eco-tourism (e.g. boat drivers, tourist guides, lodge owners etc.). These groups depending on tourism roughly corresponds to approximately 2-5% of the JFM beneficiaries and are expanding with tourists frequenting in the Sundarban mangroves. Among our sample size of 13 boat drivers and local tourist guides, majority of the members expressed their profound interest to be a part of JFM activities, mostly because of the direct economic opportunities extended to them. They mentioned that it has been made mandatory to use tourist guides and registered boats while taking a joy ride in and around the mangroves. Additionally, around half of them were given short term training by the local forest offices. Although, many of them are also involved in some small scale livelihood activities, roughly 60% of their household income are derived from tourism activities. The surveyed population, however, have some key concerns like (a) they fear about increasing competition as many opt for being tourist guides and most importantly, (b) existence of outsiders, especially city-based tour operators.

6.7. Discussion

The present research attempted to understand the effectiveness of the participatory mangrove management (JFM) in the conservation of the Indian Sundarban mangroves. Two specific areas were particularly investigated in order to understand the long term sustainability and effectiveness of participatory mangrove management, i.e. the prevailing ‘incentive design and delivery mechanism’ and ‘community perception over the derived benefits’. In addition, the study characteristically examined several socio-economic, institutional and environmental factors that forms the basis of a sustainable, long-term, participatory mangrove management mechanism.

The main finding from this study indicates a ‘precariously safety margin based incentive design’ approach which largely restricts the overall goals and objectives of JFM, i.e. ecological conservation through improvement of community livelihood. Secondly, the study observes that the beneficiaries and other forest users, in general, are bifurcated into supporters (e.g. agricultural communities, forest product collectors) and criticizers (e.g. Fishermen, prawn seed collectors) of the JFM arrangements, and the division has strong correlation with the share of household income derived out of forest benefits. In particular, perception generally tends to be negative (anti-institutional) with greater degree of dependence on mangroves. Theoretical implication of this observation can be interpreted in two ways, firstly, despite most of the community members recognize regulating, sheltering or recreational services of mangroves (*especially awareness about the role of mangroves in cyclone risk reduction is exceptionally high*), they only rely on the access to economically exploitable provisioning services in making crucial decisions for participation. Secondly, any hindrance to such access are considered as a threat to their livelihood and prosperity and therefore affect their willingness to participate in the existing JFM arrangements. A multitude of additional factors, such as lack of market and poor pricing of forest products, territorial rights are identified to play a significant role in shaping user perception. Given the existing complexity of the stakeholder’s interest where collective consensus is barely reached, long term sustainability of the existing JFM arrangement is clearly arguable.

As have been mentioned in the **Table 6.2.**, in case of the existing JFM arrangements, several socio-economic and institutional factors can be held responsible that is essentially limiting the opportunities of the existing JFM arrangement. Of which, the principal factor in the large size of the mangrove dependent community, in the particular the fishermen. In addition, due to the large size of the community along with its heterogeneity, it was also observed that the potential individual share is not satisfactory for making a sustainable living out of the existing incentive mechanism. Among the institutional factors, the study typically observed high restriction and control of exploitable forest resources. In particular, the study identified the ineffectiveness of the JFMCs as a potential mediator between the local forest department and the dependent communities. A number of factors, such as improper structural representation, dominance of local political elites, lack of legal and technical knowledge of the committee members were identified to have adversely impacted the desired performance of the JFMCs. Consequently, the local forest department justified their stand for restricting the property and tenurial rights. Nevertheless, the study observes the existing role of the JFMCs in monitoring and controlling the forest crimes is satisfactory. Therefore, in summary, it can be mentioned that by restricting forest uses through effective community policing, the local forest departments were fairly successful in halting further degradation of the Indian Sundarban mangroves, however, it failed to improve the poor economic scenario of the communities as desired in the JFM arrangements. As have been argued by Pagdee et al. 2006, success of forest management cannot be defined only by the increase in forest cover, but also, the well-being of forest fringing communities serves as an integral component. Indicators such as more than half of the fringing population lives under the nationally designated poverty line and an increasing 'forest crime trend' depict a clear message of the inability of the existing JFM arrangement to improve local livelihood through effective and sustainable utilization of the mangrove forests. Besides, it also serves as a prominent threat to future sustainability. Therefore, despite of having a supportive legal arrangement to involve communities in mainstream forest management, the existing performance of the JFM arrangement in Indian Sundarban is certainly underachieved and needs further refinement in order to achieve its designed objectives. **Table 6.5** summarizes the above discussion into a SWOT (Strength, Weakness, Opportunities and Threats) analysis and thereby, presents the summary of key factors facilitating or hindering the performance of the existing JFM arrangement.

Nevertheless, apart from the community dissatisfaction over the derived incentives, another important threat looming large on the Indian Sundarban mangroves is the recently enacted Tribal Forest Act or Forest Rights Act of 2006. The law essentially acknowledges the traditional rights of communities over the forests, giving wider authority and exploration rights.

Table 6.5: SWOT Analysis of the Existing Participatory (JFM) Mangrove Management

Strength	Weakness
• Existing Legal arrangements in form of JFM Notification, Statutory Compulsion. • Effective 'Community Policing', specially controlling biodiversity poaching. • Defined responsibility and legal sanctity of the FPCs and EDCs. • Secured Funding, although small, from the forest department leading to some community development work.	• Absence of alternative fuel and dependence on mangrove wood. This increases forest violations. • Insufficient economic outcome in terms of NTFP, lack of marketing provisions. • High rate of poverty in forest fringing blocks. • Absence of local market and initiatives. • Lack of monitoring and evaluation mechanism.
Opportunities	**Threats**
• High environment & disaster awareness of the community with increased awareness of protective functions of mangrove forests; especially after the cyclone 'Aila' in 2009. • Improved relationship between the Forest Department (local officials) with the local community. • Small scale livelihood generation work such as plantation programs etc.	• Dissatisfied occupational groups, especially fishermen. • Polarization of the community due to political interferences. • Prevalence of Political Agendas. • Lack of Alternative Livelihood, skills and provisions • Implementation of Tribal Forest Act, 2006 which gives traditional rights to forest dwelling communities.

Criticized as a license for resource exploitation by several researchers, this act has long-term implications in mangrove conservation in Indian Sundarban or elsewhere, and emerges a distinct threat for the effective conservation and utilization of the mangrove forest. In view of the above, it is highly imperative that the existing JFM comes up with a better incentive design and a holistic reform through 'bottom-up planning'. Unfortunately, that the general forest management practices in India is still heavily skewed towards the forest departments and takes its shape from an age-old distrust between communities and the forest departments. Therefore, any drastic reform and paradigm shift to complete decentralization is highly unlikely. Over the past, reliance on protected areas for the ease and convenience of forest management has been the signature of the country's forest administration, and even after the enactment of JFM, the field implications sometimes fall short of expectations. It is, however, cannot be denied that protected areas in Indian Sundarban have played an important role in conservation, despite curtailing the local needs and economic wellbeing. Therefore, as a 'tested strategy', the forest department in Indian Sundarban recently proposed (2012) an additional wild life sanctuary *('Sundarban West' consisting 462 sq.km.*), the largest of all, to curtail unwanted interventions in the mangroves and wildlife. Needless to say, the strategy, if implemented against the will of the local communities, will undoubtedly lead to further lack of motivation among the communities, besides reducing mutual trust and per capita benefits with severe undesirable consequences. Hence, the forest department should rethink over such preventive management and should come-up with strategies and innovative policy responses to strengthen the existing JFM arrangement.

6.8. Key Recommendations

Mangroves are vital for the continual survival of the Sundarban delta and its dwellers. As recommended by many researchers over the years, it needs to be preserved and possibly restored under any cost. Deployment of an ameliorative participatory conservation mechanism, therefore, remains highly imperative and as suggested, it should evolve from ‘people-centered’ policies and bottom-up incentive design. The following section provides some key recommendations, based on the field survey and data analysis, that have the potentials to enhance the performance of the existing JFM arrangements within the stipulated policy guidelines. For the ease of understanding, the suggested recommendations are broadly classified under socio-economic, institutional and ecological intervention that is required to enhance the performance of the existing JFM arrangements in Indian Sundarban.

a) Socio-Economic Interventions

➢ ***Competitive Benefit Sharing Mechanism through ‘Bottom-up’ incentive design***

It is evident, based on the above discussions, that poverty and resource dependency are the major governing factors in undermining spontaneous community participation. This is further magnified by enormous density of resource dependent population and a series of restrictive policies enforced within the JFM mechanism. Consequently, the existing benefits are insufficient to provide an economically lucrative model to motivate the fringing communities. However, the study also observes that the incentives are mostly derived out of an arbitrary safety margin based approach, with no real estimations of maximum sustainable yields of forest and associated products. Although this can be justified considering the magnanimity of the Indian Sundarban mangroves, however, there are also substantial opportunities to expand the scopes and benefits of the present incentives. For example, sharing 25% of ecotourism revenues can be increased to at least 50%. Similarly, official fishing areas can also be extended to selected protected areas with enforcement of auxiliary regulations. However, given the complexity of situation and the ‘demand and supply’ of the available ecosystem services, it is imperative to understand, that mangrove based incentives, alone, is insufficient to cater the heterogeneity of demands of the communities.

Although, it can be argued that the existing safety margin based incentive design does not reflect community's interests and can be more competitive by stretching its exploitation limits, this might also indulge overexploitation of the mangrove resources. As an alternative, small scale developmental incentive can supplement the ecosystem based incentives. For example, as revealed by the local farmers, construction of sluice gate or small water retention structures, markets, seed and fish storage facilities might work wonder to motivate the local communities and restore the lost trust. Also, forest department need to strongly collaborate with the civil government in order to foster alternative livelihood and skill development of the forest fringing communities. As mentioned in Chapter 5, the Indian Sundarban has high potential for freshwater aquaculture and crop diversification with localized irrigation facilities. In addition, infrastructural development such as construction of roads, markets would ensure better connectivity and create considerable job opportunities. This will not only facilitate a truly participatory environment but also play a significant role towards restoring the trust between communities and the forest departments. However, to what extent developmental incentives need to supplement the ecosystem based incentive, requires intensive need assessment of communities and examination of ecological carrying capacity in an unbiased and participatory environment.

- ***Rehabilitation of Vulnerable Occupational Groups***

It is also imperative, considering the socio-economic marginalization of the prawn seed collectors (especially windows and separated), that a proper rehabilitation scheme is launched to support these occupationally and socially vulnerable group. In particular, their nature of engagement is destructive to both for human and ecosystems. Forest department can involve the local women's self-help group for alternative skill development with some initial financial assistance or grants.

b) Institutional Interventions

- ***Provision of Markets and Price Revisions of Exploited Forest Products***

Provision of markets and price of forest products is an extremely sensitive issue for participatory mangrove management. It is evident from the present study that most of the marketable mangrove products in the Indian Sundarban have negligible local demands, yet, have significant demands in the nearby city of Kolkata. However, the market connectivity is not so established. Considering this, the present effort of the forest department to collectively market the forest products, especially honey, is praiseworthy. However, pricing of the forest products need to be equally competitive. Communities should not feel that they are deprived of a reasonable share from the actual market value. Periodical price reviews of exploited forest products are highly recommended. In case of fish and crabs, which also has exceptionally high demands in the nearest city of Kolkata, markets and distribution strategies need to be further strengthened. In this regard, forest department need to closely collaborate with the civil government and extend its role from the mere conservator of mangroves. Cold storage and proper market connectivity is the primary requirement for the estuarine fishermen which the forest department can facilitate through the fisheries cooperatives. In addition, forest department should also extend their present vocational training and capacity development program on agriculture, tourist guides and small business enterprising.

- ***Screening Political Interferences and Representation of All Occupational Groups in JFMCs***

On the other hand, the requirements of an effective screening of the core committee members of the JFMC is extremely necessary. As mentioned, that the JFMC performance is heavily interrupted due to the presence of the local political leaders and their vested agendas. Political favoritism in job allocation is the most commonly mentioned problem during the interviews, thereby, affecting poor participation and performance of the deprived community members. On the other hand, representation from all stakeholders group in the core committee is extremely necessary rather than the secondary feedbacks from village or political elites. Therefore, it requires some local level policy amendments and guidelines to ensure that all stakeholder’s voice is equally heard.

- ***Coordination with Civil Administration at the local level***

Lastly, the forest department needs to closely collaborate with the local civil administration, especially at the block level or lower level of governance. This collaboration is necessary for mutual interest in several developmental fields, especially in diversification of community livelihood, eco-sensitive development in the mangrove buffer areas etc. Conversely, the technical expertise of the forest departments can also be effectively used for the development of social forestry and mangrove plantation in civil administered area (reclaimed areas).

c) Environmental/Ecological Interventions

➢ ***Attitudinal Change: From Conservation to Restoration of Mangroves***

One of the major deficiency of the entire JFM arrangement is its general approach of conservation. The JFM arrangement is primarily designed to conserve the existing mangrove forests but not necessarily restore the degraded and/or deforested areas. Despite of some plantation work that the forest department conducts on sporadic basis, there is clear need to involve the JFMCs in exhaustive plantation in degraded/ deforested areas. These would have two direct benefits. Firstly, it will create more plantation based job opportunities and secondly, the performance of the JFMCs can be easily evaluated and therefore can be given preferential benefits. These approach would also enhance healthy competitiveness among the JFMCs and make them more performance oriented. In lieu with this, scientific assessments such as Maximum Sustainable Yields and ecological carrying capacity also needs to be carried out simultaneously.

References

Adhikari, S., Kingi, T., & Ganesh, S. (2014). Incentives for community participation in the governance and management of common property resources: the case of community forest management in Nepal. *Forest Policy and Economics, 44*, 1-9.

Andersson, K. P. (2004). Who talks with whom? The role of repeated interactions in decentralized forest governance. *World Development, 32*(2), 233-249.

Bandyopadhyay, S. (1997): Natural environmental hazards and their management: a case study of Sagar Island, India. *Singapore Journal of Tropical Geography*, 18(1), 20-45.

Barlow, A.C.D., (2009): The Sundarbans Tiger: Adaptation, Population Status, and Conflict Management. Doctoral thesis submitted to University of Minnesota.

Behera, B., & Engel, S. (2006). Institutional analysis of evolution of joint forest management in India: A new institutional economics approach. *Forest Policy and Economics, 8*(4), 350-362.

Berg BL. (2001). Qualitative Research Methods for The Social Sciences (4th Ed.), Allyn & Bacon.

Beveridge H (1876): Were the Sundarbans inhabited in ancient times? *Journal of the Asiatic society of Bengal,*1, 71-76

Bhattacharya, P., Pradhan, L., & Yadav, G. (2010). Joint forest management in India: Experiences of two decades. *Resources, Conservation and Recycling,54*(8), 469-480.

Das G.K. (2006): Sunderbans, environment and ecosystem, Levant Books, Kolkata.

DasGupta, R., & Shaw, R. (2013). Changing perspectives of mangrove management in India–An analytical overview. *Ocean & Coastal Management*,*80*, 107-118.

DasGupta, R., & Shaw, R. (2014). Role of NGOs and CBOs in a Decentralized Mangrove Management Regime and Its Implications in Building Coastal Resilience in India. In *Civil Society Organization and Disaster Risk Reduction* (pp. 203-218). Springer Japan.

Datta, D., Chattopadhyay, R. N., & Guha, P. (2012). Community based mangrove management: a review on status and sustainability. *Journal of environmental management*, *107*, 84-95.

Datta, D., Guha, P., & Chattopadhyay, R. N. (2010). Application of criteria and indicators in community based sustainable mangrove management in the Sunderbans, India. *Ocean & Coastal Management*, 53(8), 468-477.

ENVIS (2002). Mangroves of India: State-of-the-art Report. Environmental Information System Centre, Centre of Advanced Study in Marine Biology, Annamalai University, India.

Forest Survey of India (2013): State Forest Report, Government of India

Giri, C., Pengra, B., Zhu, Z., Singh, A., & Tieszen, L. L. (2007). Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science*, *73*(1), 91-100.

Giri, S., Mukhopadhyay, A., Hazra, S., Mukherjee, S., Roy, D., Ghosh, S., ... & Mitra, D. (2014). A study on abundance and distribution of mangrove species in Indian Sundarban using remote sensing technique. *Journal of Coastal Conservation*, *18*(4), 359-367.

Government of West Bengal (2009): District Human Development Report, South 24 Parganas.

Hsieh HF, Shannon SE. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288.

Hunter W.W. (1875): A Statistical Account of Bengal, Volume 1, District of 24 Parganas and Sundarbans, Trubner & Co., London (Reprinted by West Bengal District Gazetteers, Department of Higher Education, Government of West Bengal, Calcutta in 1998

Kumar, S. (2002). Does "participation" in common pool resource management help the poor? A social cost–benefit analysis of joint forest management in Jharkhand, India. *World Development*, 30(5), 763-782.

Mitra A. (2013): Sensitivity of Mangrove Ecosystems to Climate Change, Spinger, India.

Murty, T. S., Flather, R. A., & Henry, R. F. (1986). The storm surge problem in the Bay of Bengal. *Progress in Oceanography*, *16*(4), 195-233.

Melana, D. M., Melana, E. E., & Mapalo, A. M. (2005). Mangroves management and development in the Philippines.

Pagdee, A., Kim, Y. S., & Daugherty, P. J. (2006). What makes community forest management successful: a meta-study from community forests throughout the world. *Society and Natural Resources*, *19*(1), 33-52.

Parker, B. (2010). *The power of the sea: Tsunamis, storm surges, rogue waves, and our quest to predict disasters*. Macmillan.

Patel, V., & Rajagopalan, R. (2009). Fishing community issues in the Sundarban Tiger Reserve: a case study.

Paul, S., & Chakrabarti, S. (2011). Socio-economic issues in forest management in India. *Forest Policy and Economics*, *13*(1), 55-60.

Rishi, P. (2007). Joint forest management in India: An attitudinal analysis of stakeholders. *Resources, Conservation and Recycling*, *51*(2), 345-354.

Rudra K. (2014): Personal Interview

STR (Sundarban Tiger Reserve) 2013: Annual Forest Report

Suich, H. (2013). The effectiveness of economic incentives for sustaining community based natural resource management. *Land Use Policy, 31*, 441-449.

Vyas, P., Sengupta, K., 2012. Mangrove conservation and restoration in the Indian Sundarbans. In: Sharing Lessons on Mangrove Restoration, Proceedings and a Call for Action from an MFF Regional Colloquium, pp. 93-101.

CHAPTER 7: Strategies and Actions for Embankment Protection

“This is a land half submerged at high tide: it is only the falling that the water gives birth to the forest. To look upon this strange parturition, midwifed by the moon, is to know why the name ‘tide country’ is not just right but necessary.”

Amitav Ghosh in ‘The Hungry Tide’

CHAPTER 7: Strategies and Actions for Embankment Protection

The vast network of earthen embankments, spreading over nearly 3500 km in the Indian Sundarban delta, is a critical coastal infrastructure that are imperative for continual survival of the communities. Being particularly susceptible to high winds and storm surges, long term survivability of these extensive network is crucial considering the disaster resilience of the communities. During the Cyclone Aila in 2009, these embankments suffered massive damage leading to instant and prolonged flooding of the low-lying deltaic islands. Following the Cyclone Aila, the provincial and federal government of India jointly initiated a massive embankment reconstruction project costing nearly 1 billion USD. Therefore, this chapter mainly focuses on the mid-term evaluation of 'Sundarban Embankment Reconstruction Project'. By using key informant surveys with the administrative officials and experts involved with the embankment reconstruction, the chapter aims to understand technical, social and institutional features of this project. In lieu with this, considering the embankment network as a critical socio-technical system, this chapter formulates several key strategies and actions for the future sustainability of the embankments, especially considering the critical management aspects.

Outline of the Chapter 7

7.1. Introduction

Nearly 70% of the existing land of the Indian Sundarban delta is submergible under the high tide and it is the 3500 km long network of marginal earthen embankments that make human habitation possible in this extremely low-lying deltaic islands. This girdle of earthen embankments along the myriads number of creeks and tidal channels in the Indian Sundarban delta has sprung up nearly two centuries ago to prevent the entry of saline water, thereby, facilitating agricultural possibilities of the delta. Earliest reference of premature land reclamation in the delta dates back to 1770, when the north-eastern area (Haroa- Minakhan-Sandeshkhali) were reclaimed out of the dense mangrove forests because of its proximity to Kolkata (Sarkel 2012). In comparison, the south west area (Kakdwip–Sagar–Patharpratima area) were reclaimed much later during the late nineteenth century. The average ground elevation in the above-mentioned North-Eastern and South-Western area is about 1.5 meter and 2.0 meters (MSL) respectively; whereas the observed average High Tide Level (HTL) is measured as 2.75 meter., which essentially justifies the need of an extensive embankment network (Department of Irrigation and Waterways, Government of West Bengal, 2010). No wonder, the existing network of embankments plays a vital role in the daily life of communities living in Sundarban, by providing opportunities for agriculture, settlement and security against the actions of tides and waves. As have been identified during the Participatory Action Planning (see Chapter 4), communities attach great importance to the future survivability of these extensive embankment network as a necessary prerequisite for their disaster and climate resilience. In addition, it also serves as the peripheral road connecting small hamlets in these remote deltaic islands, and undoubtedly remain as the most critical and vulnerable coastal infrastructure of the delta. Although these embankments were not always of the height and stability to withstand the impact of tidal waters and sea waves, and, there has been cases of overtopping or breaches, it continues to serve as the lifeline of the Indian Sundarban Delta.

Box 7.1. Embankments of Indian Sundarban Delta

The total length of 3,500 km of earthen river embankments and coastal dykes, along with 862 drainage sluices, are maintained by the I&W Department (Mainly) and PWD (partially).

- Length of River Embankment on Major Estuaries: **700 km**
- Length of River Embankment on Medium Estuaries: **2,750 km**
- Length of Sea Dyke on the sea coast: **50 km**
- Embankments without Mangrove Cover: **More than 2000 km**

Source: District Human Development Report (2009), South 24 Parganas, Government of West Bengal

Created under the British regime nearly one and half century back to reclaim marshy lands for agriculture, marginal embankments across the small deltaic islands were mostly managed by local village administration during the British era in India. However, during the permanent settlement act in 1793, a small section (Section XXIII) were introduced about the onus of embankment. It mentioned that while the government will principally look after the embankments, local communities, especially the local landlords would also be responsible for the maintenance of the embankments. However, considering the highly uncertain agricultural revenues, local landlords declined the proposal which resulted in the formation of a state administrated Embankment Committee in 1803 for the supervision and maintenance of the embankments. In the following years, maintenance of the embankments was bestowed with Government run Public Works Department (PWD) through the enactment of the Bengal Embankment Act, 1873 (Sarkel 2012).

In the independent India, after enactment of 'The Estate Acquisition Act 1955' which abolished the landlord based revenue management system, these embankments were vested with the Provincial Government of West Bengal, initially with the District Magistrate of undivided 24-Parganas and afterwards it was handed over to the Irrigation & Waterways (I & W) Department during 1961. At present, about 3122 km length of embankment are maintained and managed by the Irrigation & Waterways Department, whereas, the rest is governed by the District Public Works Department (PWD). Although some improvements were done under the various state plans mostly on a reactive basis, considering the huge cost to strengthen or heighten the embankments, no major modification of the embankments were conducted during the previous years. In fact, as per the official reports of the Department of Irrigation and Waterways (I & W), it clearly mentions that even the proper maintenance of the existing embankments is troublesome involving huge recurring expenditure every year (Department of Irrigation and Waterways 2010). In a cost-benefit analysis, Sarkel 2012 also mentioned that the recurrent cost involved per mile of embankment in Indian Sundarban is much higher compared to any other places in West Bengal.

7.2. Impact of Cyclone Aila on the Embankment Network

The makeshift arrangement of embankment management underwent a critical break point when severe cyclonic storm 'Aila', with measured wind speed of 100-110 km per hour hit the delta on 25th May 2009. The storm overlapped with the morning high tide on the day just before of a new-moon night, and generated a storm surge of more than 3 meters above the HTL; higher than the maximum height of the most of the earthen embankments protecting the low-lying islands of the delta. This was unique in the remembered history of Indian Sundarban and highest since the independence (1947). Needless to say, the entire network of earthen embankments, especially those on the north-eastern area, lying in the path of the storm, were tested to its capacity. Overtopping of embankments occurred at numerous locations, and in several places embankments were breached. Out of total 3122 km length of embankment maintained by the I & W Department, wash out / breaches occurred in about 177 km length and a further 601 km stretch suffered extensive damage (Department of Irrigation and Waterways, Government of West Bengal, 2010). As per the official damage assessment report prepared by the South 24 Parganas District Authorities, the total length of the damaged embankments is reported as 613.785 km (**Figure 7.1**) (Office of the District Magistrate, South 24 Parganas 2010).

Following the cyclone Aila, the I & W department of the Govt. of West Bengal, upon receiving a grant of INR. 1147.0 million (18.2 million USD approximately) from the National Disaster Management Authority, initiated temporary arrangements to erect the damaged/washed away embankments. The earmarked length of 398 km long embankment was repaired on war-footing as the monsoon was approaching and the communities apprehended long term inundation due to the absence of embankments. However, the low rainfall in June, 2009 eventually prevented further worsening of the situation. Partial reconstruction of damage embankments also took lesser time. As have been reported, involvement of local people and quick utilization of MGNREGA fund lead to an active restoration process (Department of Irrigation and Waterways, Government of West Bengal 2010). However, there was a need to revisit the embankment protection scenario aftermath the cyclone Aila as the government feared that another catastrophic cyclone, even at a lesser magnitude compared to cyclone Aila, may have disastrous impacts on the delta. In view of this, a Task Force on 'Restoration of Sundarban embankments damaged by the cyclone Aila' was constituted by the Union Ministry of Water Resources in May 2009. The State Irrigation & Waterways Department submitted a proposal to the Task Force for undertaking improved reconstruction works of total 778 km length of embankment (177 km washed away or breached and 601 km severely damaged) fearing that these particular stretch would be much susceptible to future cyclones and tidal surges. The estimated cost of the up-gradation of the project was INR 50.320 billion (roughly USD 0.90 billion) and a decision was made that the provincial government will bear 25% of the developmental cost while rest of the fund will be allocated by the federal government. The project was supposedly to be completed by 2013, however, suffered from various social and technical challenges. Even during late 2014, the project remained virtually stagnant impounding the threat perception of local communities as reveled in chapter 4. This chapter, therefore, primarily attempts to understand the basic constraints of the existing arrangements

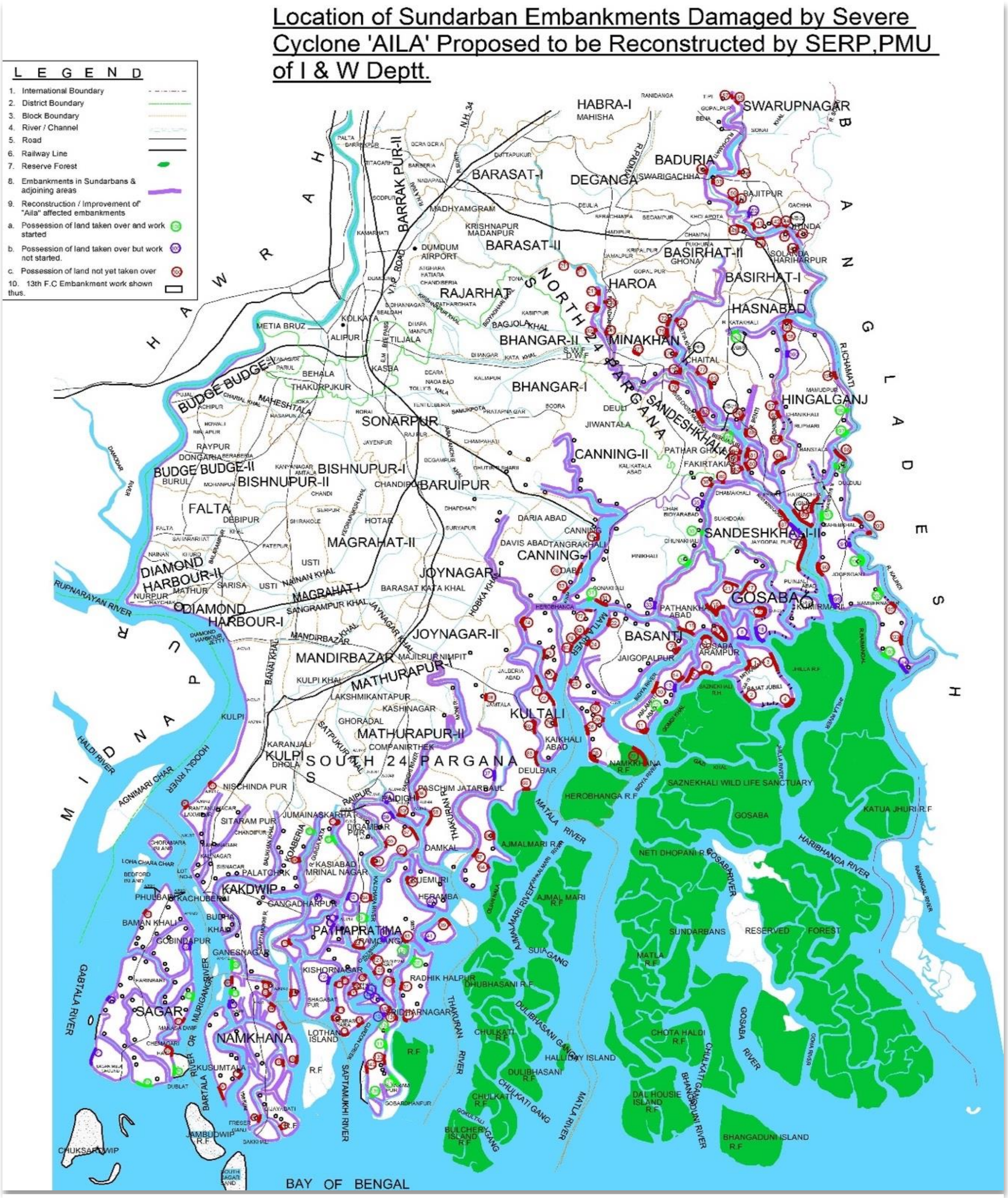


Figure 7.1. Location of Damaged Embankments and Proposed Reconstruction of Embankments in the Indian Sundarbans Delta.

Source: Department of Irrigation and Waterways, Government of West Bengal, 2010.

Figure 7.2. (A) Women crossing a breached embankment during Cyclone Aila (B) Overtopping of an embankment during Cyclone Aila (C) Sea dykes completely washed away in Cyclone Aila in Sagar Islands (D) New construction of embankments in Sagar Islands

Source: (A) & (B): Office of the District Magistrate, South 24 Parganas, 2009

(C) & (D): Author, 2012-13

of the Sundarban embankment reconstruction Project through a critical insight into its various social, technical and institutional components. In addition, it also looks at the broader embankment management system as a complex socio-technical system rather than a mere physical infrastructure and analyzes its components in details. The specific research objectives are furnished below.

7.3. Research Objectives

As discussed above, embankments remain among the most critical infrastructure in the Indian Sundarban delta and in broader perspective it represents a critical ‘socio-technical’ system that are imperative to achieve disaster resilience of the communities. Needless to say, sustainability of such systems are composed of several technical and socio-institutional factors that are complexly interlinked to each other. Therefore, apart from the timely execution of the Sundarban Embankment reconstruction Project, it also imperative that a sustainable ‘socio-technical model' is adopted that includes rigorous maintenance and effective community participation for embankment protection. However, considering the existing scenario of the delta, it is highly imperative that the execution of Sundarban embankment reconstruction project is done in a timely manner. Nevertheless, as mentioned, implementation of the project is far away from its original proposed schedule. Delayed by more than two years, execution of this project went into severe turmoil due to several social and institutional factors. In addition to this, there has been enormous uncertainty on the sustainability of some the reconstructed embankments. Therefore, it is imperative to understand the salient features of the project and its continuity in the backdrop of complex 'socio-technical system'.

The research primarily attempts to investigate the technical, social and institutional component of the Sundarban embankment reconstruction project, however, in doing so, it also attempts to narrate the future uncertainties attached with the performance of this crucial 'socio-technical' system. Hence, the basic research objective can be summarized as-

- **To understand the key technical features of embankment reconstruction project**, especially from the perspective of eco-sensitive design, local geographical scenario and long term sustainability.
- **To evaluate the key factors affecting in delay of the proposed reconstruction** of the embankment projects.
- **To identify the underlying risk of embankment failure** in future.
- **To formulate recommendation for specific strategies and action of embankment sustainability** in the Indian Sundarban delta.

7.4. Research Design

Reconstruction of the damaged embankments is a provincial government subject, which ideally means that reconstruction planning and execution would be the sole responsibility of the provincial government agencies i.e. Department of Irrigation and Waterways (I & W) of the Government of West Bengal and partially by the Public Works Department (PWD). However, it is also imperative to understand, that the local communities, being at the core of the sustainability of the embankment systems, can not be ruled out from the construction and long-term management of the embankments. For example, one of the major challenges in the recent past have been traditional way of brackish water aquaculture and intentional breeching of the embankment by a section of communities. On the contrary, in many cases, it has been observed that the local communities repair the embankments on their own, irrespective of government support, particularly, during an emergency situation.

As have been mentioned, the 3500 km long network of earthen embankments represents a complex socio-technical system. Therefore, the research essentially uses a three dimensional conceptual framework for determining the embankment sustainability against future coastal disasters, particularly from Cyclone Aila like events. The framework is furnished in **Figure 7.3.** and consists of three major components, i.e. technical, institutional and social

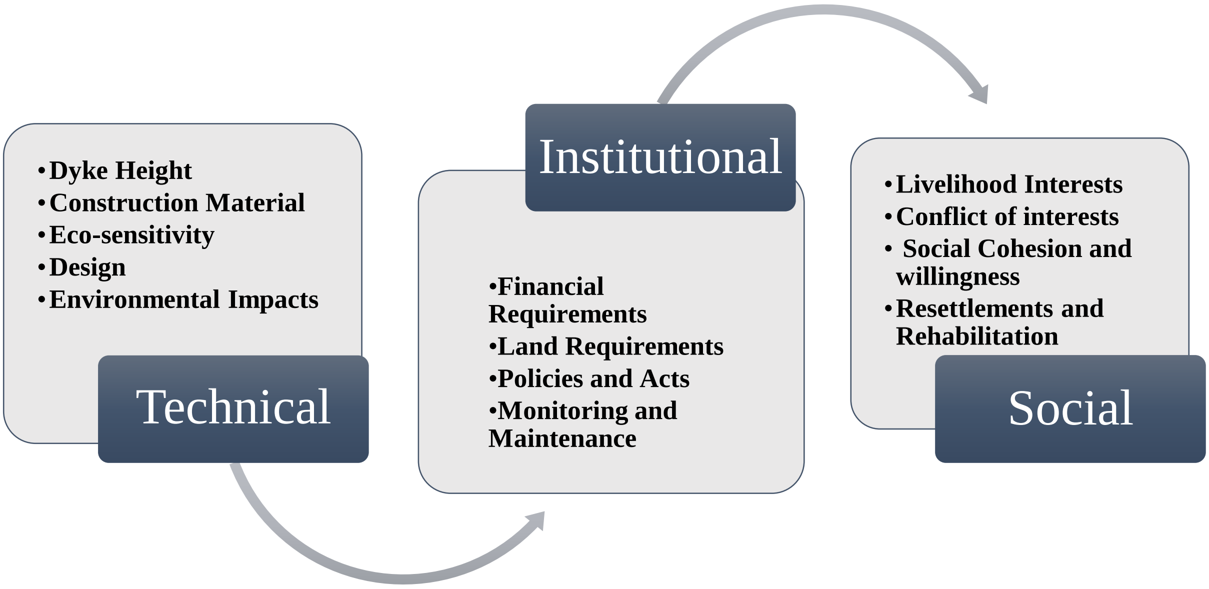


Figure 7.3. Socio-Technical Conceptual Model for Embankment Sustainability

sustainability. While technical component mainly depicts the design factors (such as embankment heights, construction methods and material, eco-sensitivity, safety factor etc.), institutional component deals with fund availability, land management, policies and acts for land acquisition etc. As mentioned earlier, social issues such as specific livelihood interest associated with embankments, social cohesion and collective decision making etc. are also important component of embankment sustainability. However, it is important to mention that these factors have strong over lapping and are broadly interlinked with each other.

7.5. Methods

As mentioned earlier, two broad objectives of this research is to understand and evaluate the salient features of the 'Sundarban Embankment Reconstruction Project' through the lens of the above mentioned framework, and to further examine future embankment sustainability under the regional scenario of coastal disasters. In order to achieve the above mentioned objectives, the research applies the methodology of key informant surveys of the project officials and technocrats including the key officials of the Sundarban Embankment Reconstruction Project.

These officials were interviewed and enquired about the specific design parameters under the technical, institutional and social sustainability of the embankment system as reveled in Figure 7.3. Several project documents including the engineering drawing of the proposed reconstruction methods were also collected from the officials. In the second step, another set of expert interview (from the field of hydro-geology, policy planning and social sciences who are aware of the local issues) were conducted with local academia/experts in order to understand/evaluate the design criteria and long term sustainability of embankments, especially against the risk of future Aila like events. The research findings were later summarized under the technical, institutional and social factors and recommendation were furnished based on the subjective evaluation of major components furnished in Figure 7.3.

7.6. Results and Discussion

7.6.1. Evaluation of the Embankment Reconstruction Projects

As mentioned, the project proposal includes reconstruction as well as improvement of 778 km of earthen embankments, which includes 18.95 km of damaged sea dykes and 758.8 km of river embankments. However, it is very important to mention here, the project is specifically aimed at strengthening of only 778 km long embankments, while, the rest is not considered for financial purposes. The choice of specific stretches of embankments is solely based on the damage caused by the Cyclone Aila and are not representative of any inclusive risk assessment. Therefore, as reveled by the officials, this project can be denoted as mostly 'reactive', although, the scale and magnitude is much higher than the previous reconstruction efforts. For instance, as the Detailed Project Report suggests

> *"...unless the reconstruction works are taken up immediately after the monsoon, the entire stretch of 778 km of embankments, either washed away or severely damaged by 'Aila', will be susceptible to failure under the possible attack at cyclone in future, even of much lesser magnitude compared to 'Aila'."*
>
> Department of I & W, Government of West Bengal, 2010

As per the nature of damage and proposed reconstruction methods, the 778 km long damaged embankments are again subdivided into six categories under this project. The detailed of proposed embankment reconstruction in Indian Sundarban is furnished in **Table 7.1.**

Table 7.1. Detailed Breakup for Sundarban Embankment Reconstruction Project

Category	Description	Length (in km)
1A	Reconstruction of washed out sea dykes to be constructed by local earth from countryside, along with block pitching on sea-side slope.	10.20
1B	Reconstruction of washed out river embankment in critical locations (length in individual stretch around 1 km or more) by dredged riverbed materials, along with block pitching on riverside slope.	28.80
1C	Reconstruction of washed out / breached river embankment at other locations (length in individual stretch generally less than 1 km) by local earth from countryside, along with block pitching on riverside slope.	137.90
2A	Reconstruction / improvement of severely damaged sea dyke by local earth from countryside, along with block pitching on seaside slope.	8.75
2B	Reconstruction / improvement of severely damaged river embankment by local earth from countryside or other suitable places and with block pitching on countryside slope, along with block pitching on riverside slope.	477.10
2C	Reconstruction / improvement of severely damaged river embankment by local earth from countryside or other suitable places but without block pitching on riverside slope.	115.00
	Total Length of Proposed Reconstruction /Improvement of Embankments	**777.75**

The following section briefly narrates specific components of this project vastly relying on the feedback received from the officials and experts and by utilizing the proposed socio-technical framework for embankment sustainability as mentioned in **Figure 7.3.**

7.6.1.1. Technical Features

- ***Height of the Embankments***

As per the official sources, the design of new embankments is based on the combination of mostly four factors, i.e. maximum observed tide level, wind speed, subsidence and a freeboard space to counter the future uncertainties (mainly subsidence). It was mentioned by the officials of I & W Department officials that the maximum observed tide level at the location of Sea Dykes is 3.90 m and for the river embankment is 4.90 m which determines the minimum embankment height. In addition to this, the design of proposed embankments is also aimed to sustain wind speed of 126 km/hr. (for sea dykes) and 100 km/hr. (for river embankments). Further, the officials expected that the dyke / embankment will consolidate the foundation soil under its self-weight both during and after its construction and will undergo gradual subsidence. Therefore, a uniform value of 0.30 meter has been adopted for all categories of embankments, considering mechanical compaction of the embankment. In lieu with this, a uniform freeboard of 1.5 meter is considered for all categories of embankments as per guidelines of Ganga Flood Control Commission. In summary, the designed height of the embankments is calculated as 8.20 m for sea dykes and 7.50 to 7.80 m for the river embankment; superior than the collapsed or overtopped embankments in the 'Cyclone Aila'. While the previous observed maximum surge level was around 3 to 3.5 meters, this height seems to be sufficient with considerable safety margin. However, the maximum wind velocity considered for the reconstruction project contains little safety margin. For example, as have been revealed by the officials, the probability of Cyclone with maximum sustained wind speed over 100kmph for the region is more than 10% (observed from the trend of cyclonic disasters in the delta). Further, as mentioned in Chapter 1, intensity may well rise in future. Considering the above, these design criteria might be inadequate for the future cyclones.

- ***Construction Methods and Materials***

The proposed reconstruction of embankments has been planned to be conducted mostly in a mechanical way, i.e. the excavation and compaction of earth materials will be done by heavy earth moving machineries. Describing the lack of adequate resources, the officials mentioned that much of the work has already been outsourced to city based construction agencies. This is quite unique, since earlier construction or occasional repairing of embankments have been mostly done by manual labor from the local villages. Even the temporary reconstruction just after the Aila has been conducted along with the local community members using the MGNREGA fund. While officials mentioned the need of mechanical compaction and technical expertise as a major compulsion to outsource the job to private agencies, they are also aware of the common disagreement among the communities, as the communities believe that they can be effectively utilized for reconstruction purposes. Particularly, following devastation caused by the cyclone Aila, community livelihood could have been substantially improved if the manual process had been adopted. In general, there are distinct bifurcation among the experts, while some puts stress on the mechanical need for reconstruction, many also argue, such as Bera 2012 that the work should have been conducted along with the communities. While one hand, the officials mentioned the requirement of using mechanical means to improve the structural efficiency, they also mentioned that directions have been issued to the construction agencies to recruit unskilled manpower from the local community (not legally binding). However, in reality the execution of this proposal is not properly followed, leading to several social and political conflicts among the communities and executing agencies.

Unfortunately, this had led only to corruption and lack of transparency of the hiring process, and many villagers have complained of poor quality work and no involvement of the local communities.

The islands in Sundarban are made of river sediments, especially silt and clay. Because of its impervious nature, it is a natural choice of construction material, and therefore, no change of construction material has been considered for reconstruction. As per the argument made by Rudra 2010 any use of concrete materials in the delta will not only be expensive, but also, be equally dangerous for the ecological sustainability of the delta leading to further clogging of the tidal river channels. However, earlier proposal to create concrete sea dyke has been dropped, and, in order to control erosion of the embankments, several alternative proposals have been planned, such as, brick lining, bamboo thatching, use of Polypropylene (PP) lining etc. Particularly, the local experts are bit skeptical about the use of Polypropylene (PP) lining, since they fear adverse ecological scenario due to non-degradable nature of this material. Bera,

Figure 7.4. (A) Brick Lining of embankments in order to control erosion (B) Bamboo thatching to protect embankments (C) Damaged embankments and newly constructed embankments (D) Newly Constructed Earthen embankment in no protective lining.

Source: Author, 2012-2014

2012 also mentioned, that its protective role is also questionable, since earlier use of Polypropylene lining in Ganga Bank Protection has not resulted in any significant improvement. However, the officials consider the proposed construction is customized to the ecological sensitivity of the region and they do not assume any adverse environmental consequences from the construction materials.

The proposed embankment will be constructed approximately 50-100 meter inside than the existing/ damaged embankments [as shown in **figure 7.4. (c)**] and to collect earth, pits of 2-meter depth has been planned 15 meter inside of the new embankments. However, one technical problem identified by the officials is that, if the soil is borrowed from the foot of the embankment, it increases the effective height of the embankment making it rather unsafe, therefore, they mentioned about the requirement of intense monitoring. However, they also mentioned that the existing monitoring framework is inadequate to have a close vigilance over the construction process. Nevertheless, there is also proposal to collect embankment material i.e. sediment deposit by dredging of 28.80 km of river bed (for construction of 1 B type of embankments), but, for all the other embankments, materials will be excavated from the islands itself. Since reallocation of the existing embankment are mostly scheduled on private land, therefore, the government needs to acquire 5996 acre of land to execute the existing reconstruction plan.

- ***Use of Mangrove as Additional Buffer***

As per the official data available, more than 2000 km of embankments are unprotected (void of mangrove cover as buffer). As have been identified during the participatory action planning, in addition to the heightening of embankments, communities attached great importance to the development of barrier plantation as a potential mean for safeguarding the vulnerable earthen embankments (see Chapter 4). Empirical evidences from around the world have also indicated that the mangrove cover helps minimize the damage from storm surges and tidal waves, by absorbing a significant amount of wave energy (see Chapter 2). This remain especially important considering the lack in safety factors for wind abatement capacity of the earthen structures. Considering this, the proposed plan for embankment reconstruction has kept some provision for generating mangrove buffers, ranging from 10-15 meters (although not very significant) in the river/sea side of the embankments. The following design, as suggested in **Figure 7.5. and 7.6**, shows the specific details of mangrove plantation for embankment protection. However, as reveled by the officials, two major problems are observed during such plantation program. Firstly, due to diurnal tides, seedlings are unstable and as result, the survival rate is significantly low. One the other hand, the I & W department planned to utilize the ‘Green Sundarban Project’ (see chapter 6) to mobilize human and financial resources for the plantation activities. However, due to partial discontinuation of MGNREGA funds, the future of plantation activities remains at a great stake. In addition to this, smaller stretch of mangrove plantation, particularly in case of the sea dykes, may be inadequate to provide any substantial protection to the earthen dykes.

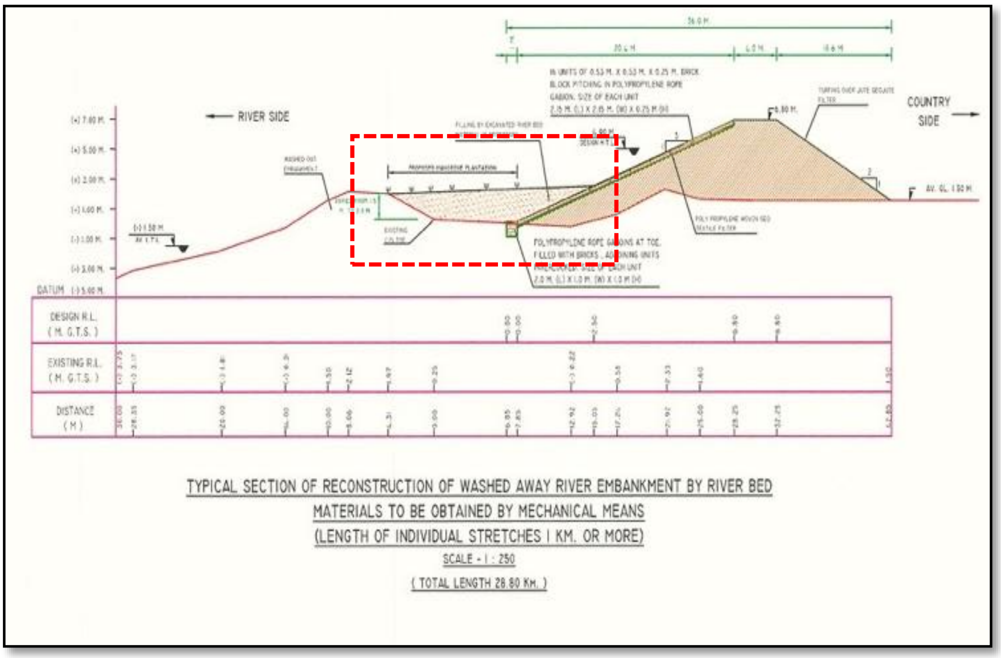


Figure 7.5. Section of Proposed River Embankments with Mangrove defense marked in Red
Source: Department of I & W, Government of West Bengal.

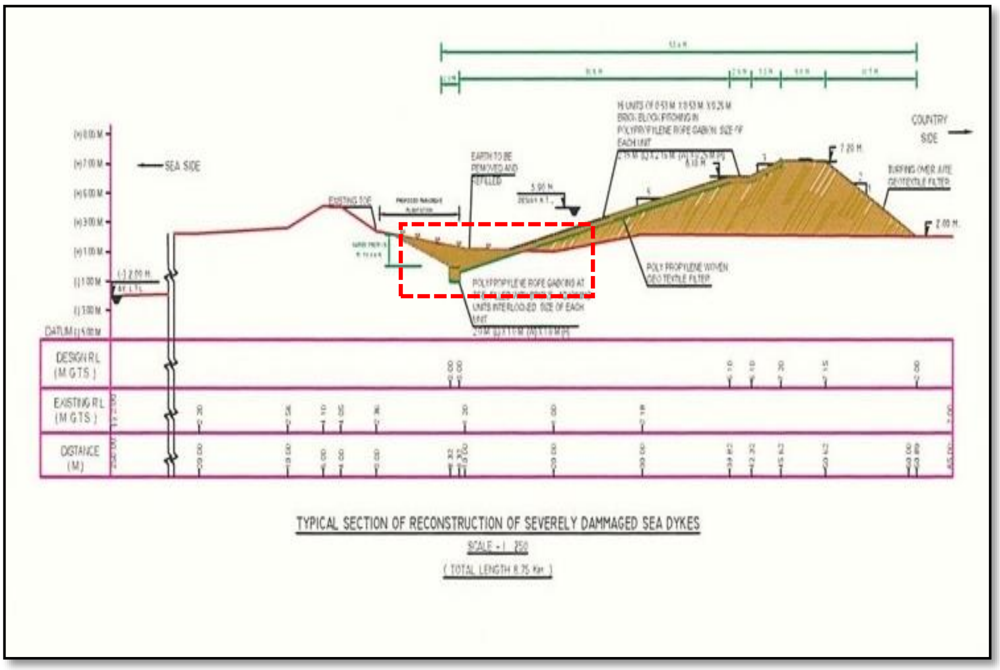


Figure 7.6. Section of Proposed Sea Dykes with Mangrove defense marked in Red
Source: Department of I & W, Government of West Bengal.

7.6.1.2. Institutional Features

- ***Financial Issues***

As have been mentioned, the project is included under the centrally assisted State Sector Scheme 'Flood Management Program' (FMP), under a pattern of funding of 75(Government of India): 25 (Government of West Bengal), which was earlier recommended by the 'Task Force'. The total revised cost of the project has been estimated as INR 5063 crores (0.9 billion USD) and allotted money will be issued in three phases. Since, the project is supported by the federal government, it attains some sort of financial assurance/security. Hence, considering the nature and magnitude of the project, particularly with respect to manage the technical as well as financial issues, a separate Project Management Unit (PMU) has been created under the I & W Department under the supervision of senior technocrats and several executives. However, it is also clear that embankment restoration would not only involve a substantial fixed cost but there are also issues of operating cost or cost of maintenance in the long run (Sarkel 2012). Unfortunately, however, there is no significant provisions for including maintenance cost for this project.

As mentioned earlier, execution of this project is majorly outsourced to city based construction agencies and it has been estimated, that in order to build every kilometer of embankment, INR 5 crore to 18 crores (roughly 1 million to 2 million USD) will go to the city based contractors (Bera 2012). It can be, therefore, argued that the amount of money could have been used to revive the local economy by providing job opportunities to the disaster affected and poverty stricken communities. Bera, 2012 also argued that the local communities and villagers were not even informed properly about the proposed construction methods, site selection, land acquisition etc. However, the officials largely denied it and cited that the delay in construction, itself is a result of longer time required to build community consensus.

Here it is important to mention, the management of embankments, at least in the recent years, were mostly done by the *Village Panchayats* by utilizing the MGNREGA fund and by hiring locally man power. National funding from the MGNREGA project, which started in 2006 and provide assured 100 days' job to the village poor, has been instrumental in gradual decline on state expenditure on embankment. Importantly, this process also facilitated decentralized management. However, Sarkel, 2009 argued that the shift from state to community based management started since nineties as the government gradually reduced the maintenance expenditure of the embankments, and even without the financial help, communities were taking the responsibilities of the maintaining the embankments **(Figure 7.7.).** Needless to say, the existing financing mechanism for the embankment reconstruction project clearly bypasses the village institutions and the communities, leading to lack of involvement and participation from the local communities.

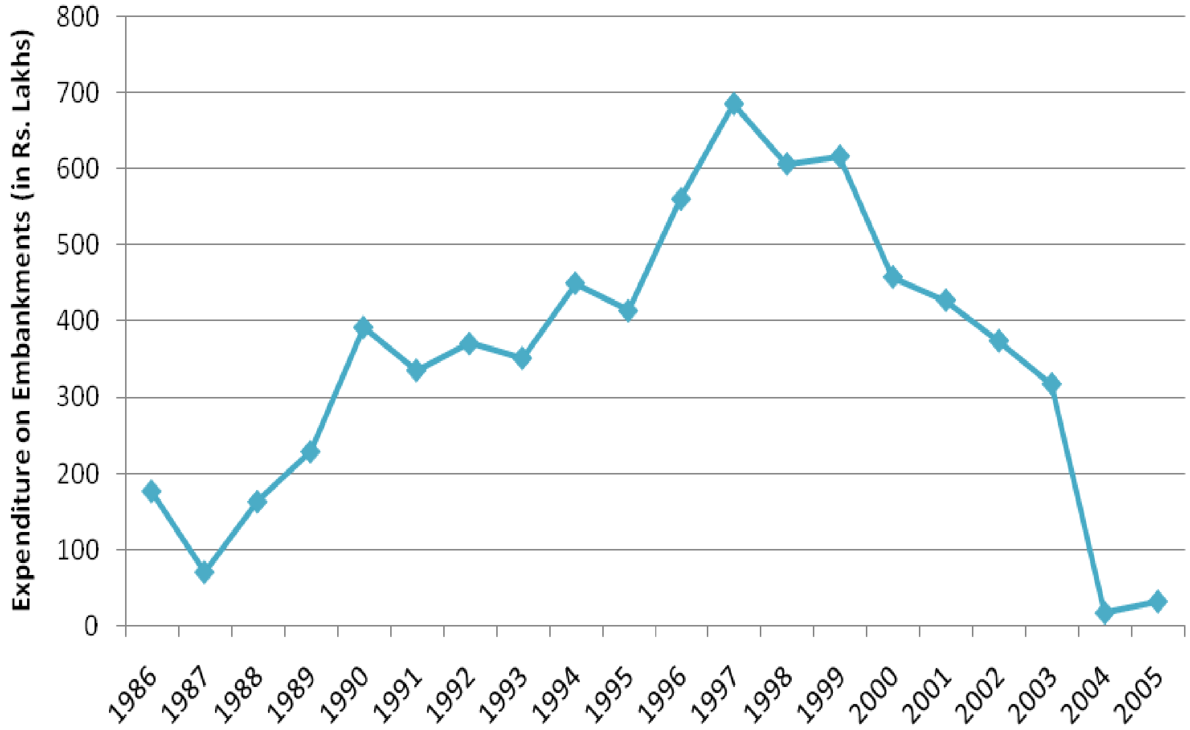


Figure 7.7. Investment on repairing work of Embankment before Aila, Source: Sarkel, 2009

- ***Land Acquisition***

As mentioned by the project officials, any work related to reconstruction / improvement of embankment will require additional strip of land of width varying from 60 m to 150 m for accommodating the section of embankment, and for making of borrow pits from which earth is to be collected (I & W Department, Government of West Bengal, 2010). The proposed embankments are much wider than the previous, extending to 50 meters in case of sea dykes and 30 meters for river embankments, hence, it requires substantial amount of land. In addition, the existing embankments are almost located at the edge of the islands leaving no room of reconstruction. Officials further suggested that in order to develop the barrier plantation, the government will consider realigning the embankments if adequate land is unavailable in the river side. Since there is no Government land adjacent to the existing countryside toe of embankment, entire land, measuring about 5996 acres, is proposed to be acquired as per provisions of Land Acquisition Act-I of 1894. The Department of I & W will take over the land from the District Land Acquisition Department of North and South 24 Parganas respectively. The amount specified is about 4195 acres for South 24 Parganas and 1801 for North 24 Parganas. Principally, the land acquisition will be facilitated by providing compensation to the land owners (as per the LA Act-I of 1984) which includes the sum of existing market prices and an additional fee of 30% over the market prices. In addition, the land owner will get market available prices for housing infrastructure or agricultural establishments. The District land acquisition officials mentioned that in lieu with these benefits, special financial packages have been established to support the agricultural labors, who cultivate over these lands, however, does not possess the land. They will be further entitled to receive a pay for 340 days as a compensation.

While theoretically the land acquisition plan sounds inclusive, District Officials mentioned that only approximately 40% of the required land could be taken over as of August, 2014. For example, in case of South 24 Parganas, out of the required 4330.785 acre of land, only 1566.141 acre could be acquired as of 24th July, 2014 (as revealed by District Land Acquisition Officer of South 24 Parganas). Needless to mention, delay in land acquisition process has vastly resulted in late execution of the project. The main drawback, as highlighted by the officials, is the absence of community consensus and vested political/financial interests. In this regard, it is important to mention the existing land acquisition policy of the state government is highly people centric, and therefore, unless individuals are specifically willing to give away their piece of land, it is rather difficult to acquire the land even for purposes that are aimed for collective benefits.

- ***Monitoring and Maintenance***

The greatest institutional challenge for the embankment sustainability remains as the absence of a robust monitoring and maintenance mechanism. As argued by Sarkel 2012, this research also confirms with the officials that there has been a series of dilemma of taking the accountability of the embankments. Particularly, officials mentioned that due to availability of MGNREGA fund, repairing and patchwork just before the Aila was mostly coordinated by the village panchayats, whereas the I & W Department had little role to play. Investment trends of embankment maintenance confirms that the provincial government owned I & W is gradually withdrawing from the management responsibilities of the embankments. While decentralization is not a bad thing for effective management, particularly considering the lack of human resources of the local I & W offices, Sarkel 2009 argued that the embankment damage caused by the Cyclone Aila was vastly predictable. He mentioned that the stretches which were damaged remained critically vulnerable prior to the cyclone Aila and the local government was well aware of the fact. It is however, the responsibilities of the local village panchayats to repair and upgrade the dykes by utilizing the fund available with them. Unfortunately, even the embankment reconstruction project, there is no clear provision about the future monitoring and maintenance of the embankments.

7.6.1.3. Social Features

- ***Livelihood Interests***

One of the critical aspect of the embankment reconstruction as well as future sustainability of the entire embankment network is the livelihood interest of certain group of people who intentionally breach the embankment for brackish water to fill the aquaculture ponds. The process in well documented in the Northeastern part of the delta where the emergence of large-scale aquaculture pond is of serious environmental concern. As argued by Sarkel 2009, this process is a major determinant for the local I & W offices to decentralize embankments management and giving responsibilities to those groups who are involved in intentional breeching. As common pool resources, this has been the major problem associated with management of embankments. However, these activities can be controlled through installation of sluice gates and the Sundarban Embankment Reconstruction Project has considered the same. However, in lieu with this, a certain section of the communities has damaged the earthen embankments for vested interests. For example, officials mentioned that many times the bamboo based structural unit used for reconstruction has been intentionally dislocated or stolen by a section of the communities. Hence, building a collective consensus is very important only to control the people with vested interest, but also to develop a participatory management scheme.

- ***Social Cohesion***

Despite of common resource sharing, political bifurcation of the communities has been largely identified by the officials as a triggering factor for delay in the reconstructions and towards the overall sustainability of the embankment network. Officials mentioned that earlier even with limited technical knowledge, they observed high rate of participation of the local communities, as they themselves took initiatives for embankment repairing. However, such type of social cohesion is largely missing probably due to high migration of male population, lack of community ‘feeling’, political bifurcation and anti-institutional sentiments.

7.7. Challenges for Embankment Sustainability

The above discussion on the Sundarban embankment reconstruction project is a close narrative of the future sustainability of the socio-technical system, i.e. the sustainability of the vast 3500 km network of earthen embankments. Although, the discussion primarily focused on the different aspects of the Sundarban embankment reconstruction project, however, in doing so, several key challenges were identified to have impacted the sustainability of the entire system. Based on the interview with government officials and in particular with those who are responsible of the management of this vast network of embankment, several key challenges were identified. **Table 7.2.** provides a component wise summary of the entire 'socio-technical system' of embankment reconstruction project and its future management, particularly aiming at the key sustainability challenges. Here it is important to mention that the sustainability or safety component is founded on author's own discrimination based on the interviews with experts as well as review of the similar case studies and consultation of technical documents.

Table 7.2. Summary of Factors Affecting Embankment Sustainability

Components	Proposed in the Project	Sustainability Factor/ Safety Margin	Key Features	Challenges	Remarks
Technical Components					
Embankment Height	8.20 meter (Sea Dykes) 7.50 to 7.80 meters (River embankments)	High	Brick Lining, Polypropylene (PP) lining etc.	Soil Collection at the foot of embankments leading to instability.	Long term erosion control is impossible with this.
Construction Material	Local Earth	Moderate	Mechanical Compaction	Lack of Monitoring Mechanism	Eco-friendly construction material but highly susceptible to erosion and human intervention, vessel generated waves etc.
Construction Method	Mechanical Compaction by city based constructors by using Heavy Earthmoving machinery	Moderate	Partial Use of locally available manual labor	Lack of community participation, no belongingness	Without the involvement of local community, it would be difficult to develop a post-construction participatory monitoring mechanism

Use of Mangrove Cover	10-15 meter mangrove cover in the riverside area	Low	Plantation by Communities through Green Sundarban Project	Low survivability, Lack of technical knowledge	The idea of mangrove buffer is imperative, however, execution needs further technical consultation. In particular, 10-15 meter would not provide the desired objectives.
Institutional Components					
Financing	Mostly Federally funded, no proper provision for management of embankments	Low	Present Funding is available only for the establishment cost	Securing funds for continuous monitoring and management	The existing funding mechanism needs to be extended for monitoring, whereas there is also a need to create funding mechanism for prolonged maintenance.
Land Acquisition Laws	Land Acquisition based on voluntary basis with compensation but without time limit.	Very Low	No specified time limit	Establishing individual and collective consensus/ Political Interferences	The existing land acquisition policy of the local government is in adequate for creating emergency public services.
Maintenance	Not specified in the project	Very Low	Partly Centralized, partly panchayat based	No clear accountability with corruption	Need for synergy between centralized and decentralized management, fulfilling the technical gaps
Social Components					
Livelihood Interest	Proposed Sluice gates	Moderate	Sluice gates for aquaculture ponds/restricting saline water	Building collective consensus among aquaculture farm owners and government	Need for negotiation and incentive based mechanism
Social Cohesion	No specified	Moderate	No mention of communities as a stakeholder in the project document	Lack of Participation of communities, political bifurcation	Need for a participatory management mechanism

7.8. Recommended strategies and Action for Embankment Protection

Performance of the embankment network in the Indian Sundarban is vital for disaster resilience as well as future survivability of the entire delta, particularly considering the rapid sea level rise, settling of deltaic islands, severe coastal erosions, high intensity storms and overall changing hydrological scenarios of the complex river systems. Needless to say, that adapting to such adverse situation is highly challenging, and it can be argued that by using these earthen fragile embankments, whether or not it is at all possible. While many argue that Indian Sundarban need to adopt some robust strategy such as 'Planned Retreat' or 'Netherland Model'[1] to control future cyclones and surges, both of the suggested strategies seems to be impossible for the delta. For example, Rudra 2010 argued that the hydrological systems in Indian Sundarban represents a unique dynamic system and any permanent structure will lead to further conglomeration of sediments in the river beds. In addition, the huge cost involved in constructing such robust engineering system is largely beyond the financial and technical capacity of the government. High ecological fragility remains another critical determinant for not advocating any high-end engineering mitigation measures. On the other hand, as per the author's interview with Rudra, 2014, 'Planned Retreat' and controlled flooding of the islands would probably help in sediment accumulation and future survival of the delta. However, considering the number of people needs to rehabilitated, this option is clearly not a feasible alternative for the government. Therefore, the Indian Sundarban delta needs to find a natural, low-cost solution which is sustainable against the backdrop of its complex social, economical and ecological characteristics. In view of the above, the best possible option is to uptake an adaptive management of the existing earthen embankment network and to ensure the integrity of these vast embankment network. However, as have been identified, the existing management of this critical socio-technical system requires several adjustments, and to enhance embankment sustainability, an integrated planning is highly imperative. Based on this, the following key recommendation are based on the specific improvement opportunities under the existing embankment management arrangements, especially focusing on its technical, social

[1]*Here the term Netherland model is meant as series of human made robust engineering structures with high resistibility against storms and surges. In comparison to the earthen dyke systems of Indian Sundarban, the dyke systems of Netherlands attain much higher safety margins and are designed to counter natural events that may occur once in a thousand year. In addition, robustness and reliability of the dyke systems of Netherlands are of international repute and considered as an Engineering approach of storm surge mitigation. Needless to say, the model is extremely cost intensive and huge recurring investment is incurred throughout the years (See chapter 2).*

and institutional components considering the long-term sustainability of these complex socio-technical systems.

a) Technical Requirements

- ***Extension of the current project to all the existing embankments***

There are no doubts that the proposed new embankments are technically more reliable than the old one, especially in terms of height, width and nature of construction. However, the extent of reconstruction covers approximately one fifth of the existing embankment network, while, the rest of the embankments are not considered in this project. Despite of the recommendation of the task force to consider a thorough assessment, only 778 km damaged embankments has been chosen for reconstruction and/or up gradation. Therefore, in line with the recommendation of the task force, it remains imperative that in the next couple of years, all the old earthen embankments are replaced gradually by improved structures. However, as argued by Rudra, new embankments also create new risks such as alteration of river dynamics that may result in local erosion. In addition, the existing scientific observations of relative sea level rise is highly skeptic. For example, while some islands continue to get eroded, new islands also emerge. Hence, it remains very important to have a thorough high resolution, hydrological and spatial scenario assessment.

- ***Control of Large Ship Movements and Re-routing***

Many of the administrative officials mentioned about the adverse impact of large ship movement in the creeks of Sundarban which generates strong waves that heavily erodes the earthen embankments. Operation of cargo vessels through Indian Sundarbans have vastly increased after India and Bangladesh signed a tread treaty in 2012, allowing movement of vessels through this eco-fragile corridor. Hence, much of the estuarine water surrounding the densely populated islands suffer from ship induced high waves. Apart from its ecological impacts, e.g. a recent oil spill in Bangladesh counterpart of Sundarbans sent a gross alarm for this high eco-fragile area, this has immense negative impact of the extensive earthen embankments in both of the country. Therefore, a scientific committee needs to critically examine this problem and find an alternative route for trade and business. The key arguments that the author encountered is that, the earthen embankments are not essentially designed for handling the thrust generated during large ship movements, particularly during the high tides. The current shipping routes encompasses densely populated islands, especially in the Gosaba block. To the best of author's knowledge, no environmental impact assessment has been conducted before introducing this routes. Therefore, these additional risks from man made activities needs to be acted upon.

b) Institutional Requirements

- ***Creation of Supportive Land Regulations***

As mentioned earlier, the major hindrance of executing the embankment reconstruction project is lack of availability of land due to unwillingness among the landowners and vested political/financial interests of some of the community members/leaders. Despite of an agreeable compensation package, this has been a problem running deep into the efficacy of the provincial government land management policy, particularly due to the lack of robustness in the state government's land acquisition policies. While such people-centric policies can be justified for industrial land acquisition, where the landowners might negotiate for a better compensation or job etc., this policy is particularly crippled when land acquisition is required for public goods or delivering community services, especially when the community's life and property remain at a stake. In order to facilitate faster land acquisition, especially considering the future scenarios, the local government need to develop a separate policy arrangement that empowers faster land acquisition for public interests. In addition, areas adjacent to the embankments needs to be demarcated as 'High Risk Area', prohibiting constructions of houses and other facilities. In short, the state government needs to create suitable legislative arrangement to enhance faster land acquisition and delivery of public goods and services.

- ***Establishing Participatory Monitoring/Management Mechanism***

Earthen embankments are intrinsically prone to erosion, and therefore, requires intensive monitoring and maintenance throughout the year, and in particular during the pre-monsoon season. As discussed earlier, the State Irrigation and Waterways department is gradually withdrawing itself from the management responsibilities due to decentralization of embankment management through the increasing participation of the village panchayats. This has been largely facilitated by the MGNREGA funding mechanism which ensures 100 days' job for rural poor. This fund, available since 2006, has been rigorously used in embankment protection. While decentralized management by utilizing local funds is prospective and are typically appreciated, it also comes with risk of lack of technical expertise, financial uncertainties and local political inferences. In view of the above, the government should facilitate an institutionalized co-management mechanism (e.g. Village embankment committee) through creation of community level institutions or groups. It is important that these groups work strongly in collaboration with the the state I & W local offices based on the recommendations furnished by I & W Offices.

c) Social Requirements

- ***Enhancing Community Awareness***

A certain part of the community, with negative vested interests, damage the embankments for various reasons such as aquaculture, construction of shops, houses on the embankments etc. Being a common property resource, it is extremely difficult for the local government for maintain a strong vigil on such activities. Therefore, community awareness regarding the sustainability of the embankment needs to be enhanced. While, the government is always held responsible for the damage, the role of communities, particularly, activities that lead to premature collapse of the embankments, can not be ruled out. Village Panchayats needs to play a greater role in protecting public interests in form of safeguarding embankments from certain groups of people.

References

Sakel P. (2012). Examining Private Participation in Embankment Maintenance in the Indian Sundarbans, South Asian Network for Development and Environmental Economics (SANDEE) Working Paper No.75-12

Bera S. (2012). Fancy Wall of Sundarbans, Down to Earth, Centre of Science and Environment, May, 2012

Government of West Bengal (2009). District Human Development Report, South 24 Parganas.

Department of Irrigation and Waterways, Government of West Bengal, (2010): Sundarban Embankment Reconstruction Project, Details Project Report (Unpublished)

Rudra K. (2010).The Proposal of Strengthening Embankment in Sundarban: Myth and Reality, Discussion paper -I, No-. 35, 2010, The Mahanirban Calcutta Research Group

Krishnamurthy, R. R., DasGupta, R., Chatterjee, R., & Shaw, R. (2014). Managing the Indian coast in the face of disasters & climate change: a review and analysis of India's coastal zone management policies. Journal of Coastal Conservation, 18(6), 657-672.

Office of the District Magistrate, South 24 Parganas (2010): Internal Report on the Damage and response of Cyclone Aila (unpublished).

Sarkel (2009): Vulnerability from Embankment Damage in Indian Sundarbans: Recent Evidence from Cyclone Aila, Working Paper, South Asian Network for Development and Environmental Economics (SANDEE).

CHAPTER 8: Towards a 'No Regret' Approach for Disaster Risk Reduction in Indian Sundarban

"… and I realized that there's a big difference between deciding to leave and knowing where to go."

Robyn Schneider in 'The Beginning of Everything'

CHAPTER 8: Toward a ‘No Regret’ Approach for Disaster Risk Reduction in Indian Sundarban

This chapter provides the conclusive arguments of this research and attempts to formulate a locally applicable disaster/climate risk reduction strategy for the Indian Sundarban Delta by incorporating specific research findings and recommendations that have been furnished in the previous chapters. The chapter firstly focuses on the human and physical developmental deficits and argues that, in order to have resilience to costal hazards and/or the possible impacts of climate change, the local and federal government need to adopt a risk –sensitive, strategic development plan for the delta. The chapter further argues that the existing development strategy, at least as per the official records, have several ambiguities, and therefore propose an alternative model which does not trigger massive investments or alteration of land uses. Despite of the fact that the region has adopted the Integrated Coastal Zone Management Plan (ICZM) as a part of sustainable development strategy, the chapter argues that inclusion of disaster and climate risk reduction component within the existing developmental plans remains highly imperative. Based on the research findings made in the previous chapters and principally focusing on the low-cost, disaster/climate risk reduction doctrine, the proposed strategy includes the application of non-engineered risk reduction through an integrated ‘No/Low Regret Approach’.

Outline of the Chapter 8

8.1. Introduction

As mentioned in section 1.4., the present research characteristically attempts to answer four vital research questions. Based on the analysis of qualitative and quantitative data, collected over the period of three consecutive years (2012-2014), the following findings can be summarized in cognition to each of the proposed research questions. The succeeding section, therefore, briefly narrates the findings of this research under sequence of each of the research questions.

- **Research Question-1: 'To what extent are the communities resilient to coastal hazards and/or the possible impacts of climate change?'**

Index based resileince assessment conducted for all the 19 coastal blocks of the Indian Sundarban region principally aimed to answer this research question (*see* Chapter 3). Based on an appropriate resilience assessment framework that was principally designed for complex coastal socio-ecological systems, the study arrived at an inference that the current disaster and climate resilience of the communities can be categorized between 'low' to 'moderate' resilience category. These categories essentially depict very limited coping capacities of the communities. The detailed analysis provided under the socio-economic and physical dimensions strongly indicated severe 'developmental deficit', both in terms of human and physical development. Therefore, the principal observation made from the assessment reveal that, despite of the region's high exposure, the existing risk of coastal disaster is primarily magnified by lack of physical and human development.

- **Research Question-2: 'Which are the key attributing factors that are impeding communities' resilience?'**
- **Research Question-3: 'Which are the precise tasks and actions required to enhance the disaster and climate resilience of the communities?**

In order to answer these two research questions, the study engaged a series of participatory rural appraisal tools (FGDs with follow-up questionnaire survey at the household level) to identify the key attributing indicators that can be considered as the 'impeding factors' behind the observed poor resilience of the communities. Taking the rampage of Cyclone Aila (2009) as the major reference point, participatory action planning revealed a multitude of problems that is believed to have resulted in severe suffering of the communities' aftermath the cyclone

Aila. In order to overcome these problems, Chapter 4 summarized a total of 18 'Tasks' and '54 broad corrective actions' that are imperative for enhancing community's resilience against coastal hazards at the very local level. Further, the ranking of tasks (indicators) through household survey pinpointed five specific indicators which remain highly important in the backdrop of community's disaster resilience. These sectors being- 'enhancing livelihood resilience', 'improve physical connectivity (transportation)', 'provisions of safe drinking water', 'conservation of mangroves' and 'embankment protection'. Nevertheless, considering a close nexus between 'community livelihood', 'mangrove conservation' and 'enhancing the existing performance of the extensive embankment network', as have been revealed by the communities during the FGD sessions and the follow-up prioritization survey, the study took up these three sectors for detailed action planning. The findings have been revealed in Chapter 5, chapter 6 and chapter 7 respectively.

Research Question-4: What would be the appropriate regional risk reduction strategy against the current and future ecological, disaster and climate risk of the delta?

As mentioned in the Chapter 3, the Indian Sundarban delta represents a complex 'socio-ecological' system and the 'lack of resilience' can be theorized by severe deprivation of physical and human development, including social, economic and infrastructural deficits such as limited livelihood, high population density, lack of connectivity, vulnerable infrastructures etc. The subsequent chapters (e.g. chapter 4, 5, 6 and 7) also highlight that the 'developmental deficits' as the core concern behind the upscaling of adaptive measures, diminishing mangrove resource dependency etc. The research also observed that lack of human development and limited economic opportunities essentially erodes the ecological resilience of the systems, as communities continue to depend on mangrove ecosystem, its product and services. Consequently, probabilities of overexploitation remain extremely high despite of significant enforcement of forest legislations. Loss of mangrove ecosystem services further adds to the existing disaster and climate risks, thereby, minimizing the natural capacity of the socio-ecological systems to rebound. Therefore, it can be inferred that the existing risk factors for the Indian Sundarban delta is actually threefold, i.e. ecological, disaster and climate risk. Hence, it is imperative to execute a risk reduction strategy which can minimize the three above mentioned risk components, on the other hand, overcome the huge developmental deficit of the delta.

This particular chapter is dedicated to formulate a 'No-regret' or 'Low regret' risk sensitive regional risk reduction strategy by inculcating the specific research findings presented in the previous chapters, especially chapter 5, chapter 6 and chapter 7. The following section attempts to justify the findings of this research with the broader arguments of developmental deficits, lack of economic opportunities to the observed poor resilience of the communities.

8.2. Summary of Research Findings: Identification of Potential Risk Contributor

As discussed earlier in Chapter 2, disaster risk reduction, on a strategic platform includes reducing community's vulnerability, controlling exposure and increasing community's coping capacity. In addition, as the Eqn. 2.3. suggested that within the vulnerability component, the main variable is the basic vulnerability which is expressed as V_b in the following equation.

$$\textit{Disaster Risk } (R) = H \times E \times V_b \times (1 - C/C_{max})$$

Where, R: Disaster Risk, H: Hazard, E: Exposure, V_b: Basic Vulnerability, C: Community Coping Capacity, C_{max}: Potential Maximum Coping Capacity. [*see section 2.2. and Eqn. 2.3. for more details*].

As have been mentioned earlier in Chapter 2, the basic vulnerability mostly denotes the poorly performing 'Human Development Indicators (HDI)' such as livelihood, education, awareness, public health, employment and physical components such as transportation, water access, access to electricity etc. As the above equation suggests, if the basic vulnerability can be substantially reduced, the overall risk factor can also be reduced, although vulnerability arising from physical location (such as living near the coast) remains constant. The theoretical argument is that a community which has high basic vulnerability also lives with higher amount of risk compared to other communities irrespective of similar exposure to disasters.

In case of Indian Sundarban, as evident from this research, basic vulnerability of the communities is strongly interlinked with the lack of physical and infrastructural development. This has been a result of historical negligence of the provincial government and a serious of dilemma arising from suspected negative ecological impacts that restricted industrial or general development of the communities. Part of the developmental deficit can also be attributed to extreme remoteness of the area and lack of financial capacity of the government. Consequently, the region remained 'backward' in terms of all the major human development indicators compared to the neighboring areas (Government of West Bengal 2009). On the other hand, despite of significant efforts adopted by the national and local government, conservation of mangroves and its vital ecosystem services were largely hampered as local communities were impelled to exploit the mangrove resources for the sake of livelihood and other daily necessities (e.g. firewood for cooking). Therefore, the Indian Sundarban delta clearly represents a complex scenario of developmental dilemma which is partly responsible for the present high risk of disasters *viz.-a-viz.* poor resilience of the communities. In particular, the outcome of this dilemma has led to primitive form of livelihood (with no diversification in the past 50 years), lack of infrastructural and economic development and an extreme remoteness resulting in the serious lacking of general well-being of the communities. Needless to say, if left unaltered, stressors such as global climate change induced sea level rise or increased cyclone frequency in the region is only expected to make the situation further worse. In order to have a more pragmatic view on how this lack of human and economic development is attributing to poor resilience of the communities, the following sections provide a chapter wise summary of major research findings and its linkages with existing disaster and climate risk of the communities (**Figure 8.1.).**

It is evident that the study area already suffers from high risk of coastal disasters, and as the **chapter 1** summarizes, the current exposure from coastal disasters is most likely to increase with the persisting trend of climate change and associated environmental factors, especially the gradual subsidence of the delta. In addition, study area specific literature review also provides a brief overview of high social and economic vulnerability of the communities against a complex regional topography that increases the disaster and climate risk by many folds.

The **chapter 2**, which is mostly a literature review, provides an in-depth analysis of contemporary coastal DRR approaches with a special focus on the role of mangroves in reducing coastal exposure and fostering resilient coastal communities. Analyzing in a comparative scale, the review indicates the prospective applicability of the Eco-DRR approaches in socio-economically deprived coastal areas, compared to hard engineering based approaches. However, it also exemplifies the grave scenario of mangroves along the South and Southeast Asian coasts and identifies the existing challenges in mangrove conservation. In particular, the literature review identified the lack of alternative livelihood as the major factor that have led to extensive conversion of mangrove forests into agricultural lands and aquaculture ponds in South and Southeast Asia, indicating a general lack of human development around the major mangrove habitats. As have been observed in the following chapters, the Indian Sundarban delta is no exception.

Detailed analysis of community resilience of the Indian Sundarban delta, as depicted in the **chapter 3**, vastly elaborates the developmental deficits of the Indian Sundarban delta in almost all the respects. For example, the majority of indicators used for assessing socio-economic resilience were underperforming, especially high density of Below Poverty Level (BPL) population with strong livelihood dependence on the limited natural resources. In addition, high rural population density with low landholdings are clear narratives of lack of rural development and limited economic opportunities. Particularly what is striking is that, nearly the entire population of the delta lives on fragile natural resources in absence of any other potential livelihood. Needless to say, when such an enormous population is directly or indirectly survives on the fragile and limited resources, conservation goals are definitely underachieved. Therefore,

Figure 8.1. Key Findings of the Research

it is imperative that in order to foster ecosystem based disaster risk reduction strategies, first and foremost, community livelihood through appropriate economic development needs to be secured. In addition, an analysis of the physical resilience of the delta is also characterized by poor communication, absence of rural electricity, water and sanitation facilities. In particular, performance of extreme coastal blocks, in this regard, are typically poor. Hence, development of basic rural infrastructure remains highly imperative to fulfill the basic human needs. On the other hand, improper coastal zone management in the sea facing blocks in terms of mangrove deforestation, land use alteration and poor maintenance of the earthen embankments are specific components that add to the vulnerability of the isolated rural communities.

As have been mentioned in the **chapter 4**, during the participatory action planning exercises with the communities, poor community resilience has been characterized by mostly five factors, especially in the backdrop of Cyclone Aila. These are poor physical connectivity (transportation), scarcity of drinking water, limited provisions of livelihood (mostly mono crop agriculture and/or estuarine/inland fishing), deforestation and degradation of mangroves due lack of community participation in the existing participatory arrangement, poor maintenance and frequent failure of the age-old earthen embankments. Conducted in the backdrop of the extensive damage caused by Cyclone Aila, the identified components can be translated into the following categories such as lack of rural infrastructures (e.g. drinking water, transportation facilities) and unsustainable human-environment relationship (e.g. mangrove degradation, embankment failure etc.).

The planning exercises for enhancing local livelihood, as discussed in **Chapter 5**, describes the primitive form of agro-based livelihood that is highly susceptible against coastal hazards. Particularly, salinization and lack of freshwater availability are the two most prominent factors that led to an agricultural drought in the post 'Aila' period. As observed in the survey, this scenario continued for more than three years leading to almost no agricultural production from the delta during 2009-2011. Although the research identified several potential adaptation options to increase the productivity and profitability from the existing livelihood, lack of land holding, economic and technical capacity of the communities are detrimental to foster large scale adaptation measures. Therefore, within the current agricultural scenario, possibilities of a sustainable agro-based livelihood look unlikely. Similar observation is also found in case of the inland and estuarine fishing, where the potential adaptation/coping measures such as tank based pisiculture, goatery etc. are also limited by lack of physical and economic assets of the community. These findings also indicate a general lack of economic and institutional support system, lack of capital and collective learning mechanism.

In **chapter 6,** the research identified that improper economic outcome from the existing ecosystem based incentives, and observed that poor economic outcome of participatory mangrove management is evidently attached to restricted or limited participation of the communities in the existing Joint Forest Management (JFM) Program. It also observed that apart from some tourism opportunities, direct cash provisions are limited. Additionally, it was observed that the mangrove management in the delta generally follows the restrictive governance principles, and as a result the existing incentive design predominantly relies on high safety margin on resource exploitation. Therefore, the chapter inferred that participatory conservation and restoration of mangroves, although superior than the hierarchical, centralized management, are at present, impaired by lack of economic reward. The research also suggested that given the goals of JFM in India (i.e. ecosystem conservation with community development), the case of JFM in Indian Sundarban can be regarded nothing more than a mere tokenism. Hence, within the existing arrangements, the research findings outline the need of 'developmental incentives' that can supplement the traditional ecosystem based incentives to lure the communities for active participation in the participatory conservation of mangroves. These incentives should be targeted at the mangrove users (irrespective of legal status) in the forest fringes and can range from basic rural infrastructures, rigorous training for alternative livelihood, promoting social business etc. In short, the current ecological risks of mangrove degradation need to be managed with active community involvement.

On the other hand, as the **chapter 7** argues, difficulties in land acquisition and developing mangrove barriers against the earthen embankments are the key factors that needs to be streamlined for enhancing structural resilience of the vast 3500 km long earthen embankment network. For the longer run, restrictive planning and planned retreat principles may be adopted in case of high erosion prone areas and extremely vulnerable embankments. However, in order to achieve this, community consensus and participation is extremely crucial. In addition, this study also observes that, in case of the reconstructed embankments, there is no long-term monitoring/maintenance plan nor a permanent funding mechanism that remain imperative to have a constant vigil over these fragile embankments. Hence, the local government, particularly the irrigation and waterways department need to develop an exhaustive participatory monitoring mechanism (e.g. village embankment committee etc.) for long-term sustainability of the embankment network. In addition, community consensus and awareness needs to be enhanced for embankment protection and management.

8.3. Existing Approaches of Coastal Development in Indian Sundarban

It is important to mention that the economic backwardness of the region has received several institutional responses throughout the previous years. Several governments, NGO and developmental agency reports exists on the Sundarban which, more or less, advocate for the Integrated Coastal Zone Management (ICZM) principles for the region. This includes sustainable management of coastal resources- including mangroves, poverty reduction of the coastal communities, sustainable fisheries and effective bio-diversity conservation. Although most of these plans and program are strong on policy front, ground level implementation is far from the expected results. Consequently, local communities continued to suffer from immense poverty and are currently devoid of basic minimum amenities. Considering this, the provincial and federal government have taken ambitious plans and projects for rapid economic development of the Indian Sundarban region. This comes as an argument for swift economic development through provisioning of external investment. This incudes extensive development of tourism, shipping ports, special economic zones, chemical hubs etc. within and around the Sundarban Biosphere reserve. Yet, most of these mega economic projects have been strongly criticized by several groups, including NGOs and civil societies. The following section lists some of the major projects that have been planned as a mean to channelize external cash flow in order to uplift this grave economic scenario of the delta.

(a) Mega Tourism Project in Indian Sundarban

In 2002, The provincial government of West Bengal signed a Memorandum of Understanding (MoU) with SAHARA Industries Limited for a potential investment of 7 billion Indian Rupees (nearly 11million USD) for a Mega Tourism Project in the Indian Sundarban Delta. This massive investment included the development of 35000 sq.km. area, including both land and water with tourism infrastructures such as hotels, water parks, floating boats, diving facilities etc. However, the project, being earmarked within the world heritage site and highly volatile ecological region, received vast amount of national and international criticism. In addition, it was reported that the project is against the general interest of the local fishermen who feared restriction of fishing zones and lack of fish catch. They also feared that massive tourism investment will also invite city based agents neglecting the marginalized local communities. Due to strong protest from the communities, the provincial government eventually withdraw from this project. However, theoretically the plan of development mega-tourist project is not abandoned yet.

(b) The Kulpi Port Complex and the Kulpi Industrial Park

The Kulpi Port and Industrial Park is a proposed industrial complex in the northwest corner of the Indian Sundarban Delta, approximately 25 km from the Diamond Harbor. The Special Economic Zone (SEZ) will combine modern all weather port facilities, a ship breaking yard, and an industrial park with a massive foreign investment of Rs. 925 crore or nearly 212.6 million USD. As per the local estimations, 150,000 people living in 90 villages spreading across 8000 acres of land will face eviction. This also includes prime agricultural land, shops and rural facilities. Being immediately upstream of the eco-fragile delta, this mega-project will bring about major water pollution and affect the fishing communities in the downstream. In addition, the project may have several adverse ecological consequences on the mangroves and its ecosystem services. Despite of significant protests from environmental NGOs and other relevant groups, Government of West Bengal gave its final clearance for the development of a ship-breaking yard in January, 2014.

(c) A modern deep-sea port in Sagar Islands

Government of India has already expressed its interest to invest massive Rs. 12,000 crores (approximately 2 billion USD) in setting up a deep sea port at Sagar Islands, while a floating LNG terminal at Sandheads; around 40 nautical miles of the Sagar coast. The massive constructions for the port with floating berths and other facilities is within the prime fishing areas. Although, if implemented, the project is expected to radically change the physical connectivity of the Sagar islands, yet, ecological risk associated with this project can not be overruled. An NGO assessment report suggests that the project will not only deny access to the prime fishing area but also massive construction works are expected to significantly damage the mangroves and estuarine ecology. Around 30,000 fishermen from Kakdwip, Sagar, Patharpratima are expected to get affected with this proposed Deep Sea Port (Disha, 2006). However, a MoU between the National Government of the provincial government has been signed in this regard in January, 2015.

Beside these projects, there are several high impact developmental projects have been planned in the Indian Sundarban Delta. For example, Oil and Natural Gas Corporation (ONGC) have extensive plan for a mega gas exploration project near the coast of Sagar islands. In addition, the provincial government is also planning to develop a chemical hub in the Nayachar islands in the Hoogly estuary. Needless to say, all these projects, if executed, will bring massive economic investment in the delta and have the potential to dramatically change the physical infrastructures. However, the key question remains that whether or not, these industrial projects will be capable of enhancing the community's ability to cope with future disasters and/or climate change, particularly when it is believed that communities have to bear the high environmental costs of these projects. It can also be argued that whether these massive investments itself are disaster or climate risk sensitive and survive for the long run, since similar approaches earlier (e.g. Port Canning) were left to ruins following major cyclones. Despite of the fact that some of these projects have faced strong opposition from the environmental organizations and yet to obtain a comprehensive environmental clearance, if implemented, the potential adverse environmental impacts of these projects will surely hinder traditional livelihood of the communities. Although it can be argued, that the projects will create vast employment opportunities and trigger infrastructural development, considering the size and stature of the delta communities, where majority of the communities are unskilled, there is not enough reason to believe that it would bring about drastic changes in community livelihood profile. Therefore, even with these massive investments, economic sustainability of the local communities is not guaranteed. On the contrary, it might lead to deterioration of the ecological scenario of the delta and may well lead to further erosion of natural resilience.

8.4. Feedback from Stakeholder's Workshop

In order to understand the stakeholder's perspectives, particularly on the specific research finding and recommendations furnished in Chapter 5, 6 & 7, a stakeholder's workshop was organized in Kolkata on 5th December, 2014. This workshop was attended by policy planners and implementers including Ministers of the Provincial Government of West Bengal and Block and District administrative officials, academia from local universities and representatives from several NGOs working on different environmental and social aspects of Indian Sundarban. The research findings were presented by the author and a 'Policy Advocacy Report' was also published. The report can be downloaded from http://www.filedropper.com/sundarbanresileincestakeholderbriefing. On basis of the research findings and a follow up group-discussion, representatives from various stakeholder's group were requested to furnish their specific opinion, comments and recommendations for developing a strategic approach for disaster risk reduction. Recommendation furnished by the various stakeholder groups are summarized below.

(a) Government officials, particularly the block officials, consented that the three prioritized sectors (i.e. livelihood, mangrove conservation and embankment sustainability) are among the prime factors behind poor resilience and high disaster vulnerability of the

Figure 8.2. (A) Author Presenting the Key Research Findings (B) Publication of the Key research outcome and Policy Recommendation Report (C) Local Block Development Officer (Joynagar II) suggesting administrators' opinion (D) Group Discussion on research findings by local academia

communities. In addition, they characteristically mentioned about the lack of human development, especially community awareness and training in their respective blocks. As per their local experiences, they particularly highlighted the difficulties in management of high soil salinity that destroyed community livelihood in the post 'Aila' period. Hence, they reinforced that management of high soil salinity and soil development for diversification of crops (crop variety as well mono crop to multi crop) as an immediate priority. Additionally, they also consented for the need for freshwater conservation/storage facilities and development of alternative livelihood to support the majority of landless communities. Regarding the mangrove protection, officials mentioned about the illegal deforestation and suggested that it can only be controlled through development of alterative livelihood. However, they observed that due to geographic isolation, such scopes are limited. In addition, some of the technical issues and legal constraints such as land acquisition for embankment reconstruction were also emphasized. The officials also mentioned about the adverse impact on the earthen embankment for large ship movements within the estuarine waters.

(b) NGO representatives typically highlighted the need for pollution control in the upstream of Indian Sundarban, particularly from the city sewage discharge which is strongly hampering the ecological sustainability of the Indian Sundarban. In addition, they also urged the government to develop land saving technology as an adaption option, by which the productivity of land can be sustainably managed. Regarding the mangrove conservation, NGO representative also affirmed the need of considering the Sundarban mangroves as a critical biosphere reserve, including both the social and ecological issues rather than just a mangrove forest. They also highlighted the need for mangrove plantation in char areas and linking livelihood programs with mangrove conservation.

(c) Academia represented by local university faculties and researchers briefly explained the need for science-policy collaboration. They mentioned about high dominance of invasive mangrove and allied species in Indian Sundarban which is affecting the ecological sustainability. In addition, the need for a thorough assessment of geological vulnerability of the delta was proposed. Particularly, some of them mentioned that the government should also prepare for a 'planned retreat' approach from the vulnerable areas of the delta.

Despite of some minor differences of opinions, all the above three groups strongly envisaged that in order to foster resilient communities, firstly the existing lack of economic and infrastructural gap needs to be fulfilled. Secondly, addressing local level risk scenario remains highly important, since the nature of ecological, climate and disaster risk extensively varies within the delta and demands differential management response.

8.5. Need for Risk Sensitive Development in the Indian Sundarban Delta

As have been mentioned before, the existing risks of the Indian Sundarban Delta is actually three folds, i.e. the ecological risks (mainly from degradation and annihilation of the exuberant mangroves and its services), disaster risks (such cyclones, storm surges etc.) and climate risk (with an assumption that the existing trend of climate change will make the coastal disasters more intensified than before). Needless to say, these risk factors are strongly inter-linked. However, what is important to recognize is that, the lack of basic human and physical development contributes to all these three risk components. Nevertheless, since the relationship between development and disaster risks are non-linear, there is a persistent need to carefully balance these components to optimum conditions. In addition, policy planners need to ascertain that the 'development' itself, should not beget any further risks.

Coastal areas, particularly estuaries and deltas are complex socio-ecological systems and keeping a balance between ecological conservation and economic development have been traditionally seen as a conflicting process (Fidélis & Carvalho 2014). While till date, the

Sundarban delta remain ecologically productive and support wide natural resource based livelihood, geographical complexity and high risk of disaster increases the uncertainty in developmental decision-making. In particular, the impacts of conventional investment based development methods might be inappropriate for such high degree of uncertainty. Therefore, while investment based social and economic development model can be advocated for the rest of the country, this is clearly not the appropriate development model for a highly eco-fragile delta like Indian Sundarban. On the contrary, industrial development, without understanding of the environmental and social boundary conditions, can be potentially dangerous and may lead to further escalation of ecological, disaster and climate risk of the delta. Hence, it remains highly imperative to formulate a risk reduction model for the delta, by which, the basic developmental deficits can be fulfilled and the three risk reduction components are carefully optimized. Keeping this in mind, the following section narrates several theoretical approaches for coastal disaster risk reduction that are existing in scientific literature.

8.5.1. Risk Reduction Approaches for enhancing Coastal Community's Resilience

In general, the existing literature on coastal resilience can be classified into three types of risk reduction doctrines that are designed to enhance community resilience in vulnerable coastal areas. These doctrines are essentially considered on the basis of 'long-term uncertainties' of disasters and climate change in coastal areas. In a comparative review of different risk sensitive developmental doctrines, Hallegatte, 2009 mentioned about three types of possible approaches, i.e. (a) selecting 'no-regret' strategies that yield net social benefits even in absence of future natural calamities and/or climate change; (b) favoring reversible and flexible options which can be propelled through restrictive planning such as restrictive zonation in coastal areas (c) buying 'safety margins' such as construction of sea dikes and hard engineering structures **(Figure 8.3).** Needless to say, these doctrines also align well to some traditional and contemporary DRR approaches, such as engineered DRR, Eco-DRR and Restrictive planning approaches (for more details see section 2.4.).

Importantly, all these three approaches have certain limitation and advantages over each other. For example, the 'No or low regret' approach which is considered as the combination of 'soft engineering approaches' are sometimes debated to have lack of robustness and visibility. Nonetheless, 'No-regret' approach is particularly suitable when the local government or the implementing agencies do not have strong financial capital or social acceptability to promote hard engineering defense to coastal disasters /climate change. As have been mentioned in section 2.4., these approaches are mostly aligned to Eco-DRR and are congruent with the *'working with nature'* principles. However, at the same time, this does not restrict the policy planners to foster resilient communities through better early warning mechanism, adaptive planning and awareness mechanism. More or less, these approaches are often regarded as community based and be fostered by bottom-up community development planning.

No-Regret Approach	Buying Safety Margin	Favoring Reversible
No- or low-regret options generate net social benefits with no or low regrets irrespective of the future outcome of climate change. In majority of cases, it represents a combination of ecological engineering with behavioral changes of communities.	Investment in technical measures to combat sea level rise, such as erecting or heightening of dykes, water retention structures etc. (Mostly referred Hard Engineering Solutions)	Favor strategies that are reversible and flexible over irreversible choices, e.g. restrictive planning or retrofitting traditional coastal infrastructures to higher degree of tolerance.
Best applicable when, (i) Financial and technology constraints. (ii) lack of adequate information on the extent of change (iii) institutional, social and legal constraints. (iv) High amount of dilemma in policy making	Best applicable when, (i) High financial and technical capacity. (ii) Social acceptability. (iii) Established monitoring and review mechanism. (Recurring Cost).	Best applicable when, (i)Already existing set-up. (ii)Social acceptability (e.g. fishermen restricted to live by the sea) (ii) Strong Policy and Institutional Support
Reversible Solutions	Irreversible Solutions	Reversible Solutions

Figure 8.3: Developmental Doctrines for Community Resilience in Coastal Areas

On the contrary, 'buying safety margin' is typically feasible when the government has strong financial and technical capacity. In general, this particular approach aligns with the hard engineering based approaches of DRR. As discussed in the Chapter 7, the 'Netherland Model' of dyke construction to protect sea level rise and sea ward hazards can be typically considered as 'Safety Margin' based approach. Buying Safety margins or probability-oriented risk reduction approach can cope well with the uncertainty of future risks, including ecological and disaster risks. This approaches are often anticipatory and depends on science based decision making. Conversely, favoring reversible approach is mostly based on the restrictive planning principles. For example, following the Indian Ocean Tsunami, many governments prevented to rebuild settlements in the vicinity of the sea. However, the major problem of this approach revolves around the social acceptability. Particularly, in case of resource dependent coastal communities where livelihood is interlinked with the sea, it is extremely difficult to promote such approach. In case of India, Krishnamurthy et al., 2013 mentioned that the country has faced tremendous challenges in implementing regulatory measures like Coastal Regulation Zone (CRZ, 1991) since the restrictive zonation was not done with proper consultation among stakeholders. Considering the above prose and cons, Cheong et al., 2013 argued that instead of promoting one particular strategy, a combination of existing approaches may provide synergic effects, although implications might vary from case to case basis.

8.5.2. Synergies and Differences between Integrated Coastal Zone Management (ICZM) and 'No-regret Approaches of Coastal Resilience'

The last three decades witnessed several emerging policies to manage highly challenging coastal areas all across the world. Among the several of these, Integrated Coastal Zone Management (ICZM) is the most discussed strategy that was an outcome of the Rio Earth Summit in 1992. Subsequently, the Agenda 21 dedicated a full chapter (*Chapter 17- Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources*) on sustainable management of coastal resources including the welfare of communities. The ICZM method essentially envisaged a long-term, holistic approach integrating human, environment and developmental components. The advocacy of the Agenda 21 gave a broader pathway for sustainable development of the coastal areas through the incorporation of integrated coastal zone management framework. Moreover, it mentioned that coastal managers should integrate broader stakeholders including the local resource dependent communities such as fishermen and other beneficiaries. Nevertheless, one of the major drawbacks of ICZM is the lack of risk reduction component in it.

Over the previous years, many countries and governments have adopted, or expresses their interest to adopt the ICZM tool of ameliorative management of their coastal areas. India also developed an ICZM plan in order to manage its coasts, however, as argued by Krishnamurthy et al. 2014, this has been crippled with inadequate institutional arrangement and lack of involvement of communities. What is evident from the previous years, that mere integration of social and ecological aspects through programs such as Joint Forest Management does not necessarily guarantee sustainable development of coastal areas, and, community participation is an essential prerequisite for implementing this approach. 'No'- or 'low-regret' options, on the other hand, are aligned to ecosystem based approaches and attempts to generate net social benefits irrespective of the uncertainties of disasters and climate change. This is based on the precautionary and participatory principles, mostly by putting reversible low-cost solutions (e.g.

enhancing ecosystem services for livelihood generation, community development etc.) that extends the possibilities of minimizing the future risks of the coastal communities.

However, it can be argued that such approaches are just an ameliorative version of ICZM approach, which not only envisages a synergy between coastal development, ecological sustainability and human well being, but also attempts to mainstream ecological services for the betterment of community wellbeing and to minimize disaster and climate risks. As have been shown in Figure 8.4., ‘no-regret’ and the ICZM approach has significant overlap among its main components. Specifically, ‘no-regret’ approach can be defined as a combination of all possible soft approaches across the social, ecological, institutional and technical systems. For example, Cheong et al. 2013 argued that in the coastal zone, ‘no- or low-regret’ options also include revamping early warning systems, preventing land reclamation, offering beach nourishments and improving housing and transportation systems. However, this approach refrains from major alteration of social, technical or existing ecological settings, rather attempts to build on this. In addition, ‘No- or low-regret options’ also envisages capacity building of the communities in order to to reduce vulnerability and contribute to building resilience (Heltberg et al. 2009).

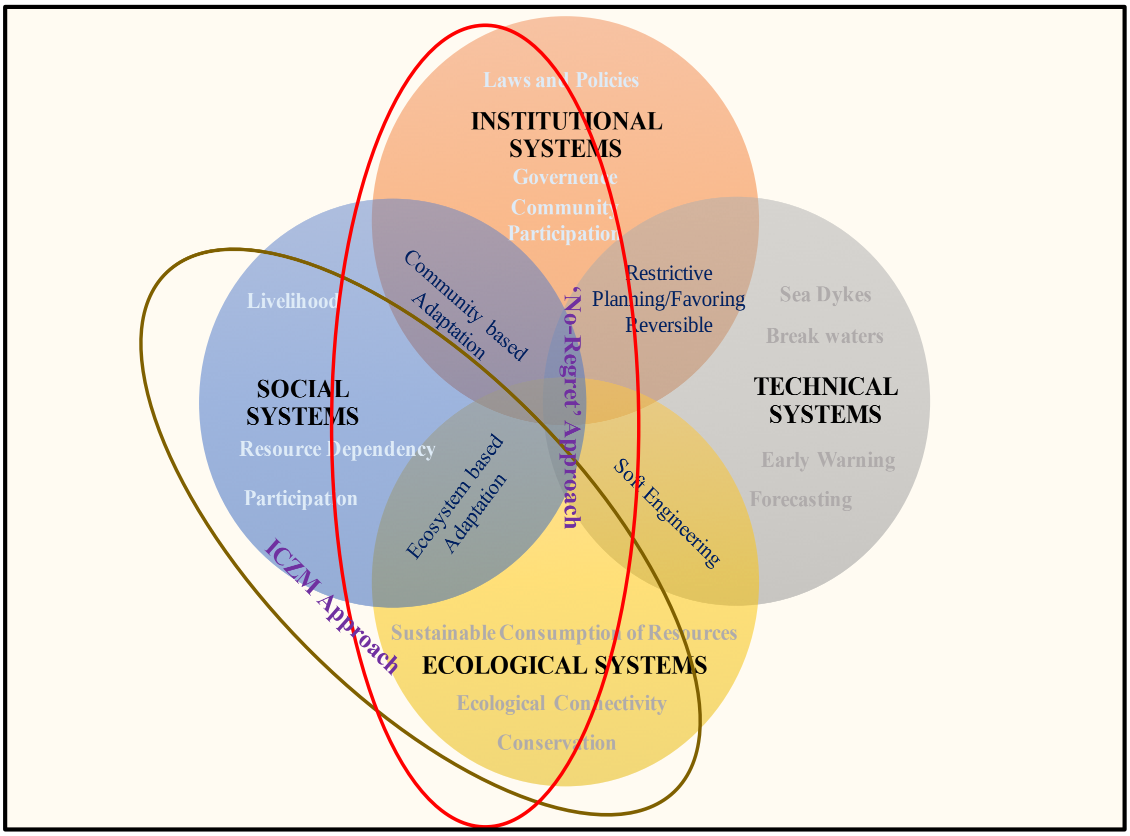


Figure 8.4. Synergies Between ICZM and 'No-Regret' Risk Reduction Approaches

8.6. A 'No-Regret' approach for Disaster and Climate Risk Reduction in the Indian Sundarban Delta

In order to design a 'No-Regret' risk reduction model for the Indian Sundarban Delta, this section attempts to club the major findings and recommendations of the previous chapters into an appropriate risk reduction model. In addition, recommendation suggested during the stakeholder workshop was also taken into consideration. This model essentially advocates for implementing a risk sensitive economic development plan which depends on combining social and ecological engineering for fulfilling the current human and infrastructural deficits. Needless to say, the proposed 'No regret' development model aligns mainly with the Eco-DRR and CBDRR principles and primarily attempts to enhance the poor community resilience through risk sensitive local development. Considering the risk profile of the delta which varies extensively at even the block level, the model primarily considers the block boundaries as the units for implementation. In lieu to this, the model essentially advocates for adopting a bottom-up, participatory risk reduction strategy than the conventional, hierarchical approaches.

The model is comprised of four essential components of DRR based on the recommendation furnished in recently concluded Sendai Framework for Disaster Risk Reduction (SFDRR). These areas being-

(a) ***Reduce already Developed Risks*** which is the current human and infrastructural developmental deficit, for example, reduction of poverty and improving local economic alternatives, facilitating swift and safe connectivity etc. In addition, this also includes the possible mangrove restoration in the blocks which suffered mangrove degradation over the previous years as well as historically. (b) ***Strengthen the Disaster Risk Management (DRM) components***, particularly by developing local capacities and emergency response mechanism. This also includes a precautionary monitoring mechanism for the vulnerable infrastructures such as embankments and basic rural infrastructures e.g. drinking water tube wells, cyclone shelters etc. (c) ***Reduce the underlying risk factors***- This includes controlling further degradation of mangroves and protection of earthen embankment from future failures. In addition, this also includes proper zonation in the small islands and gradual provisioning of planned retreats from extreme vulnerable areas. (d) ***taking care of the future uncertainties***, mainly focusing on implementation of planned adaptation process for sustainable livelihood, long-term management of earthen embankment systems etc. Nevertheless, these four components, as mentioned above, are closely interlinked with each other. As marked by blue arrows in **Figure 8.5,** this can be argued as a combined entity rather than specific component.

In order to implement this model, the study proposes a theoretical implementation strategy which is essentially is divided into three components, i.e. **Low Impact Economic Development**, **Developmental Incentives and thirdly, community development**. Here it is important to mention that by the term Low Impact Economic Development (LIED), the model favors economic interventions that are reversible, can count on less cost to install, have lower operational and maintenance (O&M) cost and provide more cost-effective measures of future disaster/climate risk reduction (MacMullan 2007). Technically, Low impact Economic development (LIED) is known to be an alternative economic development approach that is intended to reduce the adverse ecological impacts and utilize the ecosystems or environmental services for the betterment of the communities. In this model, it is argued that in order to enhance the economic capacities of the communities as well as to reduce high poverty, LIED approach is the most suitable approach in the backdrop of the Indian Sundarban Delta. Often attributed to 'Ecosystem based developmental Approach', LIED is not only sensitive to the ecosystem services, but also does not attract massive societal changes, such as community structure, traditional livelihood profile etc. The superiority of LIED over the conventional high investment based development approach can be broadly summarized in the following points:

(a) Firstly, LIED deals with small capital investments and therefore, remain much feasible under the local government's financial capacity. In addition, it does not attract massive external investments from the national government or private sectors.
(b) The principles of LIED are based on the '*building with nature*', therefore, possibilities degradation of essential ecosystem services are far less than the conventional developmental approach. In addition, it promotes the methodical utilization of ecosystem services for community benefits, thereby, fostering economic and ecological resilience simultaneously (e.g. barrier plantation, making space for flood water retention ponds etc.)
(c) In addition, LIED, in general, has greater social acceptability, since, it does not aim to alter any massive changes in the social structures, community profile and livelihood etc. This remains imperative as the suggested model for risk reduction is essentially participatory in nature.

The second part of the model, i.e. 'Developmental Incentives' is the possible funding scopes and sources that can be utilized for facilitating the LIED. Considering the existing poor economic scenario of the communities, it remains imperative that some of the economic interventions should be used as 'incentives' for the communities, rather than only as capital investment. Thirdly and most importantly, the last of component of the model includes 'Community Development' as a key strategy for disaster and climate risk reduction in the study area. The following section discusses in details about the the proposed implementation plans, priority sectors of investments and major funding sources and the potential areas of community development. **Figure 8.5** draws a schematic flow of this model. The following section elaborates the specific perspectives of this model in greater details.

(a) Low Impact Economic Development

The key argument of this chapter is the high developmental deficit that makes communities extremely vulnerable to natural disasters and contribute to their poor resilience. In order to overcome this developmental gaps, this chapter argues that there is no immediate need of massive investments as mentioned in section 8.3. However, the existing income and economic gap can be gradually overcome by investing in key sectors of rural development and strategic small scale investments. A social business model can be applied for facilitating the much desired economic development of the communities. Based on the research findings, the following potential areas remain heavily imperative that requires significant investment in order to facilitate the community's economic growth. Nevertheless, the scope of LIED is certainly not limited to these identified sectors and can be diversified based on the local priorities and community feedbacks.

Firstly, the provincial government should provide its main thrust on developing a **sustainable agriculture model** for the delta, which have been the traditional livelihood for the majority of the communities. Developing agricultural utilities such as seed conservation center, implementation of ameliorative farming methods, incentives for farm modernization are some of the potential areas to invest, keeping in view of existing economic risk reduction of the local farmers and fishermen. Specific investment is required in the field of developing agricultural extension centers, capacity development of the local farmers and fishermen, construction of sluice gates, providing market intelligence to the communities to help them to achieve better economic outcome. Local government also need to establish and coordinate with agricultural research centers (such as Central Soil Salinity Research Institute, Canning or the extension centers of Bidhan Roy Agricultural University) and ensure a 'Lab to Land' policy with continuous improvement of agriculture and estuarine fisheries. However, for the longer run, as mentioned in chapter 5, the local government including the Block Offices and the village panchayat also need to prepare for a planned adaptation process for which a dedicated block specific adaptation plan needs to be prepared with proper consultation with the communities. As mentioned in Chapter 5, adaptation intentions vary with individuals, and therefore, prior to facilitating any plan, creating a consultative platform is highly imperative.

Another priority sector of possible LIED is developing **water harvesting structures**, particularly fresh water ponds and reservoirs. Despite being surrounded by water, what is important to understand that the majority of the delta is void of fresh water resources which is impairing several livelihood and social development aspects. This has been traditionally a major challenge for crop diversification or cultivation during the lean season. In addition, as mentioned in chapter 5, this ponds can be used for fresh water aquaculture and development of localized irrigation facilities. State Government Flagship Rainwater Harvesting Project of '*Preserve Water, Reserve Water'* has high significance in this regard. The local government, particularly the block offices should put its priority to enhanced facilitation of these project. At the same time, risk proofing of the existing water resources remains highly imperative. For example, nearly 160,000 water ponds were destroyed during the cyclone Aila. These ponds need to be rejuvenated with dyke construction. In addition, as mentioned during the participatory planning exercises, heightening of the existing tube wells also remain crucial.

The third important sector is to **connect rural producers to urban markets**. As discussed in chapter 5 as well as chapter 6, local farmers, fishermen, forest product collectors are deprived of getting access to urban markets which has higher demand for the products and ensures a better price. This is primarily because of high transportation costs and time required to travel that the communities can not afford. Establishment of connecting markets and storage centers and ensuring that the rural producers get a fair access to the nearby urban markets should be an immediate priority for market based economic development. Creation of booster markets at strategic locations with proper access to urban markets, therefore, need to be facilitated. In addition, an apex body at the block offices can be created for providing the local communities with market intelligence, so that suitable crops and vegetables can be grown.

The fourth component of possible LIED is to enhance **rural connectivity**. Majority of the Indian Sundarban Delta, particularly villages close to the mangrove forests suffer from remoteness and this has been traditionally the root cause for not having access to employment, health and other essential facilities available in the nearby areas. While the water transportation

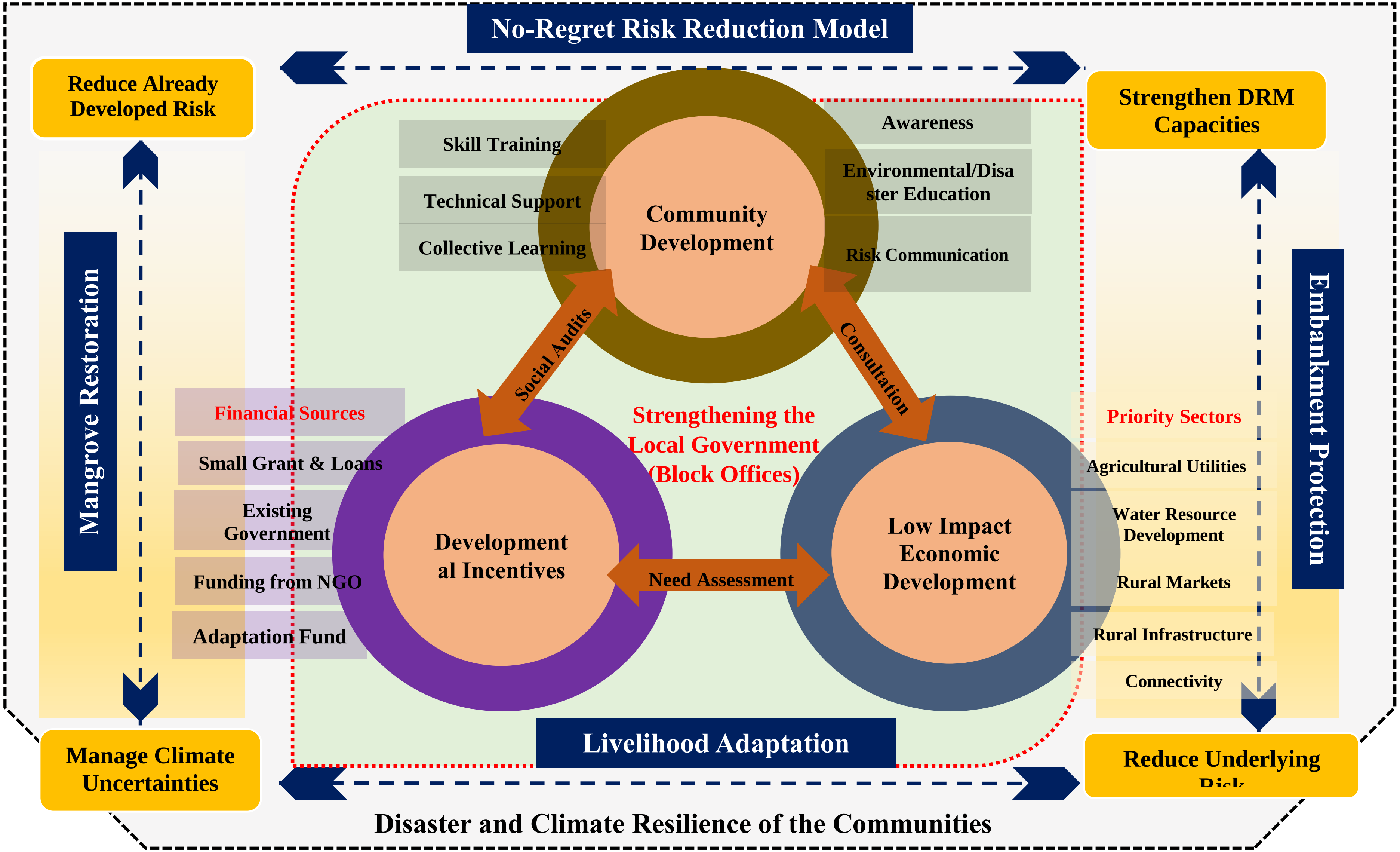


Figure 8.5. ‘No-Regret’, Participatory model to enhance Coastal Community’s resilience in the Indian Sundarban Delta

is primitive, conditions of roads in rural areas are extremely poor. Enhancing rural connectivity remain a major priority for the local government since long, however, in reality the problem remains unaltered. Better connectivity would not only facilitate rural employment but these will also give an access to rural development in some of the remotest part of the delta.

Another developmental priority is fulfilling the gaps of basic **rural infrastructural development** including the access to drinking water, energy, banks, health facilities, education, cyclone shelters etc. This is particularly important for the sustainable management of the forests since villages surrounding the reserve forests are mostly devoid of the basic facilities and often depend on the forest resources for various daily necessities including fuel wood (which is considered as the major cause of deforestation). Sustainable mangrove management can only follow when communities get the basic utilities, otherwise irrespective of legislations, it would be difficult to implement the existing forest legislations.

It is important to mention that while the above mentioned sectors need urgent priority, associated sectors can not be overruled. Also, development of rural infrastructures should be need-based, which can be determined through creation of a participatory platforms. Rural empowerment and need based economic development, therefore, remains crucial.

(b) Development Incentives

The key argument of the proposed ‘No-regret’ model that some of the LIED measures should come as incentives rather than investments to make the existing ecological conservation initiatives robust and dynamic. In lieu to this, developmental incentives are also required to improve the local livelihood scenario, infuse adaptive practices and community development at large. This is particularly in line with the recommendation furnished in Chapter 6 where it was observed that current ecosystem based incentives for participatory mangrove management are insufficient to warrant effective community participation in the existing JFM arrangements. The key argument, is therefore, to supplement the ecosystem based incentives with developmental incentives as and when necessary. Particularly, villages surrounding the mangrove forests characteristically suffer from high developmental deficits and therefore it remains imperative that such deficits can be fulfilled with direct or indirect assistance. In addition, the chapter 5 also mentioned about lack of upscaling of the promising adaptation options as a result of the financial and technical incapacity of the communities. The key argument that are made in this strategy that developmental incentives should act as a psycho-social accelerator and an economic catalyst to community development. These can be facilitated by the creation of local market and better pricing or marketing of forest products, arranging sluice gates for flood control, providing scientific fishing nets and training for livelihood diversification, rehabilitation for prawn seed collectors, promoting disaster insurance, counseling and guidance etc. Fortunately, there are number of potential funding sources to support these initiatives, especially from the federally administered social development projects. Meaningful and strategic implementation of these projects, therefore, remain highly imperative. In the following section, some of the potential funding mechanism and financial sources are shortlisted.

Firstly, **small grants and loans** can be used as potential incentives for the communities considering the economic backwardness of the delta. For example, this arrangement already exists with the Eco-Development Committees as they receive an annual revenue from the local forest department in return to their contribution in forest protection. However, apart from economic incentives which largely target an institutionalized body where the individual benefits are undermined, developmental incentives may be aimed more at individuals or sub-groups. Particularly with respect to ecological conservation, local forest department receives a good amount of fund for the forest protection which can be spent over diverse non-forestry budgets including provisioning of community livelihood, creating rural job opportunities etc. Some of these fund can be also utilized on providing small grants/loans to marginal farmer's or fishermen, both individually or to the cooperatives, for livelihood diversification and promotion of some ameliorative measures for income generation. The same can be taken up by the civil government, especially by the block offices and village panchayats. Small grant or loan can also be supported with capacity development program to promote alternative livelihood. On the other hand, as mentioned above, rural banks and financial institutions can be formed by the intervention of local government to support the communities to obtain small grants or loans for livelihood improvement projects. In addition, a social business model can be adopted by the local government, which will be highly imperative in the backdrop of the study area.

Majority of the current developmental programs run by the state government of West Bengal in the Indian Sundarban region are from **nationally funded schemes** in various social development sectors. These schemes are particularly important for the communities, however, are subjected to several managerial constraints. For example, one of the potential livelihood scheme such as National Rural Employment Guarantee Act that provides 100 days assured job opportunities to the poor unskilled workers (through the village Panchayats and the local Block

Offices) have been under several criticisms including untimely and delayed payments, lack of reliability, lack of continuity and political favorism. This scheme is an assured way of funding and can be diversified for a multitude of rural development projects such as construction of roads, ponds and water harvesting structures and even for mangrove plantation. For example, the Green Sundarban project, which was adopted just after the Cyclone Aila envisaged barrier plantation through generation of rural livelihood is a good example for effective utilization of such scheme. However, the challenge is to mainstream such projects and timely execution. In addition, linking several other developmental assistances to ecological conservation remain highly imperative for the local government which currently remain underutilized. Assured employment during the lean season by proper utilization of these projects can be a great incentive. In this respect, timely execution of other social development schemes, such National Rural Drinking Water Mission, Rural Road Construction Projects, Rain water Harvesting schemes should also be a priority of the local government. It is also imperative to implement these project through active community participation in order to facilitate rural livelihood as well as to improve the sense of belongingness.

Being a Critically Vulnerable Coastal Area and a regional Hot Spot of Climate Change, the Indian Sundarban Delta have attracted several national and international NGOs and **funding from developmental agencies** including World Bank, UNDP and many other institutions. Here it is important to mention that these funding are mostly project based and occupies small territorial domain. Despite of this, they continue to remain a potential source for community development with relatively high technical expertise. Despite of that, it can be observed that many of them are concentrated in the same hotspots. Hence, management of NGOs with the perspective of regional development is important. On the contrary, the NGOs should also make a coordination plan with the local government agencies, particularly with the District and sub-district government agencies rather than working in isolation. Developmental benefits provided by the NGOs needs to align with local government's development plan. In addition, as successfully implemented in parts of Bangladesh, the scopes of social business, rural banking and micro-finance can also be explored by the NGOs.

One of the specific recommendation made in the Chapter 5 is to create an **Adaptation fund** at the district level to facilitate the adaptation process which includes farm mechanizations, diversification of crops, dual crop cultivation, production of salinity resilient crop etc. The existing adaptation process is mostly driven by NGOs and remain very much localized to the project sites. While there is a requirement to scale up the possibilities, it is also imperative to understand that the government need to provide a start-up fund by the mean of loan or grant to facilitate such processes. Importantly, the federal government of India has recently (2015) established a dedicated adaptation fund under the Ministry of Environment, Forests and Climate Change (MOEFCC) with an initial start up fund of Rs. 350 crores for the year 2015-2016. According to a press release made available by MOEFCC, the National Bank for Agriculture and Rural Development (NABARD) has been appointed as National Implementing Entity (NIE) responsible for implementation of adaptation projects. In lieu with this, the state action plan on climate change has also outlined the provision of adaptation funding. Nevertheless, the implementation mechanism of this fund is not yet properly established. Considering the coordinating abilities of the district administration, it remains imperative that this funds are utilized through the district administration. In particular, the district agriculture and fisheries department need to establish strong collaboration with NABARD in this regard.

(c) Community Development

The success of 'no-regret' risk reduction doctrine essentially depends on the performance and participation of the communities at risk. Therefore, the suggested model is incomplete without a strategic action plan of community development. Although, the concept of community development encompasses broad dimensions, the model especially focuses on six main components i.e. creating community awareness on the existing environment and disaster vulnerability, skill training for diversification of livelihood, promoting environment and disaster education, technical support and capacity development for livelihood adaptation and lastly community based risk communication and collective learning mechanism. In the following section, the scope of the above mentioned interventions are briefly described.

Among the several important components of community development, as identified in this research, **technical support and capacity development** may prove highly effective against the multiple problems faced by the local communities, especially the farmers with possession of land. The existing scope of training of farmers, fishermen or local communities are limited to some sporadic government training program which mostly depends on occasional funding from the state government. As have been identified, lack of technical knowledge is also a potential factor that is restricting the mass applications of the suggested adaptive measures. However, there are scopes for decentralization of these training program with local NGOs to increase its effectivity and community reach. Another important aspect of these training programs is that, it should align with the market demands and should be capable of supplying suitable manpower and to achieve the desired objectives. In lieu with this, the existing training program need to be scaled up, particularly in the remotely located extreme coastal villages. In particular, the training should be provided to the rural farmers for taking up intensive adaptation measures against the existing environmental adversities. In addition, technical support for crop diversification, promotion of intercropping, breed selection, and training for dual use of agricultural land remains imperative. There are already some capacity development projects taken up by the local government such as customized training to farmers and local fishermen under the Block agricultural extension officers. Also, agricultural fairs and exhibition are organized for wide dissemination of knowledge. However, this ameliorative practices needs to be further enhanced and scaled up to some of the remotest corners of the delta.

As have been observed in this study, a significant portion of the communities (54%) are landless. One of the signature characteristics of the cyclone Aila was huge outward migration of more than 60,000 people that mainly consists agricultural labors. For this vulnerable population, skill training and development of alternative livelihood remains imperative. **Skill training** may include training for making rural handicrafts, ornamental fisheries, hospitality services for promoting ecotourism etc. As suggested in Chapter 6, vulnerable occupation groups such as prawn seed collectors can be diverted towards this alternative livelihood through skill training. This can be aimed at individuals as well as the existing Self Help Groups (SHGs). The implication of skill training will certainly reduce the dependence on mangrove and allied resources and can be brought under the proposed incentive based forest management. However, the capacity of the local government as well as the forest department is extremely limited in this regard. Therefore, it can be outsourced or jointly implemented with the local NGOs.

Community awareness is fundamental for inclusive resilience against natural disasters. As have been observed during the participatory action planning, the communities are, in general, highly aware of the ecosystem services of the mangroves. This was observed through intensive prioritization of mangrove based corrective actions which largely denotes the high environmental awareness. However, the perceived environmental awareness seldom gets translated into desired actions due to limited livelihood opportunities and chronic poverty in the area. The increasing rise of forest crime are a clear narrative of this problem. Hence, environmental awareness needs to be further strengthened at the local level through incorporation of awareness programs like street plays, public meetings, distribution of flyers etc. In terms of disaster awareness, the study observed limited knowledge of communities (for e.g. intentional breaching of the embankments, lack of safety arrangements in boat transportation etc.) which justifies the observed poor resilience of the communities. Therefore, it is important to enhance community's disaster awareness by imparting disaster drills and special training on day-to-day disaster reduction measures. Unfortunately, the initiative adopted by the local government after cyclone Aila by hiring and training local youths as civil volunteers have largely faded out due to lack of available funds. Therefore, this mechanism of training rural youths as emergency volunteers as well as to enhance community's disaster awareness is highly imperative. In addition, help from the local NGOs can be sought for organizing public awareness camps.

In addition to public awareness, incorporation of specific **environmental and disaster education**, both formal and informal, is essential for a resilient community. The region experiences highly varied literacy rates across the Blocks. As mentioned in Chapter 3, literacy plays an important role in fostering resilient communities which was illustrated in the comparative analysis of the blocks. Considering the role of education, both formal and informal, the local government should promote disaster and environmental education in the region by incorporating specific curricula at the schools. In addition, informal education such as emergency first-aid, vocational training on construction of resilient housing structures, making of life jackets out of locally available materials etc. should be promoted in the education for youths and adults. Innovation for informal education and curriculum design serves as one of the potential sectors for disaster risk reduction. In addition, since the communities are highly of the local hydrological scenario, especially the river dynamics, the scope of exploring indigenous knowledge for risk mapping can be a suitable input to localized DRR education. Unfortunately, the current scopes remain heavily limited and therefore, the local government should explore the possibilities for promoting environment and disaster education.

Last but very important aspect of community development in this delta is effective **risk communication** and **collective learning** from previous disaster experiences. Historically, the region of Sundarban has been subjected to number of natural disasters. Therefore, the risk experiences from elderly people should be taken into consideration and should be shared among the community. Collective learning from previous disasters as well as from the cyclone Aila is, therefore, very important for effective planning in response to future disasters. This learning experiences should be shared and documented through the Block Disaster Management officers and can be incorporated in the Block Disaster Management Plans. At the community scale, this can be achieved through various meetings held in the collective learning platforms shared by common interest groups like JFMCs, farmers' groups and SHGs. These platforms can also be utilized for sharing of adaptation experiences, local climatic variations, evacuation planning, livelihood counselling etc. Although many studies have indicated about limited community information during the cyclone Aila. In general, a major improvement in local government's risk communication strategies has been observed which is facilitated through utilization of existing human and social networks. The information received at the Block level are channelized through the Gram Panchayats to the civil volunteers in different villages. This practice needs to be followed more ardently to strengthen the risk communication process. However, for climatic uncertainties, especially for the resource dependent communities, intensive climate warning system should be developed. District agricultural department may play a significant role in developing the local scale climate warning system.

As have been mentioned, the central idea of 'No-regret' disaster and climate risk reduction approach is to enhance the community's coping capacities through proper utilization of ecosystem services and by enhancing the social and economic capacities of the rural resource dependent communities. The suggested model, as described in this chapter, especially focuses the existing development deficits and limited coping capacities of the communities and attempts to overcome the challenges through utilization of the LIED, Development incentives and strategic community development. As per the key findings of this study, the thematic areas identified for LIED, i.e. agricultural utility, water harvesting structures, markets, physical connectivity and rural infrastructures remains highly imperative from the perspective of mangrove conservation, improvement of existing livelihood, and in general, overcoming of the developmental deficits. The second component, i.e. developmental incentives is suggested as a potential mean for community development, in terms of promoting adaptation measures, livelihood diversification and capacity development. The third component, i.e. community development, largely attempts to fulfill the lack of coping capacities of the communities through proper interventions in community development.

The suggested model is essentially participatory in nature and it requires bottom-up planning and implementation. Although the study identified the potential areas for LIED, as mentioned in Figure 8.5., this demands a comprehensive and **participatory need assessment** at the block level. Importantly, as suggested earlier in chapter 4, disaster resilience is essentially a 'property of place'. Therefore, development priorities are expected to vary at local scales. Hence, before implementing, the local administrators need to be sure of the local priorities. This also remain imperative for designing the developmental incentives, since the requirement of development incentives may also vary according to the community profile. In the second step, a **consultative** platform is required to design community development programs that can sustain the scopes and opportunities defined under the LIED interventions. This includes customization of training programs based on demands, social structures such as literacy rates, community profile etc. Again, the role of local government, especially the Gram Panchayats and Block offices remain highly important. Lastly, in order to evaluate, whether or not, the suggested intervention is essentially providing the desired results, **social audit** mechanism can be adopted for a participatory evaluation and feedback mechanism.

(d) Implementation Plan

In order to implement the above mentioned model, it is imperative to identify and pin-point the potential implementers and stakeholders. It is important to note that apart from the communities, <u>the two main stakeholders in the suggested risk reduction model are the local government (including Block offices and Gram Panchayats) and the local forest department (range and beat offices),</u> especially in the mangrove fringing blocks. Despite of the fact that some NGOs have fair bit of stake in specific locations of the delta, involvement of NGOs in regional development process is much limited in Indian Sundarban as compared to the counterparts in Bangladesh. As have been identified previously, communities, in general, attach greater importance to the local government (see Chapter 4). This also provide the essential background for implementing a participatory risk reduction approach applicable at the local scale. As mentioned, the model provided at Figure 8.5. summarizes the key priorities of the study area on a regional perspective. However, disaster and climate risk reduction strategies needs to be customized for local scales in order to ensure the most effective results. Particularly, in case of Indian Sundarban, the extensive variation of community and risk profile clearly do not encourage a *'one size fits all'* approach. <u>Therefore, block level implementation and customization of the suggested model provides an optimum implementation strategy.</u>

In order to check the feasibility of suggested implementation mechanism, it remains important to understand the existing governance structures for the Indian Sundarban Delta. Within the existing civil government, many administrative bodies and departments exits which, at present, creates sufficient management problem and unclear assignment of responsibilities. In fact, the Sundarban region being covered under two districts, i.e. North 24 Parganas and South 24 Parganas also leads to significant management problems and synchronization of existing developmental plans and programs. However, on a hierarchical platform and as a consequence of the ‘Three Tiered Panchayat System’, majority of the existing rural development programs are implemented through the village panchayats in accordance with the guidelines established by the respective ministries. At the local level, this is supervised through the local Block Offices and a downward hierarchy is maintained. In respect to the management of the Indian Sundarban Delta, a dedicated ministry was formed as the Department of Sundarban Affairs from the earlier existing Sundarban Development Board in 2011-12 under the Provincial Government of West Bengal. This was a specific action taken to prioritize the development needs of the delta, however, the potential role of this particular ministry is confronting as several other departments confronts their scope of work. The following list shows some of the other important ministries/departments with respect to the management of Indian Sundarban.

➢ **Responsible Ministries and areas of operation**

- Department of Sundarban Affairs (General Development)
- Department of Forests, GoWB (Mangrove Conservation)
- Ministry of Environment, Forests and Climate Change, Government of India (Project Tiger) (Mangrove and Bio-diversity Conservation)
- Department of Panchayat and Rural Development (Social and Rural Infrastructure Development including the implementation of NREGA)
- Department of Irrigation and Waterways (Embankment, Irrigation and Waterways Management).
- Department of Agriculture (Providing Agricultural Facilities, Management and Guidance).
- Department of Transport (Rural Connectivity)
- West Bengal Disaster Management Department (Relief and Rescue, Disaster Management, Training)

As mentioned, apart from some specific or technical issues such as embankment construction etc., the main implementers of the existing developmental programs, both nationally funded and/or state funded programs are the District Authorities of South and North 24 Parganas. The funds are distributed to local block offices who further allocate the funds to corresponding *panchayat samities* (clusters). The current existing system of program implementation has been recommended by the Government of India for quite some time as a tool of decentralized management, however, decision making still remains mostly concentrated at the top level. Therefore, within the current hierarchical management, it is not possible for a village panchayat or even for a local block office to prioritize program implementation as per the local needs. This remain as the major challenge for enforcing the suggested ‘no-regret’ risk reduction model. Further, because of presence of too many agencies, even a small suggested measures proposed by the local block offices, takes longer time to be heard. **Table 8.1.** highlights some potential government agencies in terms of their capacity to fund and implement the recommended interventions, although in each of the cases, the ground implementation is expected through the mediation of Block offices and village panchayats, after extensive validation through community need assessments.

Table 8.1. Strategic Areas for Low Impact Economic Development

	Responsible Government Agencies		**Main Task and Use**	**Possible Economic Outcome**	**Scale**	**Beneficiaries**
	Primary	**Secondary**				
Extending Farm Level Facilities/Agricultural Utilities	Department of Sundarban Affairs	Department of Agriculture	Seed Conservation Centre, Cold Storage, Breeding Center	Production enhancement	Block Level	Agricultural and Inland Fishers
Required Actions: Collection and dissemination of market intelligence to the farmers and traders and creation of appropriate transitional marketing infrastructures such as cold storage, pack houses etc. Need to strengthen the role of Block Agricultural Offices.						
Water Harvesting Structures	Ministry of Irrigation and waterways	Ministry of Panchayat Raj and Rural Development	Pond excavation and Localized Irrigation	• Multi-crop • Fresh water based aquaculture	Village	Agricultural and Inland Fishing Communities
Required Actions: Priority Implementation of the Provincial Government Flagship Project- '***Preserve Water, Reserve Water'*** under Ministry of Irrigation and waterways. Required manpower can be arrangement from Central Government Funded National Rural Employment Guarantee Act. However, it demands a local level need assessment.						
Linking Rural Producers to Urban Markets	West Bengal State Marketing Board	Ministry of Agriculture, Ministry of Transportation	Creation of Local Markets, Goods Storage and Transportation	• Better Price • Larger Market	Block	Agricultural and Inland Fishing Communities
Required Actions: Development of booster markets and social business model. Need to strengthen the role of Block Agricultural Offices.						
Connectivity	Dept. of Sundarban Affairs	Ministry of Transportation	Creation of Rural Roads and Waterways	• Livelihood Diversification • Capacity Development	Village	Communities in General
Required Actions: Priority Implementation of the National Government and Rural Road Connectivity Scheme with the local community participation. Improvement of Jetties and Water Transport facilities.						

Rural Infrastructure	Dept. of Sundarban Affairs	District Authorities, Forest Departments	Improvement of basic utilities such as alternative fuel, electricity and drinking water	Reduce stress on the Forest Resources	Village	Communities in General, especially Forest Dependent Communities
Required Actions: The local government should facilitate basic infrastructure, particularly alternative fuel and electricity to the forest adjacent villages**.**						

Although it is not particularly recommended to change the current mode of implementation, i.e., through the respective block offices and Village Panchayats, it remains heavily imperative to develop a bottom-up planning mechanism - for which the current scope needs to enhanced. The role of block offices needs to be strengthened in this regard and should be given wider authority. In addition, the suggested risk reduction model requires some corrective measures to provide the best possible outcome. This includes-

(a) The current responsibilities of the Block Offices are huge in terms of the implementation of several social developmental schemes, however, most of the block offices are ill-equipped. Additionally, lack of manpower in respective departments essentially limits its potential. Primarily, this needs to be enhanced. In addition, Block offices need to be empowered in terms of decision making and should be given more authorities to plan, design and implement projects out of their local priorities. This observation is also applicable for the local forest officials such as rangers to design and implement local level programs.

(b) The Village Panchayats need to have high accountability for suitable use of the funds. In this regard, it is highly recommended that an evaluation team for fund utilization is established at the district level with annual grading system. In addition, local political leader should be made accountable for effective fund utilization. At all the level of local government, quality control of project implementation should be a priority. In addition, as mentioned, there should be a provision of shared learning from each other.

(c) The district government of South and North 24 Parganas essentially serves as the think tank for local level development. In addition, the DDMA (District Disaster Management Authorities) are the most important agencies that functions under the district government. However, as mentioned earlier, since the region is covered under two districts, it essentially creates a management problem due to lack of synchronization. This observation is equally applicable for mangrove management. Therefore, it requires some sort of synchronization at the district level, especially considering their role in community development for disaster risk reduction purposes.

References

Society for Direct Initiative for Social & Health Action (DISHA) (2006): A Study On Corporate Abuse in Sundarban

Fidélis, T., & Carvalho, T. (2014). Estuary planning and management: the case of Vouga Estuary (Ria de Aveiro), Portugal. *Journal of Environmental Planning and Management*, (ahead-of-print), 1-23.

Cheong, S. M., Silliman, B., Wong, P. P., van Wesenbeeck, B., Kim, C. K., & Guannel, G. (2013). Coastal adaptation with ecological engineering. *Nature Climate Change*, 3(9), 787-791.

Wardekker, J. A., de Jong, A., Knoop, J. M., & van der Sluijs, J. P. (2010). Operationalizing a resilience approach to adapting an urban delta to uncertain climate changes. *Technological Forecasting and Social Change*, 77(6), 987-998.

Heltberg, R., Siegel, P. B., & Jorgensen, S. L. (2009). Addressing human vulnerability to climate change: toward a 'no-regrets' approach. *Global Environmental Change*, 19(1), 89-99.

World Risk Report (2011): United Nations University, available online http://www.preventionweb.net/files/21709_worldriskreport2011.pdf

Government of West Bengal (2009): District Human Development Report, South 24 Parganas

MacMullan, E., & Reich, S. (2007). The economics of low-impact development: A literature review. ECO Northwest, Eugene, OR.

CHAPTER 9: Conclusion

'In theory, there is no difference between theory and practice. But, in practice, there is.'
Manfred Eigen, German Bio-Chemist, Nobel Laureate

Chapter 9: Conclusion

The last chapter of this dissertation summarizes the key findings of this research work and its implication in disaster/climate risk reduction in Indian Sundarban delta and beyond. In short, the thematic finding of the entire study, can be summarized as an over-lasting human and physical developmental deficit of the delta that magnifies the existing risk factors. The observed developmental deficit is not only a significant contributor of the disaster and climate risks, but also impairs the ecological sustainability of the delta. In addition, the research argues that significant interventions are also required to enhance the coping capacities of the communities. The study further identifies that, overcoming these deficits within the scope of conventional investment based approach remains particularly challenging, and such approaches may further erode community's resilience by alteration of the environmental and social limits. While the novelty of the existing research can be outlined in several thematic achievements; the main accomplishments lies in the formulation of a participatory, 'no-regret' risk reduction model to foster disaster and climate resilient communities within the social and ecological boundaries of the Indian Sundarban delta. This conceptual model can be implemented by the local government (e.g. block offices) for enhancing the capacities of the communities from future disasters and possible impacts of climate change.

Outline of the Chapter 9

9.1. Key Findings

The present research characteristically attempted to enhance the coastal communities' disaster and climate resilience in the Indian Sundarban Delta, especially against the backdrop of the rampage caused by the Cyclone 'Aila' in 2009. The research took a bottom-up, participatory approach for primary data collection hypothesizing that communities are the best judge of their risks. By utilizing extensive Participatory Rural Appraisal (PRA) tools, it reaches to an inference that the observed poor disaster resilience can be primarily attributed to the prevailing lack of human and infrastructural development, which in turn, also erodes the ecological resilience of the study area. The secondary factors are identified as lack of coping capacity, especially due to extremely limited economic opportunity in the delta. The study, therefore, highlighted the scope of an ameliorative, 'no-regret' risk reduction model which essentially advocates for Low Impact Economic Development through 'developmental incentives' and appropriate 'community development'. The suggested model remains pivotal for overcoming the existing developmental deficits, enhancing community's coping capacities and reducing direct economic and physical exposure within the social and ecological boundaries of the delta. In summary, the following important insights were obtained from this research and can be referred to the novelty of the present attempt.

- ***Ecosystem based Disaster Risk Reduction approaches have high potential in economically deprived coastal areas.***

The key finding from the literature that forms the basis of this study largely revolves around the potentials of Ecosystem based Disaster Risk Reduction (Eco-DRR) which provides a low-cost alterative to traditional hard engineering based risk reduction measures. With specific applicability in the economically deprived coastal areas, which often lacks the economic capacity to build hard engineering structures, ecosystem based disaster risk reduction provides a cost-effective, natural solution by reducing the exposure of coastal disasters. In case of communities or local governments that can afford engineered structures, an integrated approach, i.e. the combination of structural measures along with ecosystem based solutions, is more likely to bring better results. In addition, even without disasters, ecosystem based approaches generate net social and economic assets that remains imperative for enhancing economic capacities of the communities.

Under the backdrop of high disaster and climate vulnerability of South and Southeast Asian coasts, along with the limited capacity of the local governments, it was also identified that mangroves have high potential for coastal disaster risk reduction. Especially, since the Indian Ocean Tsunami in 2004, empirical and theoretical studies have proved its role in reducing the exposure of tsunamis, storms and surges beyond doubts. In addition, the provisioning, habitat and cultural ecosystem services of mangroves are essential for reducing socio-economic vulnerability of the communities. However, despite of high potential of mangrove based DRR, South and Southeast Asia continues to loose mangroves in an unprecedented way due to extensive human intervention in the mangrove habitats. The two major delineating factors for mangrove degradation have been identified as agricultural land conversion and development of aquaculture ponds in a regional perspective. Both of these indicate major socio-economic deprivation of the communities crowding the mangrove habitats in the region.

- ***Participatory mangrove management provides an ameliorative opportunity for Mangrove Conservation in developing or least developed countries.***

The other significant finding from the literature review is that, despite of ample legislative protection, mangroves in South and Southeast Asia continues to degrade. As have been identified, institutional failure to recognize the mangrove habitats as complex ‘socio-ecological systems’, largely undermined the implementation of protected area based management to conserve mangrove habitats. In addition, in cases, it has triggered conflicts between forest administrators and the communities. Participatory mangrove management or Community based Mangrove Management that involve local communities and allows scientific utilization of mangrove resources has been identified as an ameliorative approach of mangrove conservation. Especially, countries like Thailand, the Philippines, Bangladesh, community based mangrove conservation have, so far, yielded better results. In India, Joint Forest Management (JFM) has paved the way for participatory conservation of mangroves, however, it requires further adjustments to effectively engage the community in the participatory process.

- ***Development of an ameliorative resilience assessment framework in respect to understand the resilience of rural resource dependent coastal communities against coastal hazards and climate change.***

The current research attempted to develop and assess the status of community resilience through an ameliorative, indicators based resilience assessment framework, suitable for the study area or comparable ‘socio-ecological systems’. This framework is a special customized version addressing the major pertaining issues of disaster and climate resilience in the low lying coastal areas. Named as Coastal Community Resilience Index (CCRI), this tool helps to quantify the spatial variation of community resilience and provides a numerical reflection of five dimensional community resilience, i.e. Socio-Economic, Physical, Institutional, Coastal Zone Management and Natural resilience in a five-point scale. The assessment framework, developed after intensive literature review, includes an exhaustive set of relevant indicators including 25 major indicators and 125 variables to measure community resilience against coastal hazards. By using this tool, disaster and climate resilience of the communities was assessed at the Block Level (the Lowest Administrative Unit) through an institutional survey of all the 19 coastal blocks of the Indian Sundarban. In addition, the framework was also able to address respondent's priority through a 'weighted average' computation method. By using the CCRI, the research could classify all the coastal blocks in the Indian Sundarban Delta in terms of their resilience profile. This methodology provided a good starting point to scientifically identify, not only the blocks with poor resilience, but also the key indicators that are responsible behind this. On a broader scale, this methodology can be used for the assessment of community resilience in comparable socio-ecological systems, especially in the other Asian Mega deltas.

- ***Identification of Key impeding factors behind poor community resilience in the Indian Sundarban Delta through Participatory Action Planning.***

Keeping the Cyclone Aila (2009) as the major reference point, participatory action planning was conducted to understand the key attributing indicators that are responsible for the observed poor community resilience from the perspective of the disaster affected communities. This serves as the starting point of a participatory rural appraisal that is aimed to enhance community resilience through incorporation of specific suggestions/actions from the communities. In particular, this exercise provided an important clue that community resilience is a function of the 'place', since the study observed considerable variation of prioritized indicators from the surveyed 'low' and 'moderate' resilient blocks. This also implies that community perception of resilience depends on specific exposure they receive, and, therefore determines their intended actions. However, irrespective of the observed differences, the study also observed some commonalities among the surveyed blocks, i.e., enhancing rural livelihood, overcoming the physical isolation, access to safe drinking water, mangrove conservation and protection of embankments. Further, from the iterative qualitative process, a close nexus between 'community livelihood', 'mangrove management' and 'protection of the embankments' was identified. In addition, it was observed that the communities look up to the local government, particularly the village panchayat and the Block Offices as their main source of refuge, and, unlike many other places, where communities tend to depend on external funding, communities of the Indian Sundarbans attach greater importance to the performance of the local administrative institutions for enhancing their disaster and climate resilience.

- ***<u>While adaptation becomes central for enhancing livelihood resilience, intention and ability to adapt varies at Individual Level.</u>***

Development of an anticipatory agricultural and estuarine fisheries adaptation plan to enhance livelihood resilience of the delta communities is one of the main components of this research. The results from this study implies that farmer's intention to adapt widely varies based on their landholding and financial capacity. Hence, it is unwise to have a uniform adaptation plan across the agricultural societies. However, some of the adaptive actions such as salinity resilient crops, localized irrigation and fresh water fish cultivation seems to have wider acceptability among the communities. In addition, the research also observed the gaps between adaptation intentions and ability/capacity to adapt, therefore, recommends to create an adaptation fund and technical guidance center to help the local farmers/fishermen to uptake their intended adaptation actions. This finding has some implications in the ongoing agricultural adaptation research, as it opposes the relevance of any '*one size fits all*' adaptation plan and recommends micro-level assessment of adaptation behavior.

- ***<u>Ecosystem based incentives, alone, are not sufficient for ensuing community participation in the existing JFM arrangements.</u>***

Despite of the fact that participatory management of mangroves provides an ameliorative mean of mangrove conservation compared to the traditional hierarchical forest management, the research reaffirmed that community perception is generally shaped by the derived incentives, and if the derived incentives are not sufficient, conservation goals may remain unfulfilled. In the existing case of Indian Sundarban, the study observed that the forest based incentive used for ensuring community participation in the Joint Forest Management program is not considered as sufficient by nearly the half of the user communities. Needless to say, this section of the communities remains dissatisfied with the present arrangements. This finding is rather unique, since most of the current literature on Joint Forest Management have highlighted the JFM process as an ameliorative mean of forest protection as well as livelihood development. However, the current research argues that several factors are responsible for the existing situation, including diverse stakeholders, retrofitting the participatory management within the protected areas and a series of restrictive policies. In addition, the study observed a precariously safety margin based incentive design due to non-availability of baseline data such as Maximum Sustainable Yield (MSY) of forest products etc. In view with the above, the study concludes, at least within the current setup, mangrove based incentives are not enough to warrant effective community participation from across the diverse mangrove user groups. One of the suggested recommendation is to supplement the existing ecosystem based incentives with development incentives.

- ***Longer term sustainability of earthen embankment network requires active community participation and suitable legislations.***

The present research provided a holistic view and a systems perspective of the extensive 3500 km long earthen network that are the most important coastal infrastructure of the delta. In particular, sustainability of this extensive embankment network has been thoroughly analyzed from the perspective of a 'socio-technical' system, which not only includes the micro-technical features and its robustness against future disasters, but also provides a detailed account for methodical inclusion of the village communities into the management of these extensive embankment network. The study argues, although the improved design of reconstructed embankments is robust compared to earlier structures, a participatory monitoring mechanism such as 'Village Embankment Committees' can be formed for day to day monitoring and maintenance of this highly fragile systems. In addition, the study also identifies the requirement of an emergency land acquisition policy in the backdrop of the delay observed due to problem in land acquisition for reconstruction purposes.

- ***A 'No-regret' Risk Reduction Model for enhancing coastal community's disaster and climate resilience in the Indian Sundarban Delta.***

The final outcome of this research is formulation of an ameliorative risk reduction model for the Indian Sundarban delta. This model is based on the 'No-Regret' doctrine for coastal resilience which essentially targets to generate net social benefits irrespective of the possibilities of outcome of an event (disaster/climate change), while at the same time, it attempts to reduce disaster, climate and ecological risks of the delta and revolves around the concepts of 'Low Impact Economic Development (LIED)' through 'Developmental Incentives' and 'Community development'. The effectiveness of this model lies in many folds, particularly in the backdrop of study area. Firstly, despite of much being talked about 'No-Regret' approach for Disaster Risk Reduction or Climate Change Adaptation in ecological sensitive areas, examples or illustrations of such models are rare. This particular study, conducted against the backdrop of a rural, resource dependent coastal community, clearly serves as a field example for the development planners. Secondly, the proposed model does not require much of additional costs which is suitable to the existing economic capability of the provincial government. In principal, it recommends to divert some of the existing funds to prioritized areas that would enhance community's ability to cope with future disasters and/or adverse impact of climate change. Therefore, implementing such model would be much more convenient. Thirdly, the model proposes that some of the investment should come as incentives to the communities. These incentives can be the psycho-social accelerator to ensure active community participation in mangrove conservation or establishing a participatory embankment monitoring mechanism.   Lastly, this particular model is flexible and can be customized or prioritized as the need or demands at the local government level. Therefore, it would ascertain more community participation compared to the hierarchical implementation of state administered developmental project.

9.2. Limitation of the Present Research

No research is complete without the mention of its boundary conditions. Despite of the fact that every possible precaution has been adopted in this research, the current research also comes with certain limitations as listed below.

(a) Firstly, the research hypothesized that communities are the best judge of their risks. Therefore, the research essentially attempted to explore community's perception as the sole narrative for decision making. This has some sort of limitations, e.g. community's perception is mostly shaped by several preceding factors, namely, their economic condition, social status and previous disaster experiences etc. Although, addressing the community prioritized issues are important in order to implement local level risk reduction strategy, science based understanding of risk may derive some alternative factors.

(b) The study adopted a combination of qualitative and quantitative research methodology. Participatory Rural Appraisal tools such as Focus Group Discussions, Structured Interviews, Semi-structured interviews, Questionnaire survey have been extensively used in this study. While the study executed extreme precaution in performing the above mentioned PRA exercises and all recommended protocols were followed, the results might have some systematic bias due to the inherent limitations of these tools. Additionally, the small sample size may not necessarily allow the projections of the results over the entire population. Yet, the results are representative of the ground realties and worth of considering as an exploratory policy planning option.

(c) Thirdly, the study focused on three specific sectors that was prioritized by the communities, however, there are other sectors that are also important for an inclusive resilience. Some of these sectors, such as ‘Water and Sanitation’, ‘Disaster risk management’, ‘Coordination among several government agencies’, ‘land use regulation’ also remain imperative for a detailed action planning.

(d) Assessment of Coastal community’s resilience through the CCRI Framework provides an immediate snapshot of the blocks’ resilience profile. However, some of the data which were used in the framework were significantly old and were used in absence of up-to-date information. In addition, community resilience is a dynamic entity, while in the current research, a static model has been taken as the ‘baseline’.

9.3. Scope for Further Research

The research outcomes have highlighted a number of potential areas for further research both in the science and policy research domain. On a scientific front, future research should identify the possible changes of mangrove ecosystem services and its impacts on the Sundarban Bio-sphere Reserve under different land cover scenarios. This assessment is particularly relevant and will serve as a decision making tool for realigning the local level risk reduction priorities. Additionally, there is also a requirement to scientifically quantify the current sea level rise and it potential impacts on the delta. The available research reports on relative sea level rise has several drawbacks due to unreliable data and methodology. Therefore, significant research is required to further quantify the impacts of relative sea level rise in the delta. Regarding the sustainability of the massive embankment network, scientific research also need to focus on the changing dynamics of the major river courses, and thereby, provide vital recommendation on the realignment strategy of these existing embankments. On the other hand, apart from the geo-morphological changes, research should also focus on developing salinity tolerant, high yielding rice varieties, sustainable prawn cultivation methods, futuristic projections of agricultural productivity, developing low cost resilient rural housing etc.

In the policy research domain, one important aspect of future research would be assessing the effectiveness of local conservation policies including the vast protected area network, management policies for controlling upstream pollution, regional cooperation on trans-boundary ecosystem management etc. Above all, the thrust area of the policy research should remain on meaningful engagement of local communities in regional development process and methodical implementation of the same.

***

List of Annexure

- **Annexure 1:** Questionnaire for Block Level Community Resilience Assessment
- **Annexure 2:** Block wise Community Resilience Profile
- **Annexure 3 (A):** Participatory Action Planning Questionnaire for Household Survey
- **Annexure 3 (B):** Participatory Action Planning Questionnaire for Household Survey (in Bengali)
- **Annexure 4:** Questionnaire for Livelihood Adaptation Planning
- **Annexure 5:** Test Statistics on Choice of Adaptation
- **Annexure 6:** FGD Questions for the Survey of JFMCs

QUESTIONNAIRE FOR BLOCK LEVEL COMMUNITY RESILIENCE ASSESSMENTOF THE INDIAN SUNDARBANS

Background Information:

1) This study aims to analyze the **resilience of the coastal communities** living in **19 (nineteen) Community Development Blocks** of Indian Sundarbans. The resilience of the coastal communities shall be evaluated through this questionnaire survey at Institutional (Local Government Official) level. This questionnaire is focused to assess the <u>community resilience against climate-related natural hazards, such as cyclones, flooding & high tides, water salinity and also from climate change events such as sea-level rise</u>.

2) This questionnaire has been prepared by the International Environment and Disaster Management Laboratory (IEDM) of Kyoto University. It is targeted to create a **Coastal Community Resilience Index (CCRI)** suitable for the socio-economic, environmental and ecological conditions of Indian Sundarbans or comparable coastal ecosystems.

3) <u>**All the information retrieved from this questionnaire will be used for the purpose of academic research only and shall not given to any other party, except research team members from Graduate School of Global Environmental Studies, Kyoto University.**</u>

4) This questionnaire contains 24 pages and it will require approximately 1.5 hour filling it. We highly appreciate for your precious time and sincere cooperation.

PART I
BRIEF INTRODUCTION OF THE BLOCK

SECTION I

Name of the Block			
Administrative Hierarchy	**Sub-Division:** **District:**		
Types of Disaster encountered in past (Please tick , if possible provide years)	Flood	Erosion	Cyclones
Worst Areas affected areas	Name of the Villages	Year	Disaster Event (Flood/Cyclone etc)

Name of the Responder:

Official Designation:

Contact Address:

Phone/Fax:

E-mail:

PART II

HOW TO FILL THE QUESTIONNAIRE:

This questionnaire consists of five dimensions and 25 parameters. Each parameter consists of five questions to measure the resilience of the district against climate-related natural hazards. The five dimensions are: physical, social, physical, Institutional, Coastal Resource Management and Environmental & Natural Components.

DIMENSIONS AND PARAMETERS OF COASTAL COMMUNITY RESILIENCE INDEX

Socio-Economical	Physical	Institutional	Coastal Resource Management	Environmental & Natural
(P-1) Demography	**(P-6)**Transportation	**(P-11)**Laws & Policies	**(P-16)**Embankment & Shoreline Protection	**(P-21)**Frequency of Natural Disasters
(P-2) Livelihood	**(P-7)**Residential Infrastructure	**(P-12)**Coordination	**(P-17)**Mangrove Management	**(P-22)**Climatic Components
(P-3) Health	**(P-8)**Electricity	**(P-13)**Emergency Response	**(P-18)**Coastal Bio-diversity Conservation	**(P-23)**Geo-physical Components
(P-4) Community Governance & Social Capital	**(P-9)**Tele-communication	**(P-14)**Adaptive Actions	**(P-19)**Coastal Pollution	**(P-24)**Bio-geochemical Components
(P-5) Education & Awareness	**(P-10)**Water & Sanitation	**(P-15)**Governance	**(P-20)**Coastal Land use	**(P-25)**Environmental Safeguard Actions

Filling Instructions:

1. Each parameter has 5 questions/variables. For each variable a choice should be made between **1** (**very poor, not available/existent-corresponds to least resilience**) to **5 (Excellent of High resilience).**

2. After a choice is made for all variables, each of them may be ranked against each other within a particular parameter. Thus, the variables should be weight according their importance within the district's context between **1 (not important)** to **5 (very important).** A higher rank increases the weight of a particular variable. This should be done in relation to the characteristics of a particular block. It is crucial that no rank is duplicated. This weighting allows the person, or group who is filling out this questionnaire, to decide which variable should be considered or weighted more than the others within a parameter.

3. Please follow the example furnished below and feel free to ask for any necessary assistance.

Example:

1.1. DEMOGRAPHY

1.1.1. % of Average Annual Population growth in the block

					Projected (Encircle)		Choice
1. (>3.0 %)	2. (2.0-2.9%)	3. (1.6-1.9%)	4. (1.2-1.5%)	5. (<1.1%)	▲	▼	2

1.1.2. Coastal Population Density in the block (number of person / sq. Km)

					Projected (Encircle)		Choice
1. (>1000)	2. (999-800)	3. (800-401)	4. (400-101)	5. (<100)	▲	▼	1

1.1.3. Age Dependency Ratio of Block population

[(% of Population aged below 15 + % Population above 65 / % population between 15-64) x 100]

					Projected (Encircle)		Choice
1. (>80)	2. (50-80)	3. (30-50)	4. (15-30)	5. (<15)	▲	▼	3

Note: How to Calculate age dependency ratio: For example, if 41% of its population less than 15, and 4% is over 65. This makes 55% (100 - (41+4)) between the ages of 15 and 64. Hence, Dependency Ratio is [41 + 4]/ 55 x 100= 81.8 which means 81.8 persons depend on 100 working persons.

1.1.4. % of population living in rural areas

					Projected (Encircle)		Choice
1. (>80%)	2. (60-80%)	3. (40-60%)	4. (20-40%)	5. (<20%)	▲	▼	1

1.1.5. Population belonging to the underdeveloped section of the society

					Projected (Encircle)		Choice
1. (>80%)	2. (51-80%)	3. (31-50%)	4. (22.5-30%)	5. (<22.5%)	▲	▼	4

Note: Please provide the percentage of summation of Scheduled Tribe and Scheduled Cast Population/ Total population.

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.1.1. (Population Growth)	1.1.2. (Population Density	1.1.3. (Age Dependency Ratio	1.1.4. (Rural Population)	1.1.5. (Under Developed Population)
5	3	1	4	2

Stage II

After filling each dimension, please rank the subsequent parameters. Since there are five parameters for each dimension, please rank them between **1 (Least important) to 5 (Most Important).**

Example:

At the end of the first part, please rank the following variables

Demography	Livelihood	Health	Community Governance & Social Capital	Literacy and Awareness
1	5	3	2	4

SOCIO-ECONOMIC

1.1. DEMOGRAPHY

1.1.1. % of Average Annual Population growth in the block

					Projected (Encircle)		Choice
1. (>3.0 %)	2. (2.0-2.9%)	3. (1.6-1.9%)	4. (1.2-1.5%)	5. (<1.1%)	▲	▼	

1.1.2. Coastal Population Density in the block (number of person/sq. Km)

					Projected (Encircle)		Choice
1. (>1000)	2. (999-800)	3. (800-401)	4. (400-101)	5. (<100)	▲	▼	

1.1.3. Age Dependency Ratio of Block population

[(% of Population aged below 15 + % Population above 65/ % population between 15-64) x 100]

					Projected (Encircle)		Choice
1. (>80)	2. (50-80)	3. (30-50)	4. (15-30)	5. (<15)	▲	▼	

Note: How to Calculate age dependency ratio: For example, if 41% of its population less than 15, and 4% is over 65. This makes 55% (100 - (41+4)) between the ages of 15 and 64.Hence, Dependency Ratio is [41 + 4]/55 x 100= 81.8 which means 81.8 persons depend on 100 working persons.

1.1.4. % of population living in rural areas

					Projected (Encircle)		Choice
1. (>80%)	2. (60-80%)	3. (40-60%)	4. (20-40%)	5. (<20%)	▲	▼	

1.1.5. Population belonging to the underdeveloped section of the society

					Projected (Encircle)		Choice
1. (>80%)	2. (51-80%)	3. (31-50%)	4. (22.5-30%)	5. (<22.5%)	▲	▼	

Note: Please provide the percentage of summation of Scheduled Tribe and Scheduled Cast Population/ Total population.

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.1.1. (Population Growth)	**1.1.2. (Population Density)**	**1.1.3. (Age Dependency Ratio)**	**1.1.4. (Rural Population)**	**1.1.5. (Under Developed Population)**

1.2. Livelihood

1.2.1. % of Population registered under International Poverty Line [< 1.25 USD or 67 rupees/day, World Bank 2008]

					Projected (Encircle)		Choice
1. (>50%)	2. (35-50%)	3. (16-35%)	4. (6-15%)	5. (0-5%)	▲	▼	

Note: The response may be given in terms of BPL population as defined by Government of India.

1.2.2. % of population depending on Coastal Resources for Livelihood including coastal agriculture & shrimp cultivation

					Projected (Encircle)		Choice
1. >90%	2. (51-90%)	3. (31-50%)	4. (10-30%)	5. <10%	▲	▼	

1.2.3. Implementation of Livelihood Guarantee Scheme and its coverage

					Projected (Encircle)		Choice
1. Not implemented	2. Poor	3. Medium	4. Good	5. Very Good	▲	▼	

Note: Please furnish the details of NREGA implementation in the block

1.2.4. Implementation of Eco-tourism as an alternative livelihood

					Projected (Encircle)		Choice
1. Very poor	2. Poor	3. Medium	4. Good	5. Very Good	▲	▼	

Hypothesis: Implementation of Ecotourism reduces the stress on coastal ecosystems from direct exploitation.

1.2.5. % of population suffered from immediate discontinuation of livelihood after a disaster

					Projected (Encircle)		Choice
1. >40%	2. 31-40%	3. 21-30%	4. 11-20%	5. <10%	▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.2.1. (BPL Population)	**1.2.2. (Ecosystem Based Livelihood)**	**1.2.3. (Livelihood Guarantee Schemes)**	**1.2.4. (Ecotourism as alternative Livelihood)**	**1.2.5. (Discontinuation of Livelihood after disaster)**

1.3. Health

1.3.1. Average Life Expectancy at birth

					Projected (Encircle)		Choice
1. <40 years	2. 40-49 years	3. 50-59 yrs	4. 60-70 yrs	5. >70 Yrs	▲	▼	

1.3.2. Doctor : Population Ratios in the Block [Number of Qualified Medical professional available against number of population]

1. >2000	2. 1001-2000	3. 501-1000	4. 250-500	5. <250	Projected (Encircle)		Choice
					▲	▼	

Note: This figure should include only qualified doctors available in the block.

1.3.3. % Population not having access to primary health care facilities

1. >30%	2. 21-30%	3. 11-20%	4. 6-10%	5. < 5%	Projected (Encircle)		Choice
					▲	▼	

1.3.4. Condition of Public Health & hygiene

1. Very Bad	2. Bad	3. Moderate	4. Good	5. Very Good	Projected (Encircle)		Choice
					▲	▼	

1.3.5. Morbidity (Rate of Occurrence) of major diseases such as Malaria/TB/Encephalitis

1. Very High frequency of Occurrence	2. High frequency of Occurrence	3. More than National Average	4. Low frequency of Occurrence	5. Extremely Rate	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.3.1. (Life Expectancy at Birth)	**1.3.2. (Doctor: Population Ratio)**	**1.3.3. (Access to Primary Health facilities)**	**1.3.4. (Condition of Public health and hygiene)**	**1.3.5. Morbidity of major diseases**

1.4. Community Governance & Social Capital

1.4.1. Extent of Social Cohesion among community members

1. Does not exist	2. Poor	3. Moderate	4. Strong	5. Very Strong	Projected (Encircle)		Choice
					▲	▼	

1.4.2. Acceptance of local leaders amongst community members

1. Very poor	2. Poor	3. Moderate	4. Strong	5. Very Strong	Projected (Encircle)		Choice
					▲	▼	

1.4.3. Extent of community participation in decision making process

1. Very poor	2. Poor	3. Moderate	4. Strong	5. Very Strong	Projected (Encircle)		Choice
					▲	▼	

1.4.4. Homicides incidents amongst community resulting from a dispute such as land, pond etc

1. More often	2. Often	3. Seldom	4. Very Much rare	5. No incidents	Projected (Encircle)		Choice
					▲	▼	

1.4.5. Ability of communities to build consensus and deliver shared interest

1. Not able	2. Poor	3. Moderate	4. Good	5. Very Good	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.4.1. (Social Cohesion)	**1.4.2. (Acceptance of leaders)**	**1.4.3. Community participation in decision making)**	**1.4.4. Homicide incidents**	**1.4.5. Building consensus And delivering Shared interest**

1.5. Education and Awareness

1.5.1. % of Adult literacy rate

1. <40%	2. 40-59%	3. 60-69%	4. 70-89%	5. >90%	Projected (Encircle)		Choice
					▲	▼	

1.5.2. School Dropout rate amongst children of 7 to 15 years.

1. >7%	2. 5-7%	3. 3.1-5%	4. 1-3%	5. <1%	Projected (Encircle)		Choice
					▲	▼	

1.5.3. Availability and Infrastructure of Primary School against the demands of the population

1. Very much Insufficient	2. Insufficient	3. Moderate	4. Adequate	5. More than Adequate	Projected (Encircle)		Choice
					▲	▼	

1.5.4. Awareness level of the local community about the threats from Disasters and other climatic vulnerability

1. No awareness	2. Poor	3. Medium	4. Good	5. Very Good	Projected (Encircle)		Choice
					▲	▼	

1.5.5. Incorporation of disaster education in regular curriculum as well as in mass awareness programs

1. Very Poor	2. Poor	3. Medium	4. Good	5. Very Good	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

1.5.1. (Adult literacy Rate)	1.5.2. (School Drop out)	1.5.3. (Availability of Primary school)	1.5.4. (Awareness of Local Community)	1.5.5. (Incorporation of Disaster Education)

AT THE END OF THE FIRST PART, PLEASE RANK THE FOLLOWING VARIABLES

Demography	Livelihood	Health	Community Governance & Social Capital	Literacy and Awareness

2. PHYSICAL

2.1. Transportation

2.1.1. % Road coverage as per the block land use

1. <5%	2. 6-10%	3. 11-20%	4. 21-30%	5.30%	Projected (Encircle)		Choice
					▲	▼	

2.1.2. Quality of roads and their accessibility during the disasters

1. Very Poor	2. Poor	3. Moderate	4. Good	5.Very Good	Projected (Encircle)		Choice
					▲	▼	

2.1.3. % of waterways as per the block land use

1. >30%	2. 21-30%	3. 11-20%	4. 5-10%	5.<5%	Projected (Encircle)		Choice
					▲	▼	

2.1.4. Status of Jetties and water transport infrastructure

1. Very Poor	2. Poor	3. Moderate	4. Good	5.Very Good	Projected (Encircle)		Choice
					▲	▼	

2.1.5. Availability of emergency vehicle such as evacuation ship etc during a disaster

1. Very Poor	2. Poor	3. Moderate	4. Good	5.Very Good	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

2.1.1. (Road Coverage)	2.1.2. (quality of Road)	2.1.3. (% waterways)	2.1.4. (Status of Jetties)	2.1.5. (Emergency Vehicle)

2.2. Residential Infrastructure

2.2.1. % of Population live in informal settlements such as earthen buildings, mud houses

1. >30%	2. 21-30%	3. 11-20%	4. 6-10%	5.<5%	Projected (Encircle)		Choice
					▲	▼	

2.2.2. % of population live in Co-operative housing societies/group of housing

1. <10%	2. 10-29%	3. 30-39%	4. 40-50%	5.>50%	Projected (Encircle)		Choice
					▲	▼	

2.2.3. % of housing living above the normal flood line

1. <5%	2. 6-10%	3. 11-20%	4. 21-30%	5.>30%	Projected (Encircle)		Choice
					▲	▼	

2.2.4. % of population having permanent ownership

1. <10%	2. 10-19%	3. 20-39%	4. 40-59%	5. >60%	Projected (Encircle)		Choice
					▲	▼	

2.2.5. % of residential infrastructure close to hazardous activities such as industry, dumping grounds etc

1. >60%	2. 30-60%	3. 10-30%	4. 6-9%	5.<5%	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

2.2.1. (Informal settlement)	2.2.2. (Cooperative Housing)	2.2.3. (Housing above flood line)	2.2.4. (Population having permanent ownership)	2.2.5. (Proximity to Hazardous activity)

2.3. Electricity

2.3.1. % of household having access to electricity

1. <40%	2. 40-50%	3. 50-70%	4. 70-90%	5.>90%	Projected (Encircle)		Choice
					▲	▼	

2.3.2. Status of interruption per day

1. >15 Hour/day	2. 10-14 hours/day	3. 5-9 hours/day	4. 2-4 hours/day	5.<1 Hours/day	Projected (Encircle)		Choice
					▲	▼	

2.3.3. Quality of service such as maintenance of distribution network, frequency dropouts of service etc

1. Very Poor	2. Poor	3. Moderate	4. Good	5.Excellent	Projected (Encircle)		Choice
					▲	▼	

2.3.4. % population having access to alternative energy sources during an interruption

1. <5%	2. 6-20%	3. 21-40%	4. 41-70%	5.>70%	Projected (Encircle)		Choice
					▲	▼	

2.3.5. Implementation of Renewable energy schemes such as solar power, wind mill etc

1. Not implemented	2. Poor	3. Moderate	4. Good	5.Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

2.3.1. (access to Electricity)	**2.3.2. (Interruption status)**	**2.3.3. (Service quality)**	**2.3.4. (Access to Alternative energy)**	**2.3.5. (Renewable Energy)**

2.4. Telecommunication

2.4.1. % population having access to cellular phones

1. <5%	2. 6-20%	3. 21-40%	4. 41-70%	5.>70%	Projected (Encircle)		Choice
					▲	▼	

2.4.2. Quality of available cellular phone network services

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

2.4.3. % of population having access to radio or television

1. <10%	2. 11-30%	3. 31-50%	4. 51-80%	5. 81-100%	Projected (Encircle)		Choice
					▲	▼	

2.4.4. % of population having access to internet connection

1. <10%	2. 11-20%	3. 21-40%	4. 41-70%	5. >70%	Projected (Encircle)		Choice
					▲	▼	

2.4.5. Implementation of fishermen warning and tracking system

1. Not implemented	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

2.4.1. (Cellular Phone access)	**2.4.2. (Quality of service)**	**2.4.3. (access to television)**	**2.4.4. (Internet access)**	**2.4.5. (fisherman tracking)**

2.5. Water & Sanitation

2.5.1. % of population having access to safe drinking water supply

1. <50%	2. 51-65%	3. 66-80%	4. 81-90%	5. >90%	Projected (Encircle)		Choice
					▲	▼	

2.5.2. Quality of supplied water as per international drinking water standard

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

2.5.3. Scarcity of Drinking water

1. Throughout the year	2. Exist frequently	3. Only in summer	4. Exists only when failure of supply systems	5. Does not exists	Projected (Encircle)		Choice
					▲	▼	

2.5.4. % population having access to hygienic toilets

1. <50%	2. 51-65%	3. 66-80%	4. 81-90%	5. >90%	Projected (Encircle)		Choice
					▲	▼	

2.5.5. Status of wastewater treatment facility before discharging

1. No such facility exists	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

2.5.1. (access to Safe water)	**2.5.2. (Supply water Quality)**	**2.5.3. (Scarcity of Drinking water)**	**2.5.4. (Access to toilets)**	**2.5.5. (Waste water treatment)**

At the end of the second part, please rank the following variables

Transportation	Residential infrastructure	Electricity	Telecommunication	Water & Sanitation

3. INSTITUTIONAL

3.1. Laws and Policy

3.1.1. Integration of Disaster Risk Reduction in Developmental activities

1. Not implemented	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.1.2. Implementation of Coastal Regulation Zone Notification or coastal area management guidelines

1. Not implemented	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.1.3. Legislative Provision of Coastal Greenbelt as protective barrier

1. No such Policy exists	2. Exists but poorly implemented	3. Moderate	4. Good	5. Widely implemented	Projected (Encircle)		Choice
					▲	▼	

3.1.4. Effectiveness of Public awareness program

1. Does not exists	2. Poor	3. Moderate	4. Good	5. Very Good	Projected (Encircle)		Choice
					▲	▼	

3.1.5. Statutory earmarked Fund Allocation for Disaster Risk Mitigation

1. No special fund	2. Poor	3. Moderate	4. Sufficient	5. More than Sufficient	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

3.1.1. (Integration of DRR)	3.1.2. (Implementation o CRZ notification)	3.1.3. (Legislative provision Coastal Greenbelt)	3.1.4. (effectiveness of Awareness program	3.1.5. (Earmarked fund)

3.2. Coordination

3.2.1. Coordination amongst various government departments in disaster response

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.2.2. Coordination amongst community leaders and government official for disaster risk reduction as well as mitigation

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.2.3. Participation of NGO in Disaster Risk Reduction and Capacity Building

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.2.4. External assistance (national and international) in Crisis management

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.2.5. Collaboration of neighboring blocks/sub-division/districts for emergency management

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

3.2.1.	3.2.2.	3.2.3.	3.2.4.	3.2.5.

3.3. Emergency Response

3.3.1. Extent of an early warning and risk communication

1. No EW scheme	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.3.2. Adequacy of emergency response team

1. No emergency response team	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.3.3. Availability of sufficient evacuation centers

1. No Availability	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.3.4. Availability of Aids (Food, water, emergency medicine etc) after disasters

1. Not Available	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.3.5. Transparency and effectiveness of Aid distribution process

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

3.3.1.	3.3.2.	3.3.3.	3.3.4.	3.3.5.

3.4. Adaptive Actions

3.4.1. Integration of Climate change Adaptation (CCA) in developmental activities

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.4.2. Development of Forestry and Plantation

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.4.3. Implementation of Disaster insurance

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.4.4. Risk zonation and risk reduction by technical intervention such as dredging activities for flood risk reduction etc

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.4.5. Implementation of Rain water harvesting schemes

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

3.4.1.	3.4.2.	3.4.3.	3.4.4.	3.4.5.

3.5. Governance

3.5.1. Implementation of Developmental Plans

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.5.2. Private-Public partnership in Developmental activities

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.5.3. Activity of district disaster management authority in promotion of disaster awareness (in your block) such as street drama, disaster drill etc

1. Not Active	2. Rarely	3. Moderate	4. Active	5. Very Much active	Projected (Encircle)		Choice
					▲	▼	

3.5.4. Information sharing & risk communication

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

3.5.5. Adequacy of man power for various government department for smooth functioning

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

3.5.1.	3.5.2.	3.5.3.	3.5.4.	3.5.5.

At the end of the third part, please rank the following variables

Law & Policies	Emergency Response	Coordination	Adaptive Actions	Governance

4. Coastal Resource Management

4.1. Embankment & Shoreline Protection

4.1.1. % of vulnerable shoreline protected by embankments

1. <5%	2. 5-25%	3. 25-50%	4. 51-80%	5. 80-100%	Projected (Encircle)	Choice

4.1.2. Average age of the embankments

1. > 30 years	2. 30-20 years	3. 10-19years	4. 5-10 years	5. < 5 years	Projected (Encircle)	Choice

4.1.3. Material used for embankments

1. Earthen Un-engineered	2. Earthen Engineered	3. Stone	4. PCC	5. RCC	Projected (Encircle)	Choice

4.1.4. Maintenance of the embankments

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

4.1.5. Average Overtopping incidents by tidal inflection

1. Very Common	2. Common	3. Sometimes	4. Rare	5. Never Happened	Projected (Encircle)	Choice

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

4.1.1.	4.1.2.	4.1.3.	4.1.4	4.1.5.

4.2. Mangrove Management

4.2.1. % of forest cover as per land use of the block

1. <5%	2. 5-10%	3. 11-20%	4. 21-35%	5. >35%	Projected (Encircle)	Choice

4.2.2. % of community depends on mangroves for livelihood and other purposes

1. >70%	2. 50-69%	3. 30-49%	4. 10-29%%	5. <10%	Projected (Encircle)	Choice

4.2.3. Status of Joint Forest Management or Community Conservation of mangroves

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

4.2.4. Activity of forest department in conservative measures and promotion of mangrove awareness

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

4.2.5. Incidents of mangrove felling in recent past

1. Organized felling and deforestation	2. Severe unorganized felling	3. Major	4. Minor	5. No reported incident	Projected (Encircle)	Choice

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

4.2.1.	4.2.2.	4.2.3.	4.2.4	4.2.5.

4.3. Bio-diversity Conservation

4.3.1. Animal poaching incidents in last 10 years

1. Often	2. Seldom	3. Rare	4. Very rare	5. No reported incident	Projected (Encircle)	Choice

4.3.2. Activity of forest department for promotion of bio-diversity

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

4.3.3. Cooperation of Eco-Development Committees (Community based Bio-diversity conservation)

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

4.3.4. Loss & reduction of species (Turtle, Fishes etc) incurred by human intervention

1. Alarming & needs immediate action	2. Significant loss with species annihilation	3. Significant But not so serious	4. Insignificant	5. No Loss	Projected (Encircle)	Choice

4.3.5. Extent of Control on Over fishing of marine resources

1. Very Poor	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)	Choice

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

4.3.1.	4.3.2.	4.3.3.	4.3.4	4.3.5.

4.4. Coastal Pollution

4.4.1. Whether water quality has been degraded over the years?

1. Severely degraded	2. Degraded	3. Partial degradation in some places	4. Occasional degradation specially in summer	5. Not degraded	Projected (Encircle)		Choice
					▲	▼	

4.4.2. Extent of discharge of Industrial waste Water in coastal areas?

1. Regularly discharged without treatment	2. Regularly discharged with treatment	3. Occasionally discharged without treatment	4. Occasionally discharged after treatment	5. Not discharged	Projected (Encircle)		Choice
					▲	▼	

4.4.3. Discharge of Domestic waste water (sewage) in coastal areas?

1. Regularly discharged without treatment	2. Regularly discharged with treatment	3. Occasionally discharged without treatment	4. Occasionally discharged after treatment	5. Not discharged & recycled	Projected (Encircle)		Choice
					▲	▼	

4.4.4. Oil spillages in coastal areas

1. Very Frequent	2. Frequent	3. Rare	4. Very Rare	5. Never happened	Projected (Encircle)		Choice
					▲	▼	

4.4.5. Frequency of monitoring coastal water quality & remediation measures

1. Very Frequent	2. Frequent	3. Rare	4. Very Rare	5. Never happened	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

4.4.1.	4.4.2.	4.4.3.	4.4.4	4.4.5.

4.5. Coastal land use

4.5.1. Alteration level of coastal land use for agricultural purposes

1. Very high	2. High	3. Moderate	4. Low	5. Not practiced	Projected (Encircle)		Choice
					▲	▼	

4.5.2. Alteration level of coastal land use for Shrimp farming ponds

1. Very high	2. High	3. Moderate	4. Low	5. Not practiced	Projected (Encircle)		Choice
					▲	▼	

4.5.3. Extent of Coastal Urbanization

1. Very high	2. High	3. Moderate	4. Low	5. Not practiced	Projected (Encircle)		Choice
					▲	▼	

4.5.4. Extent of mining , drilling activities in coastal areas

1. Very high	2. High	3. Moderate	4. Low	5. Not practiced	Projected (Encircle)		Choice
					▲	▼	

4.5.5. Success of coastal land reclamation projects

1. No such project has been initiated	2. Poor	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

4.5.1.	4.5.2.	4.5.3.	4.5.4	4.5.5.

At the end of the fourth part, please rank the following variables

Embankments & shoreline Protection	Mangrove Management	Bio-Diversity Conservation	Coastal Pollution	Coastal Land Use

5. Environment & Natural

5.1. Frequency of Natural Disasters

5.1.1. Frequency of Flood Occurrence

1. More than one/year	2. Once/year	3. Once every 5 years	4. Once in 10 year	5. No flooding incidents in past	Projected (Encircle)		Choice
					▲	▼	

5.1.2. Frequency of Cyclone Occurrence

1. More than one/year	2. Once/year	3. Once every 5 years	4. Once in 10 year	5. No cyclone incidents in past	Projected (Encircle)		Choice
					▲	▼	

5.1.3. Frequency of Coastal Erosion

1. Every year In all seasons	2. Every year Rainy season	3. Bi-yearly	4. Once in last 10 year	5. No coastal erosion problem	Projected (Encircle)		Choice
					▲	▼	

5.1.4. Frequency of heavy tidal inception causing life or property damage

1. Every Month	2. Every year	3. Bi-yearly	4. Once in last 5 year	5. Not so far	Projected (Encircle)		Choice
					▲	▼	

5.1.5. Frequency of Tsunami or strong waves

1. Once in 5 years	2. Once in 10 years	3. Once 50 years	4. Once in 100 years	5. No reported Tsunami event	Projected (Encircle)	Choice
					▲ ▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

5.1.1.	5.1.2.	5.1.3.	5.1.4.	5.1.5.

5.2. Climatic Components

5.2.1. Extent of the impacts of the sea level rise in the block

1. Very high	2. High	3. Moderate	4. Low	5. No Impact so far	Projected (Encircle)	Choice
					▲ ▼	

5.2.2. Predicted rise of sea level and its severity for the block?

1. Very high	2. High	3. Moderate	4. Low	5. No predicted Impact	Projected (Encircle)	Choice
					▲ ▼	

5.2.3. Extent of Reduction of Fresh water Flow

1. >50 % reduction in flow	2. 30-49% reduction in flow	3. 10-29% reduction in flow	4. 0-9% reduction in flow	5. No reduction	Projected (Encircle)	Choice
					▲ ▼	

5.2.4. Increase of water salinity in inland waters

1. Significant increase	2. Increase	3. Occasional increase	4. Increase but no significant effect	5. No Change	Projected (Encircle)	Choice
					▲ ▼	

5.2.5. Extent of deterioration of mangrove health due to reduction of fresh water

1. Severe Impact	2High impact	3. Moderate impact	4. Low impact	5. No significant impact	Projected (Encircle)	Choice
					▲ ▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

5.2.1.	5.2.2.	5.2.3.	5.2.4.	5.2.5.

5.3. Geo-physical components

5.3.1. Extent of Loss of shoreline due to coastal erosion

1. Very high	2. High	3. Moderate	4. Low	5. No significant loss	Projected (Encircle)	Choice
					▲ ▼	

5.3.2. Extent of area (river bank and shoreline) prone to erosion

1. 31% of the riverbank and shoreline	2. 21-30% of the riverbank and shoreline	3. 11-20% of the riverbank and shoreline	4. <10% of the riverbank and shoreline	5. No particular area	Projected (Encircle)	Choice
					▲ ▼	

5.3.3. Extent of shoreline having Bio-shielding (mangroves)

1. <5%	2. 6-15%	3. 16-35%	4. 36-60%	5. >60%	Projected (Encircle)	Choice
					▲ ▼	

5.3.4. Level of Geo-morphological vulnerability

1. Very high	2. High	3. Moderate	4. Low	5. Not vulnerable	Projected (Encircle)	Choice
					▲ ▼	

5.3.5. Counter measures taken for controlling river bank & coastal erosion

1. No measures taken	2. Some preliminary measures taken	3. Moderate	4. Adequate	5. More than adequate (Break waters, Concreting)	Projected (Encircle)	Choice
					▲ ▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

5.3.1.	5.3.2.	5.3.3.	5.3.4.	5.3.5.

5.4. Bio-Geochemical Components

5.4.1. Level of Heavy metal (Arsenic) Contamination in coastal aquifers

1. Very High	2. High	3. Moderate	4. Low	5. Not contaminated	Projected (Encircle)	Choice
					▲ ▼	

5.4.2. % population affected by contaminated water

1. >50%	2. 31-50%	3. 16-30%	4. 5-15%	5. <5%	Projected (Encircle)	Choice
					▲ ▼	

5.4.3. Level of heavy metal contamination in sea food chain

1. Very High	2. High	3. Moderate	4. Low	5. Not contaminated	Projected (Encircle)	Choice
					▲ ▼	

5.4.4. Extent of loss to soil fertility due to heavy metal contamination or high soil salinity

1. Very High	2. High	3. Moderate	4. Low	5. No loss	Projected (Encircle)	Choice
					▲ ▼	

5.4.5. Mitigation level of heavy metal (arsenic contamination) or other Bio-geochemical hazards

1. Not mitigated so far	2. Low	3. Moderate	4. Good	5. Excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

5.4.1.	5.4.2.	5.4.3.	5.4.4.	5.4.5.

5.5. Environmental Safeguard Measures

5.5.1. Integration of Environmental hazard map in to developmental planning

1. Very poor	2. Poor	3. Moderate	4. Strong	5. Very Strong	Projected (Encircle)		Choice
					▲	▼	

5.5.2. Implementation of Environmental Protection Act

1. Very poor	2. Poor	3. Moderate	4. Strong	5. Very Strong	Projected (Encircle)		Choice
					▲	▼	

5.5.3. Control of Ground water exploitation in extreme coastal areas

1. Very poor	2. Poor	3. Moderate	4. Good	5. excellent	Projected (Encircle)		Choice
					▲	▼	

5.5.4. Monitoring & Maintenance of Environmental database

1. Very poor	2. Poor	3. Moderate	4. Good	5. excellent	Projected (Encircle)		Choice
					▲	▼	

5.5.5. Involvement of Scientific community in Research & Development on Environmental Issues

1. Very poor	2. Poor	3. Moderate	4. Good	5. excellent	Projected (Encircle)		Choice
					▲	▼	

Please Rank the variables (without duplication of ranks) as per your consideration between 1 to 5

5.5.1.	5.5.2.	5.5.3.	5.5.4.	5.5.5.

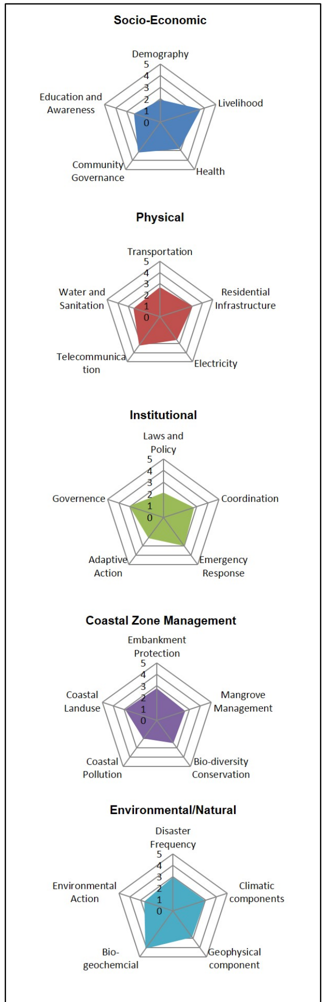
At the end of the fifth part, please rank the following variables (1 to 5)

Frequency of Natural Disasters	**Climatic Components**	**Geo-physical Components**	**Bio-Geochemical Components**	**Environmental Safeguard Actions**

----END OF QUESTIONNAIRE ----

Annexure 2: Block wise Community Resilience Profile

CANNING I BLOCK



Canning I block consists of 11 Gram Panchayats and the Sub-divisional headquarters. The existing demographic settings, i.e. high population density (1586 person/sq. km) and decadal growth rate of 21.82% is the major concern for the block. Since the block also host the administrative facilities of the Canning sub-division, in general, the livelihood scenario of the blocks is better compared to other blocks with around 12% people are involved in organized sectors. Dependency on coastal resources are also comparatively less. The block also consist a sub-divisional hospital and some private health care facilities.

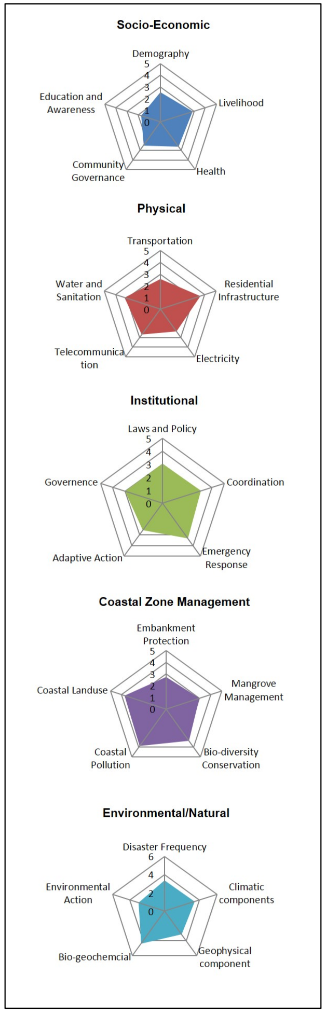
Although the block is connected by rail and road network, transportation remains a challenge, especially in the interior villages. Approximately, 15% of the household has formal electricity connection and 80% of the residential infrastructure is primitive. However, the in spite of that, tele-communication has majorly improved over the years, almost 70% of the communities has a mobile phone connection.

Since the block is centrally located and also hosts the sub-divisional headquarters, in general, the emergency response set up & coordination with the other blocks is better that the rest. However, the block is yet to implement any substantial adaptation actions to cope with its vulnerability.

Canning I block is located in the transitional zone of the Sundarban mangroves. Majority of the mangrove area in this block is unprotected open forest. Over the past few years, some of the transitional mangroves were lost in this block, although relatively small. The block has an extended stretch of embankment across the river Malta in the South east region, part of which is presently upgraded after the Cyclone 'Aila'.

Canning I block is mainly prone of tidal flooding. The main water areas of the block are now challenged with excessive sedimentation and clogging of riverbed. This has resulted in poor navigability and emerged as major threat to tidal flooding. Overtopping of tidal embankments has become more frequent in recent years. Neither of the domestic tube wells has so far been reported of Arsenic or other heavy metal contamination.

CANNING II BLOCK



Canning II block consists of 9 Gram Panchayats and is located in the North-east of the Canning town, the sub-divisional headquarters. The existing demographic settings, i.e. high population density (1156 person/sq. km) and decadal growth rate of 26.82% results in poor demographic resilience of the block. In terms of livelihood, approximately 70% of the communities depend on mono crop agriculture and half of the population lives under the designated poverty line. Around 52% of the population is literate. In terms of health facilities, it has a block health centre, however, the doctor: population ration is very poor.

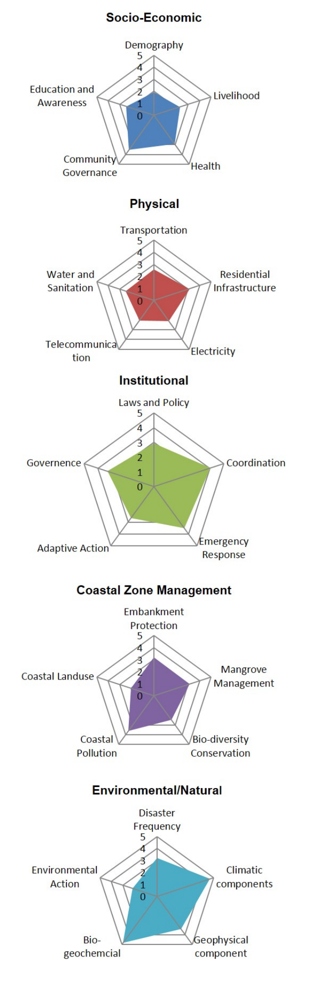
The block is poorly connected and the existing transportation facility in poor. The length of surfaced road compared to the block size is about 0.26 km/sq. km. Almost 100% of the population can be designated as rural population and suffers from poor residential infrastructure. Only 3 to 5% of the local households are having formal electricity collection.

The location proximity to the sub-divisional headquarters is a major cause behind it moderate institutional resilience. Emergency response and ordination among the communities are also satisfactory. However, no intuitional adaptation actions have been initiated by the local government or village institutions.

Coastal exposure to Canning II Block is relatively low since it only faces a small stretch of the river Matla in the South-west region. Therefore, no significant interventions into the coastal ecosystems were observed in this block. Relatively small stretch of embankment exists in this block and these embankments were not identified as vulnerable. However, structurally this is over a century old which has been repaired on demand basis.

Canning II block is primarily exposed to cyclonic storms. Particularly the rural setting is prone to high winds. The land is stable and there has not been major subsidence and erosion incidents occurred in past few years. The ground water is also relative contamination free. Overall, the natural resilience is significantly high compared to its neighboring blocks.

BASANTI BLOCK



Basanti Block consists of 13 Gram Panchayats and is located in the South east of the Canning town, the sub-divisional headquarters. This is also designated as extreme coastal blocks located in the mangrove buffer areas. The population density (821person/sq. km) and decadal growth rate of 19.16% is quite high. Almost the entire population is rural. In terms of livelihood, over 70% of the communities are involved in agriculture. This block is also characterized by a huge number (approximately 65%) of BPL population leading to very poor socio-economic resilience.

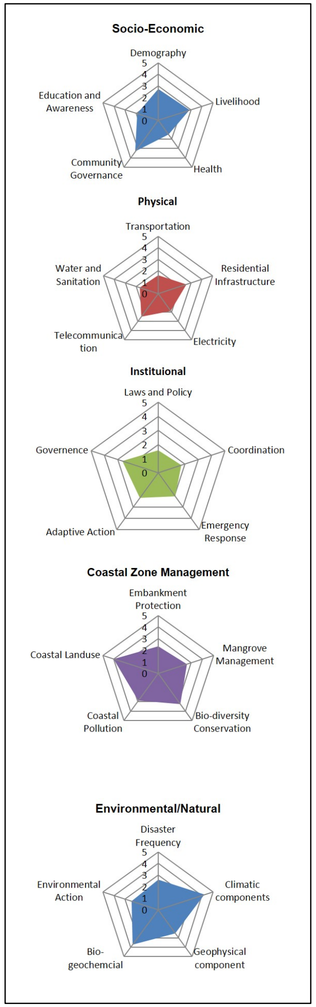
The block is poorly connected and void of formal transportation network. Approximately 80% of the housing structures are made of earthen structures. In terms of road area, the block has only 0.46 km/sq. km of the total area. Less than 1% of people are having electricity connection. Drinking water facilities are also not adequate. In general, physical resilience of the block is poor.

Since the cyclone ‘Aila’ the block has experienced some sort of institutional strengthening and received good amount of aid and attention. However, despite of that institutional intervention in promoting adaptive action is not experienced.

Coastal exposure to Basnati Block is very high since the block is surrounded by two major channels, i.e. Matla River and Bidya River. The main problem it has experienced is the land use alteration & land encroachment in the highly eco-sensitive areas, although the length of potentially vulnerable embankment is relatively small. The block has several Forest Protection Committees performing under the local forest department. This has made substantial contribution in conservation of the mangrove forests.

Basanti Block is primarily exposed to coastal flooding and storm surges. Rising of inland water salinity is also a potential concern for the local fishermen. However, the ground water of the block is void of arsenic and heavy metal contamination. Also, the majority area of this block is not prone to natural subsidence.

GOSABA BLOCK



Gosaba block is located at the fringe of the Sundarban mangrove forest and also a significant part of this block is covered under the mangroves. The Block consists of 15 Gram Panchayats. Population density (825 person/sq. km) and decadal growth rate of 9.83% is high and moderate respectively. The entire population is rural. In terms of livelihood, the block is exceptionally vulnerable. Over, 70% of the population is dependent on agriculture and rests are involved in fishing and prawn seed collection. The block lives in isolation and livelihood opportunities are very limited. Overall, the socio-economic resilience is observed to be poor.

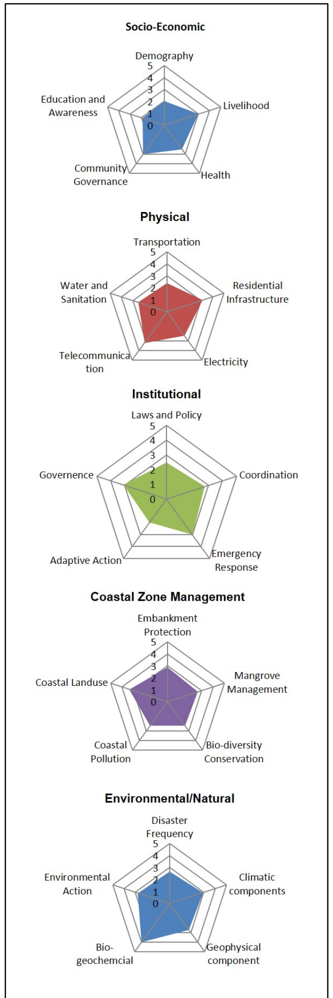
The block is very poorly connected through semi-mechanized boats. In the islands, no formal motorized public transportation is unavailable. Less than 1% of the communities have formal electricity connection and the islands are yet to be connected to the main supply grids.. Over 80% of the housing is vulnerable to storms and flooding. Although, approximately 65% of the communities have access to mobile phones, telecommunication facilities are not up to the satisfactory limit.

Physical isolation plays also an important role in Gosaba’s poor institutional resilience. Implementation of laws and policies are also another critical issue under the depleting resources and poor socio-economic condition.

Gosaba is one of the extreme coastal blocks and coastal exposure is very high. The block is entirely surrounded by earthen embankments which posses a formidable challenge. Many of its embankments were destroyed during the past cyclone leading to prolonger flooding. Gosaba has several Eco-Development Committees for bio-diversity conservation, especially tigers. The problem of man animal conflict is this block is acute.

Gosaba block is exposed to all sort of coastal hazards. The primary concern is the tidal and surge flooding. However, existence of the great Sundarban mangroves provides a strong buffer to the wind hazards. It is also experiencing severe coastal erosion and changes of river courses. Although, salinity has become a major problem in recent years, Ground water is in general free from heavy metal or arsenic contamination.

KAKDWIP BLOCK



Kakdwip block is located in the South western part of Indian Sundarban in the bank of Hooghly River. The block consists 11 Gram Panchayats and the Kakdwip sub-divisional township. The block experiences high population density (1133 person/ sq. km) with a decadal growth rate of close to 19.64%. Approximately, 53% of the population is dependent on agriculture. It also hosts a good amount of fishing communities. Apart from the Kakdwip Township which also serves as the head quarter of Kakdwip sub-division, the entire population is rural.

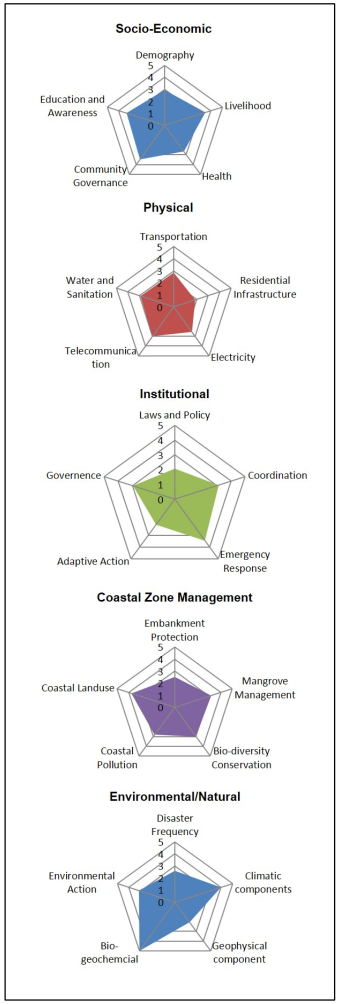
The block is connected through roads and railways. The amount of available road is 1.21 km/sq, km of the block area which is significantly high compared to other blocks. However, the interior rural areas are not very well connected. Approximately 12 % of the population, mainly residing in the township is having access to electricity. Most of the communities are having mobile phones and formal communication medium such as television and radio.

The observed institutional resilience for this block can be categorized between poor to moderate. Part of this evolves from the effective implementation of laws and policies. However, similar to the other blocks in the region, emergency response mechanism has improved since Cyclone "Aila'.

Kakdwip has significant coastal exposure since it has long strength of embankments across the river Hooghly in the west and Saptamukhi in the South. The embankment scenario is comparatively better to other blocks and also only a small stretch was breached during Aila. Despite of an entry point to the Sundarbans, mangrove cover of this area is significantly low. The Kakdwip Township also causes substantial water pollution in the adjoining rivers since it does not possess any waste water treatment plant. Also, settlement and the townships are dangerously close to the river.

Kakdwip is primarily exposed to coastal erosion and has high flooding potential. River bank erosion is also an identified as a major threat for the block under the changing hydrological scenario of the river Hooghly. However, the block does not suffer from ground water contamination with arsenic or other heavy metals.

SAGAR BLOCK



Sagar is an extreme coastal block situated in the western part of the delta. The population density of the block is 748 person/sq km and the decadal growth rate is 13.71%. Approximately, 75% of the communities are involved in mono crop agriculture. However, religious tourism has substantial positive impact in the local economy. Sagar has one of the highest literacy rates in the delta. In general, the socio-economic scenario is comparatively better than the other extreme coastal blocks.

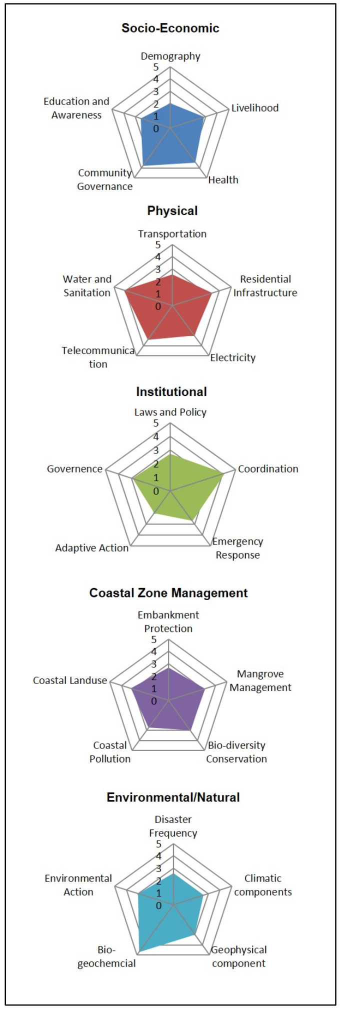
The entire block of Sagar represents islands communities and suffers from geographical isolation. The only way to enter the block is through waterways and the transportation is not well developed. However, the block has a well-developed arterial road with formal transportation such as bus, car etc. The road density is 0.59 km/sq/km. Close to 2% of the people have electricity connection, however, the situation is expected to improve as the island have been recently connected to the main power grids. Rural infrastructure such as mud houses is the major concern for this block.

Sagar has a well-established emergency response and coordination mechanism, presumably due to the annual religious event that it hosts. However, in general, implementation of CZM notification and other environmental regulations are poor. Despite of the blocks vulnerability, adaptation mechanism are also not in place.

Sagar is surrounded by rivers (Gabtala River in the west and Muriganga River in the east) and faces the Bay of Bengal in the south. The main island of Sagar is protected by sea and river dykes and maintenance of these facilities is of major concern. Some of the embankments were damaged during the cyclone 'Aila' and presently being reconstructed.

Sagar is primarily exposed to severe coastal erosion and the projected sea level rise implies a grave concern of the block. It is also equally exposed to coastal flooding and storm surges as well as high wind events. The main islands and some other nearby small islands are probability undergoing a geological subsidence leading to a rapid coastal erosion and loss of land. However, the block is free from bio-geochemical hazards such as arsenic contamination etc.

NAMKHANA BLOCK



Namkhana is an extreme coastal block in the Kakdwip sub-division. The block consists of 7 Gram Panchayats with a population density of 491 person/sq. km. The decadal growth rate is also moderate 13.22%. Approximately, 65% of the communities are involved in agriculture and rests are involved in estuarine fishing. The block is predominantly rural, however, part of this block such as Namkhana and Bakkhali are now being developed as urban townships. The block is characterized by high amount of poverty with approximately half of the population is living below the poverty line.

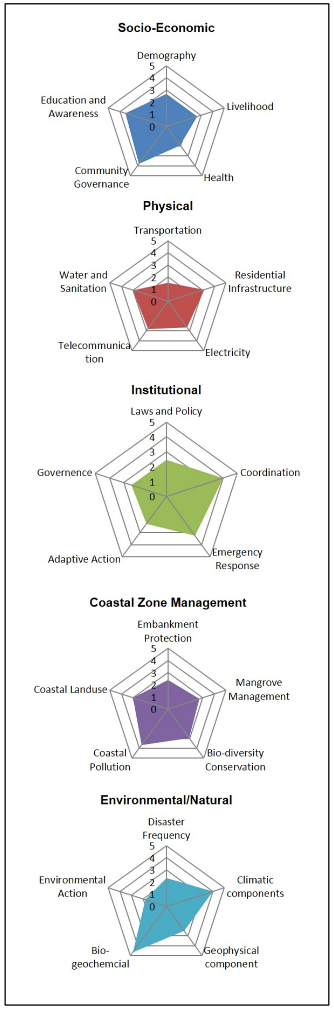
Namkhana is connected by road and water ways; however, it is difficult to reach some of the remote islands such as Mousuni. Approximately 6% of the population has formal electricity connection. In general, the population has safe drinking water supply in terms of availability of tube wells. The block is covered through both private and government telecommunication network and over 70% of the population has access to mobile phones.

The institutional resilience of this block is moderate. Similar to the neighboring blocks, it requires substantial institutional intervention to promote adaptive actions. In general, coordination mechanism among the adjacent blocks and higher level of government is well established.

Namkhana block is surrounded by several creeks and river channels and faces the sea in the south. The Henry's island in the southern tip of the block maintains a thick greenbelt of mangroves which undoubtedly increases its resilience from storm surges. The block also host several protected areas of mangroves. However, similar to other coastal blocks, maintenance of extensive embankment network remain as crucial challenge.

Namkhana is located at the central tip of the delta and exposed to severe cyclones and tidal flooding. This is also one of the extremely affected blocks in the cyclone Aila. The area is further prone to erosion and rising salinity of the inland waters. However, the region is not exposed to acute bio-geochemical hazards such as arsenic or heavy metal contamination in ground water.

PATHARPRATIMA BLOCK



Patharpratima block is located in south central region of the Indian Sundarbans. The block consists 15 Gram Panchayats. The existing density of population is about 689 person/sq. km. The decadal growth rate is 15.71, considerable high for a rural coastal area. Close to 65% of the communities are involved in agriculture and almost half of the population survive under the designated poverty line. However, close to 74% of the people are literate and well aware of their existing vulnerability.

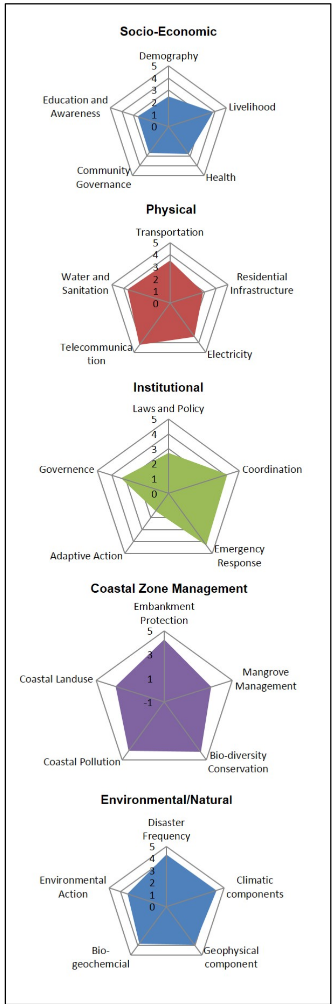
The block is connected through roads and waterways. The amount of available road is 0.23 km/sq, km of the block area which is significantly poor compared to other coastal blocks. Informal semi-motorized vehicles & boats are the lifeline for local people. Particularly, G-spot and other extreme coastal areas are highly inaccessible. The block has less than 1% of house hold electricity connection, however, localized solar power are extensively used by the communities.

The observed institutional resilience for this block can be categorized between poor to moderate. Part of this evolves from the effective implementation of laws and policies. However, similar to the other blocks in the region, emergency response mechanism has improved since Cyclone "Aila'.

Similar to the other coastal blocks, Patharpratima block has high coastal exposure. The block is surrounded by Takhurani River in the east and Saptamukhi River in the west. The Southern part of the block consists of small deltaic islands crisscrossed by several tidal creeks. Therefore, embankments are the lifeline of this blocks. However, following the cyclone Aila, the majority of the embankment need to reconstructed and need improvement. The block has significant mangrove forests in its southern tip which is being protected by the forest department.

Due to its geographical location, this block is severely exposed to coastal& surge flooding. Tidal flooding is also a mjor concern for this block. Part of this block is also experiencing coastal erosions. The projected consequences of climate change may have significant adverse impact of this block. However, the block is free of bio-geochemical contamination.

JOYNAGAR I BLOCK



Joynagar I block is located in the middle mature delta and consists of 12 Gram Panchayet. The block is under the Baruipur Sub-division and represents a mixed population of rural and semi-urban settlements. Joynagar I has the highest population density (1984 person/sq.km) with a decadal growth rate of 18.66. Approximately, 33% of the communities are involved in agricultural sector. Joynagar has a relatively better health facilities compared to the other blocks.

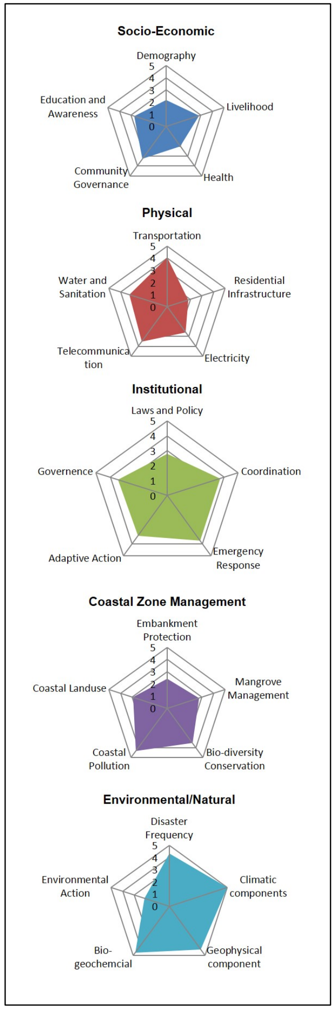
Joynagar I block is well connected via rail and road networks. Formal transportation facilities exist in almost every corner of the block. Although, some of the interior villages are difficult to reach by formal mean of transportation. Approximately 15.21% of the local populations have access to electricity. Joynagar I is also the highest amount of people having access to supplied drinking water. Over 80% of the communities have access to mobile phones, radio or television.

Due to the close proximity to the state capital, both the coordination and emergency response mechanism are satisfactory. However, implementation of laws and policies is identified as a major challenge.

Joynagar I block has significantly less coastal exposure. The Hobka Cannel flows through the north of the block. There is only a small stretch of embankment. Particularly, the embankments of this block did not suffer much damage in the Cyclone ‘Aila”. The block has a small patch of unprotected mangroves in the south east, however, there is prominent conservation imitative exists at present.

Due to its interior location in the middle mature delta, the block is relatively less exposed to coastal hazards. The block is primarily get affected by wind hazards. However, block is partially contaminated by arsenic in some of the tube wells. There is no major observed or predicted impact of climate change on this block.

JOYNAGAR II BLOCK



Joynagar II block is located in the south of the middle mature delta under the Baruipur sub-division. The block consists of 10 Gram Panchayats. Almost the entire population is rural excluding the sub-urban areas of Joynagar. The block is densely populated (1326 person/sq.km) and experiences a decadal growth rate of 18.06%. The choice of livelihood is limited. More than half of the existing population lives on agriculture. Approximately, 42.6% people live under the designated poverty line.

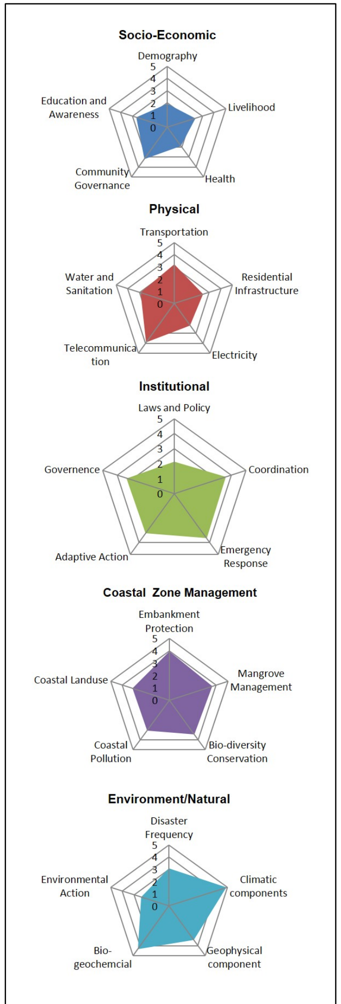
In general Joynagar II block is well connected via road and railways. The Joynagar-Majilpur station on the Seladah Lakshmikantapur railway serves the gateway of the block. Over 90% of the population lives in rural areas and live in earthen or semi structured houses. Only 5.80% of the population has formal electricity connection, although many of the communities use personalized solar electricity facilities. Similar to other blocks, majority of the communities have access to mobile phones, TV or radio.

In general, these blocks show similar institutional resilience to Joynagar I block and take the advantage of being at close proximity to the district and sub-divisional headquarters. Coordination with NGOs & research organization such as ICAR is also very satisfactory. The Nimpeeth Krishi Vigyan Kendra, an NGO & technical consultant has worked extensively with the block administration in promoting agricultural adaptation.

Joynagar II is surrounded by creeks and small channels, especially Moni River and Hobka Khal in the west and east respectively. The eastern side of the block is entirely covered by earthen embankments; part of which has been demarcated as vulnerable. There has also a bit of sparse mangrove vegetation which remains unprotected.

Exposure to Coastal Hazards is significantly low, primarily due to its location in the middle mature delta. However, southern part of the block was heavily impacted by river flooding due to the cyclone ‘Aila’. The block is void of major heavy metal or arsenic contamination.

KULTALI BLOCK



The block Kultali stretches from middle mature delta to the active delta area and consists of 11 Gram Panchayats. Kultali block has predominantly rural communities with a population density of 757 person/sq. km. The decadal growth rate 23.33%, significantly high compared to the other coastal blocks. More than 70% of the communities are involved in mono crop agriculture. Close to 46.36% of the population lives under the poverty line. The block has been infamous for law & order problem creating conflicts among the communities.

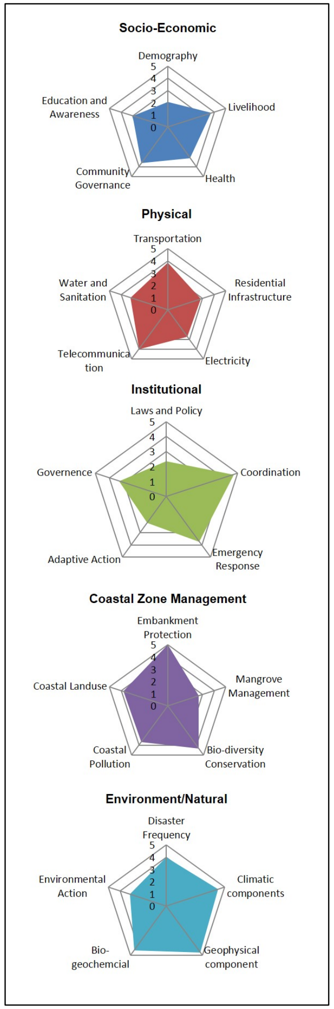
Kultali block is connected through a major arterial road; however, formal public transportation in this road is rare. Almost half of the population has access over drinking water facilities, however, only 0.15% has access to electricity. Over 70% of the communities have access to mobile phones, TV or radios. The majority of the local houses are semi-engineered earthen structures.

Implementation of laws and policies is a substantial challenge for the local administration. However, emergency response has substantially improved since the cyclone 'Aila'. The block is yet to implement any formal structured adaptation measures. Lack of human capacity in the block administration is also a major challenge.

Kultali block is surrounded by rivers. Matla River flows south to the block. It has a long stretch of embankments facing the Matla River, part of which has been restored after cyclone 'Aila'. The block also has several Forest Protection Committees in order to protect and conserve the mangrove forests. In general, the functions of FPCs are satisfactory, however, in some cases the forest cover has marginally reduced. There are some problems with illegal settlement across the river embankments.

Kultali block is primarily exposed to coastal flooding. The southern tip of the block was inundated during the cyclone Aila and a large portion of the coastal land was eroded. The changing river track of Matla near Kaikhali is also an identified phenomenon. There is no reported arsenic contamination in this block.

MATHURAPUR I BLOCK



Mathurapur I block is located in the middle mature delta under the Diamond Harbor sub-division. The block consists of 10 Gram Panchayats. Population density of this block is 1318 person/sq km. The block also experiences a decadal population growth 17.87%. Approximately 46% of the populations are involved in agriculture. 34% people live under the designated poverty line which is significantly low compared to the other blocks of Sundarbans.

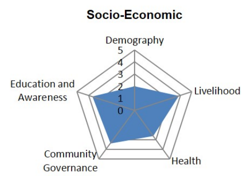
The block is well connected by road and railways. The available road length/sq. km of land area is approximately 2.06. Nearly 12% of the people have formal electricity connection while more than 50% of the population has access to drinking water supply. Almost the entire community has access to television, radio or mobile phones.

Coordination between the blocks and with other implementing agencies is substantially good for this block. This is primarily due to close proximity to the headquarters and land connectivity. In general, the block has an emergency management plan in place. However, similar to the local administrative scenario, implementation of laws and policies remain significant challenge.

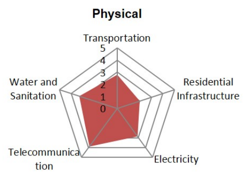
Mathurapur I has only a small stretch of embankment in the south of the block. These embankments are not classified as vulnerable; also it did not suffer major damage in the cyclone 'Aila'. The block does not possess significant amount of mangroves or designated forest land. However, there are scope for mangrove plantation.

Although it is a designated block under the Sundarban region, the block is relatively less exposed that any other blocks in the Sundarbans. It only faces significant wind hazards and some occasional flooding. No major incidents of land erosion or land subsidence were recorded in this block.

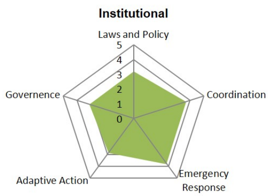
MATHURAPUR II BLOCK



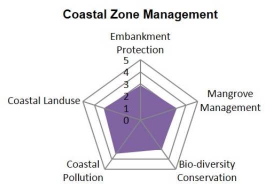
Mathurapur II block is located under the Diamond Harbor sub-division. The block has a population density of close to 1000 person/sq km. The decadal population growth has been 10.72%, relatively low compared to the other blocks. Approximately 40% of the population lives under the poverty line. Agricultural community consist amount 63% of the local population.



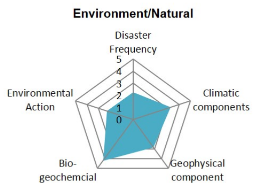
Mathurapur II is connected by roadways; however, connectivity to the interior blocks is poor. The length of surfaced road/sq km is only 0.60. Approximately 6% of the communities have household electricity connection while more than 50% of the population has access to safe drinking water.



Institutional resilience profile of the block is similar to the neighboring blocks. The block has an emergency management plan in place. The existing coordination mechanism is also good due to its proximity and land connectivity to the administrative headquarters.

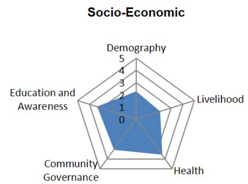


Mathurapur II has moderate coastal exposure. There is a long stretch of embankment across the Raidighi River located in the South of the Block. These stretches of embankment are relatively safe and did not suffer much in the cyclone 'Aila'. However, the block does not possess significant mangrove or forest cover and there is scope of mangrove plantation.

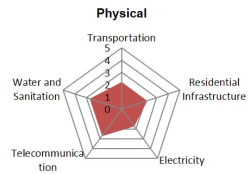


The block is relative less exposed to coastal hazards with moderate frequency of flooding. The immediate threat comes from high wind event. However, the block is experiencing river bank erosion in the south. The block is free of bio-geochemical hazards.

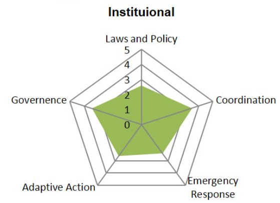
SANDESHKHALI I BLOCK



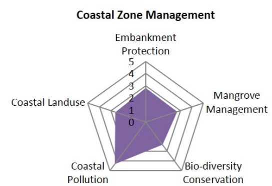
Sandeshkhali I block is located in the Bashirhat Subdivision under the North 24 Parganas. This riparian block has a population density of 901 perosn/sq. km with a decadal population growth of 16.88%. Close to 60% of the population live under the designated poverty line. Approximately, 63% of the population lives on agriculture. Approximately 59% of the communities are literate. Sandeshkhali I has extremely limited health facilities.



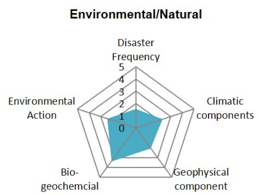
Sandeshkhali I is connected by road and waterways, although the interior villages are only connected through waterways. The block has the road density of 1.14 km/sq km. Domestic electrify connection is rare; however, many uses personalized solar facilities .The existing residential and housing facilities are mostly earthen, making it highly vulnerable to coastal hazards.



The inaccessible location of the block has been a major drawback in the emergency response mechanism adopted by the block administration. However, the block prepared a disaster management plan after the cyclone Aila.

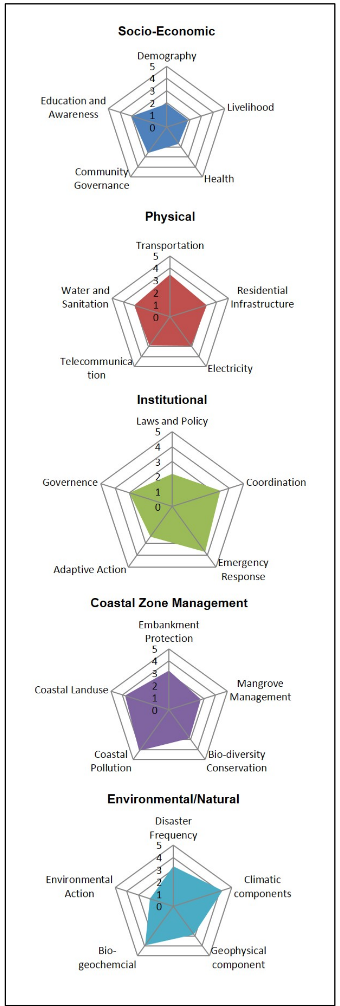


The block has significant coastal exposure. The block is surrounded by rivers and creeks and survives on a peripheral embankment. The eastern part of the block has experienced embankment failure during the cyclone 'Aila'. Majority of those is yet to be properly reconstructed. The block has several altered land of coastal shrimp cultivations adding to its vulnerability. Despite of significant mangrove cover, majority of them are not protected.



Sandeshkhali I have high coastal exposure and primarily exposed to coastal flooding, storm surges and high wind events. The block is also among the most impacted blocks in cyclone Aila. River bank erosion and changing of river courses are of primary concern for this block, especially near Dhamakhali, the entry point and commercial centre of the block. Apart from that, approximately 0.6% of the existing tube wells have arsenic contamination leading to bio-geochemical hazards.

SANDESHKHALI II BLOCK



Sandeshkhali II is located in the Bashirhat sub-division and to the north of the Gosaba block. The block consists 8 Gram Panchayats. The block has a population density of 816 person/sq. km and the decadal population growth in 17.98%. Close to 60% of the existing population live below the designated poverty line. Nearly 65% of the populations live on agriculture. Sandeshkhali II has also extremely limited health care facilities making this block exceptionally vulnerable on socio-economic front.

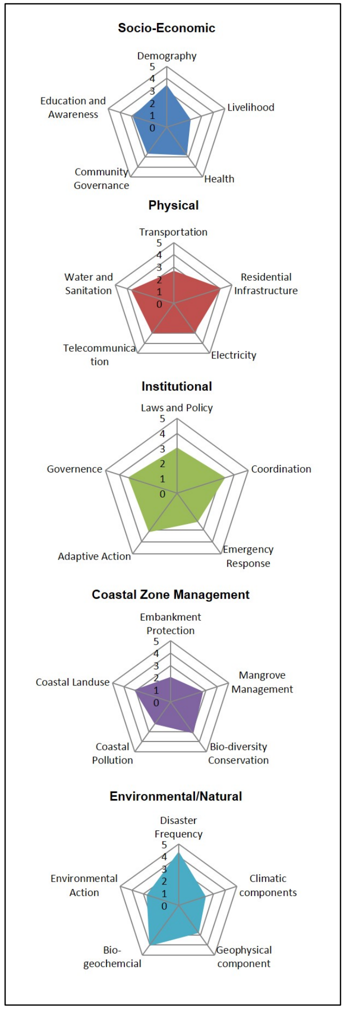
Sandeshkhali II is connected by roads and waterways. Most of the locations under this block can only be reached by semi-motorized boats. The block consists road areas of nearly 0.14 km/sq km. Similar to the adjacent blocks, the existing residential infrastructure are high vulnerable and made of semi-engineered earthen houses. However, more than 60% of the population have mobile phone and have access to radio.

Sandeshkhali II is among the most impacted blocks in the Cyclone Aila. Since then, the institutional mechanism has vastly improved. The block maintains an emergency action plan. However, similar to the regional scenario, efforts for institutional adaptation are yet to be initiated.

Sandehskhali II is surrounded by rivers and creeks. It faces the Bidya River in the South. The eastern part of the block has a huge stretch of vulnerable embankment which was destructed during the cyclone 'Aila'. Sandehkhali II also has substantial amount of mangrove forest. Especially in the southern villages of the blocks have several patches of mangrove. In general, the mangroves are well conserved.

Sandeshkhali II receives very high exposure from all sorts of coastal hazards. The block was affected by storm and floods during the cyclone 'Aila'. Change of land use in terms of development of shrimp & aquaculture ponds further adds to its vulnerability. A small number of shallow tube wells are arsenic contaminated, however, they are well segregated.

MINAKHAN BLOCK



Minakhan is located in the eastern part of the Sundarban delta under the Bashirhat sub-division. The block has a staggering density of 1208person/sq km and experiences a decadal population growth of 13.58%. Close to 55% of the local communities are engaged in agriculture. The block also has significant amount of BPL population. In general, the observed socio-economic resilience can be defined as poor.

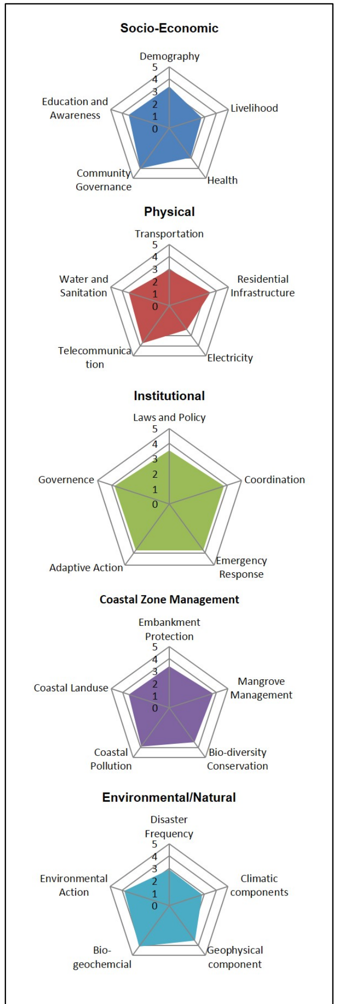
Minakhan is connected by roads & waterways. However, the interior areas are difficult to reach in absence of formal road network. The average road area is about 0.38 km/sq km. Close to 27% of the local communities has access to electricity. Compared to the other blocks, the residential infrastructure is slightly better. Majority of the community members have access to mobile phones and radio or TV.

The administrative headquarter of this block is well connected to the district headquarters by an all-weather road ensuring good coordination. In general, the observed institutional resilience is comparable to its neighboring blocks.

The block is crisscrossed by several small tidal creeks. Bidyadhari Khal marks the western border to the block while Netia Khal marks the boundary in the east. The block has long stretches of embankment; approximately 30% of them are vulnerable and was damaged during the Aila. Particularly, the block experiences sever alteration of land use due to the creation of aquaculture ponds. Similarly discharge of untreated Kolkata city sewage severely pollutes the tidal water bodies.

Majority of the existing block area is not exposed to coastal hazards. However, the southern parts of the block, especially, along the river are prone to erosion and river flooding. The transitional salinity is a major issue for the local fishing communities which have also been considered as a major treat under climate change.

HAROA BLOCK



Haroa block is located in the north of Minakhan under the Bashirhat Sub-division. The block consists of 9 Gram Panchayats and has a population density of 1403 person/sq. km. It also experiences a decadal growth rate of 17.38%. Close to 50% of the communities are involved in agriculture. Haroa has significantly low BPL population (nearly 33%) compared to the adjacent blocks.

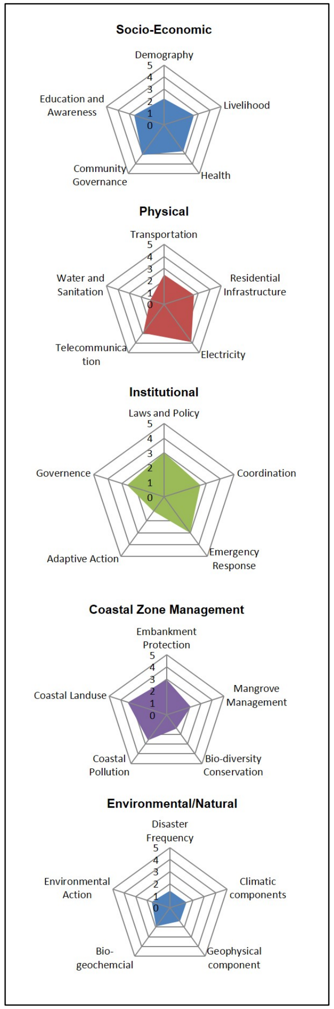
Haroa is well connected by rail and road networks. The block has one of the highest road densities (nearly 2.11 km/sq km of the total area) in Sundarban area. Approximately 60% of the communities have access to electricity. Most of community members have access to mobile phones, radio and TVs. Also, the residential infrastructure is significantly better compared to the other blocks.

Due to close proximity of the district headquarters (Barsat) and sub-visional headquarters (Bashirhat), the block is good in terms of coordination and governance. In general, the observed institutional resilience is comparable to the interior blocks.

Haroa has relative small coastal exposure. The Bidyadhari Khal (canal) flows through the western part of the block. There is a little stretch of vulnerable embankments. Although the block does not have significant amount of mangrove forests, in general, no further degradation has been reported in recent years. In also has relatively small areas designated to shrimp farming activities.

In general, the environmental and natural resilience of Haroa is significantly high compared to other blocks in this region. The block is moderately exposed to flood and high winds. However, the block has some problem with the ground water arsenic contamination.

HASNABAD BLOCK



Hasnabad block is located in the northeastern corner of Indian Sundarbans bordering Bangladesh. It consists of 10 Gram Panchayats and also hosts the Hasnabad Township; the sub-divisional headquarters of Bashirhat. The block has a high population density (1286 person/sq. km) and 36% of the local communities are involved in agriculture. The block is located in the border area. Several issues such as trans-boundary migration, illegal settlements are majorly responsible for poor community participation in developmental agendas.

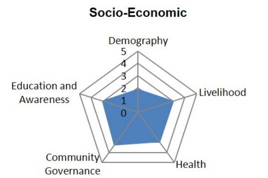
Hasnabad town is well connected by road and railways. However, interior villages are isolated and the formal road coverage is only about 0.37 km/sq.km. Close to 65% of the local households have formal electricity connections. However, residential infrastructures are vulnerable as majority of the communities live in earthen housing. Almost 75% of the communities have access to mobile phone, radio or TV.

Hasnabad being a border area, constantly faces law and order problems. The local administration is poised of several challenges, particularly conflicts among the communities.

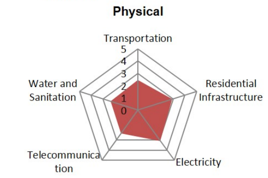
Hasnabad has high coastal exposure, particularly in the eastern part of the block. The river zone also faces the problem of industrial pollution and forcible occupation of land by people. This has resulted in several adverse consequences in the local bio-diversity. The existing small patches of mangroves and other coastal forests are highly vulnerable to human encroachment. Hasnabad has also had substantial amount of lands diverted to aquaculture ponds.

The river Icchamati marks the eastern boundary of the block. This Transboundary River has undergone severe siltation which exerts significant risk of riparian flooding. The river is also undergoing natural course changes along with changes in water quality. Hasnabad is also a designated arsenic contaminated block.

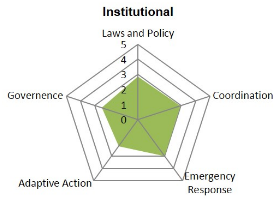
HINGOLGANJ BLOCK



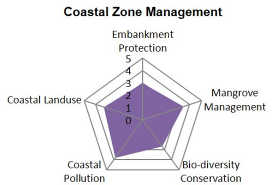
Hingolganj block is located the eastern corner of Indian Sundarbans bordering Bangladesh. The block has a moderate population density of 668 person/sq. km. Close to 60% of the communities are involved in agriculture while 45% of the local communities live under the designated poverty line. The health conditions are also below average in absence. However, on a positive note, more than 70% of the communities are literate.



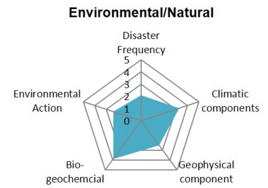
Hingolganj is connected through roads and waterways. The majority of the block is extremely difficult to reach. The road density of Hingolganj is 0.21km/sq km. approximately 25% of the local population has domestic electricity connection and the residential infrastructure is in general poor. Approximately 50% of the communities have access to mobile phones, radio or TV.



The observed institutional resilience is comparable to the neighboring blocks. As a bordering block, enforcement of laws and policies remain the major challenge of the local administration.



Hingolganj is surrounded by river and creeks in its four sides. Icchamati River marks the eastern boundary of the block. The block survives due to long stretches of earthen embankments. Significant length of which was breached during cyclone 'Aila' in the Southern corner of the block. Presently, the embankments are being reconstructed. The block does not host significant amount of mangrove or other coastal forests, however, anthropogenic interventions of forests is relatively less.



Hingolganj is severely exposed to storms and river flooding. It is also one of the worst affected blocks in Cyclone Aila. Similar to the neighbouring Bashirhat Block, heavy siltation in the riverbed of Icchamati also exerts similar risk of riparian flooding, coastal erosion and increment in soil salinity.

Annexure 3: Participatory Action Planning Questionnaire for Household Survey

HOUSEHOLD LEVEL QUESTIONNAIRE SURVEY FOR PRIORITIZATION OF TASKS AND ACTIONS REQUIRED FOR ENHANCING COASTAL COMMUNITY'S DISASTER AND CLIMATE RESILIENCE IN INDIAN SUNDARBANS

Background Information:

1) This questionnaire is a part of a social survey which is intended to **Prioritize Required Tasks and Actions** for enhancing disaster and climate resilience of the communities living in Indian Sundarbans. This questionnaire has been prepared by the International Environment and Disaster Management Laboratory (IEDM) of Kyoto University, Japan.

2) All the information retrieved from this questionnaire will be used for the purpose of academic research only and shall not given to any other party, except research team members from Graduate School of Global Environmental Studies, Kyoto University.

3) This questionnaire contains 7 pages and it will require approximately 45 minutes to complete this. We highly appreciate for your precious time and

Name & Village

Sex : Male / Female

Educational Qualification:

For Analysis Purposes Only

Question Number:

Farmer		Fisherman	
BPL		Others	

Community Prioritized Action Planning

Purpose: Following are the list of actions against each tasks which are supposed to expedite disaster and climate resilience of the Indian Sundarban Delta. Please mark your priority against each action (without repetition) and mark probable source of funds and guidance for the same.

The priority order is: **P-1:** Less Priority **P-2:** Moderately Priority **P-3:** Highly Priority.

In addition, please indicate/tick the most relevant stakeholder as per your consideration among the following stakeholders **[**G= Government VP= Village Panchayat, NGO= Non-Governmental Organization, C= Community] You may alternatively put your priorities, if you consider more than one implementers, the order of priority is

1= Major Responsibility, 2= Minor Responsibility 3= Littlie to No responsibility

Task 1(SE-2): Increase Livelihood opportunities *viz.-a-viz.* Reduce BPL Population

	P-1	P-2	P-3	Responsibilities G	VP	NGO	C
A-1: Development of Alternative livelihood such as eco-tourism							
A-2 : Implementation of Livelihood Guarantee Act (MGNREGA)							
A-3: Improvement of existing livelihood and local business							
Others (Optional):							

Task 2 (SE-4) : Promotion of People Participation in Decision Making Process

	P-1	P-2	P-3	Responsibilities G	VP	NGO	C
A- 1: Strengthening the existing Panchayat system							
A-2: Formation of specific groups such as Youth/Women							
A-3: Reduce corruption/biasness in political process							
Others (Optional):							

Task 3 (SE-5): Spread Disaster & Environmental Awareness

	P-1	P-2	P-3	Responsibilities G	VP	NGO	C
A-1: Wide campaigning, including street dramas etc.							
A-2: Disaster/Environmental Education at Primary Schools							
A-3: Evacuation mock Drills and Guidance							
Others (Optional):							

Task 4 (PH-1): Enhance safe mobility through land and water across Sundarbans							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A-1: Improvement of Jetties and Boat Condition (Safety)							
A-2: Improvement of frequencies of Local transports and boats							
A-3: Strict vigilance over boat safety standards							
Others (Optional):							

Task 5 (PH-4): Enhance telecommunication facilitates							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A-1: Promote localize (community) radio for early warning							
A-2: Increase community charging points							
A-3: Construct /Improve the existing mobile services							
Others (Optional):							

Task 6 (PH-5) : Develop Improved Source of Drinking water facilities							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: More number of deep and safe tube wells among villages							
A-2: Regular monitoring of existing tube wells							
A-3: Community water supply schemes (piped water)							
Others (Optional):							

Task 7 (IN-2): Enhance coordination between various stakeholders with the local community							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Conduct periodical meetings							
A-2: Sharing of information on developmental plans							
A-3: Increased access to government offices							
Others (Optional):							

Task 8 (IN-3): Develop quick and effective Emergency Response							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Training of local people for relief and responses							
A-2: Increase emergency infrastructure such as ambulance, evacuation boats etc.							
A-3:Develop transparency in aid distribution							
Others (Optional):							

Task 9 (IN-5): Promote Good Governance at Institutional Level							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Clean and Transparent Governmental mechanism							
A-2: Increase manpower and efficiencies							
A-3: Increase community access to decision making							
Others (Optional):							

Task 10 (CZM-1) : Strengthen the Embankment Network							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Rising the height of embankments							
A-2: Plantation of mangroves in front of embankments							
A-3: Change embankment materials (Stone etc.)							
Others (Optional):							

Task 11(CZM-2): Conservation, protection and regeneration of mangroves							
				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Plantation of mangroves by Forest Department							
A-2: Protection of existing mangroves through protected areas							
A-3: Enhancing activities of Joint Forest Management							
Others (Optional):							

Task 12(CZM-3) : Protection of Aquatic Diversity for Future				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Control of unscientific fish catch							
A-2: Ban foreign trawlers(fishing) in Sundarbans							
A-3: Develop alternative livelihood for fishermen							
Others (Optional):							

Task 13 (CZM-4): To make the river water free from anthropogenic pollution				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A-1: Stop using plastic bags and non-biodegradable materials in Sundarban area							
A-2: Develop common sewerage systems							
A-3: Control discharge of wastewater in Sundarbans, especially from aquaculture							
Others (Optional):							

Task 14 (EN-1): Reduce Number of Flooding incidents				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Mangroves plantation for sediment accretion							
A-2: Retention Ponds near river banks to protect farm lands							
A-3: Stop settling very close to the river							
Others (Optional):							

Task 15 (EN-2): Enhance resilience to Climate Change threats				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A-1: Plantation of mangroves everywhere as possible							
A-2: Implement Disaster & Climate Insurance							
A-3 : Adjust your individual practices according to CC.							
Others (Optional):							

Task 16 (EN-3) : Controlling Coastal Erosion and Land loss				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Spreading Boulders in erosion prone areas							
A-2: Deserting erosion prone areas							
A-3: Plantation of mangroves in erosion prone areas							
Others (Optional):							

Task 17 (EN-4) : Reduce salinity impact in existing salinity affected areas				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Construct fresh water supply schemes							
A-2: Control of Deep tube well in salinity affected block							
A-3: Rainwater harvesting ponds etc.							
Others (Optional):							

Task 18 (EN-5) : Promote efficient environmental monitoring, documentation and reporting				Responsibilities			
	P-1	P-2	P-3	G	VP	NGO	C
A- 1: Setting up local laboratories and testing facilities							
A-2: Sharing environmental data with community							
A-3: Stakeholders consultation for environmental action							
Others (Optional):							

PLEASE RANK 5 MOST IMPORTANT TASKS

(Rank 1 to 5, 1 being the most important)

Task 1(SE-2): Increase Livelihood opportunities/ Reduce BPL Population	
Task 2 (SE-4) : Promotion of People Participation in Decision Making Process	
Task 3 (SE-5): Spread Disaster & Environmental Awareness & educate community about coping methods	
Task 4 (PH-1): Enhance safe mobility through land & water across Sundarbans	
Task 5 (PH-4): Enhance telecommunication facilitates	
Task 6 (PH-5) : Develop Improved Source of Drinking water facilities	
Task 7 (IN-2): Enhance coordination between various stakeholders with the local community	
Task 8 (IN-3): Develop quick and effective Emergency Response	
Task 9 (IN-5): Promote Good Governance at Institutional Level	
Task 10 (CZM-1) : Strengthen the Embankment Network	
Task 11(CZM-2): Conservation, protection and regeneration of mangroves	
Task 12(CZM-3) : Protection of Aquatic Diversity for Future	
Task 13 (CZM-4): To make the river water free from anthropogenic pollution	
Task 14 (EN-1): Reduce Number of Flooding incidents	
Task 15 (EN-2): Enhance resilience to Climate Change threats	
Task 16 (EN-3) : Controlling Coastal Erosion and Land loss	
Task 17 (EN-4) : Reduce salinity impact in existing salinity affected areas	
Task 18 (EN-5) : Promote efficient environmental monitoring, documentation and reporting	

Annexure 3: Community Action Planning Questionnaire for Household Survey (in Bengali)

ভারতীয় সুন্দরবন (ভারতবর্ষ) এলাকার গৃহস্থালী স্তরে সমীক্ষার জন্য রচিত প্রশ্নমালা

প্রেক্ষাপট

১। সামাজিক সমীক্ষার অংশ হিসাবে এই প্রশ্নাবলির উদ্দেশ্য হল সুন্দরবন এলাকার প্রাকৃতিক বিপর্যয় ও আবহাওয়ার পুনঃস্বাভাবিকীকরণ প্রক্রিয়াকে কার্যকরী করে স্থানীয় জনগোষ্ঠীর জন্য অগ্রাধিকার ভিত্তিক কার্যাবলী নির্ধারণ করা। এই সকল প্রশ্নাবলী জাপানের কিয়েটো বিশ্ববিদ্যালয়ের অন্তর্গত আন্তর্জাতিক পরিবেশ এবং প্রাকৃতিক বিপর্যয় মোকাবিলা গবেষণাকেন্দ্রের (IEDM) উদ্যোগে তৈরি করা হয়েছে।

২। এই প্রশ্নাবলী মাধ্যমে সংগৃহীত যাবতীয় তথ্য শুধুমাত্র অ্যাকাডেমিক রিসার্চ-এর কাজেই ব্যবহার করা হবে। এবং শুধুমাত্র কিয়েটো বিশ্ববিদ্যালয়ের অন্তর্গত বিশ্ব-পরিবেশ বিদ্যার স্নাতকোত্তর স্তরের শিক্ষার প্রতিষ্ঠানের গবেষণা দলের সদস্যবৃন্দ ছাড়া কোনো ভাবেই অন্য কোনো ব্যক্তি বা গোষ্ঠীকে দেওয়া হবে না।

৩। এই প্রশ্নাবলীকে ৭টি পাতা আছে। পাতাগুলো পূর্ণ করে আনুমানিক ৩০ থেকে ৪৫ মিনিট সময় লাগবে। আপনাদের মহামূল্যাবান সময় দান ও আন্তরিক সহযোগিতাকে আমরা সবিশেষভাবেই স্বীকৃতি জানাই।

৪। নাম ও যোগাযোগের তথ্য জানানো কখনোই বাধ্যতামূলক নয়। তবু যদি আপনি তা জানান, আমরা যে-কোন পরিস্থিতিতেই আপনার ব্যক্তি-পরিচয় ও তথ্য গোপন ও সুরক্ষিত রাখতে প্রতিশ্রুতি বদ্ধ।

নাম ও গ্রাম

লিঙ্গ : পুরুষ/মহিলা

শিক্ষাগত যোগ্যতা

শুধুমাত্র বিশ্লেষণের প্রয়োজনে

প্রশ্ন সংখ্যা

কৃষক

মাছ-চাষী/জেলে

বিপিএল

অন্যান্য

জনগোষ্ঠীর জন্য অগ্রাধিকার ভিত্তিক কার্যাবলী

উদ্দেশ্য ঃ

সুন্দরবনে বিপর্যয়কালীন সহায়তা ও আবহাওয়ার পুনঃস্বাভাবিকীকরণ রাখার প্রতিটি দায়িত্বের পরিপ্রেক্ষিতে পালনীয় কাজের তালিকা। অনুগ্রহ করে আপনার অগ্রাধিকারটি চিহ্নিত করুন। এবং তার তহবিলের সম্ভাব্য উৎস ও পরিচালনা প্রসঙ্গটিও চিহ্নিত করুন।

পি-১ : কম গুরুত্বপূর্ণ   পি-২ : অপেক্ষাকৃত বেশি/মাঝামাঝি গুরুত্বপূর্ণ   পি-৩ : অত্যন্ত গুরুত্বপূর্ণ

(স = সরকার, গ্রাপ = গ্রাম পঞ্চায়েত, এনজিও = নন গর্ভনমেন্টাল অরগানাইজেশন, জ = জনগোষ্ঠী)

অনুগ্রহ করে চিহ্নিত করুন ঃ

১ = প্রধান দায়িত্ব, ২ = সাধারণ/দায়িত্ব ৩ = খুবই সামান্য দায়িত্ব বা কোনই দায়িত্ব নেই।

টাস্ক ১ (এস ই-২) : জীবিকা নির্বাহের সুযোগ বৃদ্ধি / বিপিএল-এর সংখ্যা হ্রাস করার প্রয়াস								
				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : ইকো-পর্যটনের উন্নয়ন/বিকল্প জীবিকা								
এ-২ : জীবিকার গ্যারান্টি-অ্যাক্ট-এর প্রয়োগ								
এ-৩ : স্থানীয় ব্যবসা/বাজারের উন্নতিকরণ								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ২ (এস ই-৪) : সিদ্ধান্ত গ্রহণ প্রক্রিয়ায় জনসাধারণের অংশগ্রহণ বাড়ানোর উদ্যোগ								
				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : বর্তমান পঞ্চায়েত ব্যাবস্থার শক্তিশালীকরণ								
এ-২ : যুব, মহিলা ইত্যাদির নির্দিষ্ট গ্রুপ গঠন								
এ-৩ : রাজনৈতিক প্রক্রিয়ায় দুর্নীতি/পক্ষপাতিত্ব হ্রাস								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৩ (এস ই-৫) : পরিবেশ ও প্রাকৃতিক বিপর্যয় বিষয়ে সচেতনতা বৃদ্ধি এবং জনসাধারণকে তার মোকাবিলার পদ্ধতি বিষয়ে প্রশিক্ষিত করে তোলা

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : ব্যাপক প্রচারাভিযান, যথা পথনাটিকা ইত্যাদি								
এ-২ : প্রাথমিক বিদ্যালয় স্তরেই প্রাকৃতিক বিপর্যয় বিষয়ক শিক্ষাদান								
এ-৩ : বিপর্যস্ত এলাকা থেকে উদ্ধার কার্যের মহড়া কুচকাওয়াজ এবং তার পরিচালনা								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৪ (পি. এইচ-১) : সুন্দরবন এলাকায় স্থলপথ ও জলপথে নিরাপদ যাতায়াতের মানোন্নয়ন।

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : জেটি ও নৌকার মানোন্নয়ন (নিরাপত্তা ও গুণগত মান)								
এ-২ : নৌকা ও জনসাধারণ পরিবহন ব্যবস্থার সংখ্যাবৃদ্ধি								
এ-৩ : নৌকার নিরাপত্তার মানের ওপর কঠোর নজরদারি								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৫ (পি. এইচ-৪) : টেলিযোগাযোগ ব্যবস্থার মানোন্নয়ন

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : স্থানীয় বেতার-ব্যবস্থার উন্নয়ন (কমিউনিটি রেডিও)								
এ-২ : গোষ্ঠীগত চার্জিং-পয়েন্ট-এর সংখ্যা বৃদ্ধি								
এ-৩ : মোবাইল পরিষেবার নির্মাণ ও উনয়ন্ন								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৬ (পি. এইচ-৫) : পানীয় জলের সুবিধার জন্য উন্নত ব্যবস্থা গড়ে তোলা

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : গ্রামে গ্রামে আরো বেশি সংখ্যায় গভীর ও নিরাপদ নলকূপ গঠন								
এ-২ : বিদ্যমান নলকূপগুলির নিয়মিত দেখভাল								
এ-৩ : এলাকায় এলাকায় নলবাহিত জলসরবরাহ ব্যবস্থার কর্মসূচি গ্রহণ								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৭ (আই এন-২) : বিভিন্ন স্টেক-হোল্ডার ও স্থানীয় জনগণের মধ্যে সমন্বয় সাধন

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : নির্দিষ্ট সময় অন্তর সভার আয়োজন								
এ-২ : উন্নয়ন পরিকল্পনার জন্য তথ্যের/বার্তার আদানপ্রদান								
এ-৩ : সরকারি অফিসগুলির ভূমিকা বৃদ্ধি								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৮ (আই এন-৩) : আপৎকালীন পরিস্থিতির দ্রুত ও কার্যকরী ব্যবস্থা গড়ে তোলা

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : ত্রাণ ও উদ্ধার কাজে স্থানীয় জনগণের প্রশিক্ষণ								
এ-২ : অ্যাম্বুলেন্স ইত্যাদি পরিকাঠামোর বৃদ্ধি								
এ-৩ : ত্রাণ ও সাহায্য বিতরনে স্বচ্ছতা বৃদ্ধি								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ৯ (আই এন-৫) : প্রাতিষ্ঠানিক স্তরে সু-পরিচালনা ব্যবস্থা গড়ে তোলা

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : স্বচ্ছ ও নির্মল সরকারি কর্মপ্রক্রিয়া								
এ-২ : লোকাবল ও যোগ্যতা বৃদ্ধি								
এ-৩ : সিদ্ধান্ত গ্রহণ প্রক্রিয়ায় জনগণের অংশগ্রহণ বৃদ্ধি								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১০ (সি জেড এম-১) : বাঁধ-এলাকার সমন্বয় ব্যবস্থার উন্নয়ন

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : বাঁধগুলি উচ্চতাবৃদ্ধি								
এ-২ : বাঁধগুলির সামনে ম্যানগ্রোভ বনসৃজন								
এ-৩ : বাঁধের নির্মাণের উপকরণ (পাথর ইত্যাদি) পরিবর্তন								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১১ (সি জেড এম -২) : ম্যানগ্রোভ বনাঞ্চলের সংরক্ষণ, রক্ষণাবেক্ষণ ও পুনরুৎপাদন

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : বনবিভাগের মাধ্যমে ম্যানগ্রোভ বনসৃজন								
এ-২ : বর্তমান ম্যানগ্রোভ বনাঞ্চলগুলির রক্ষণাবেক্ষণ								
এ-৩ : যৌথ বন-প্রশাসনের কার্যাবলির উন্নয়ন								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১২ (সি জেড এম -৩) : ভবিষ্যতের জন্য জলজ জীববৈচিত্র্যের রক্ষণাবেক্ষণ

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : অবৈজ্ঞানিক উপায়ে মাছ-ধরা নিয়ন্ত্রণ								
এ-২ : সুন্দরবনে বিদেশী ট্রলার নিষিদ্ধ করণ								
এ-৩ : বিকল্প জীবিকার পরিসর গঠন								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৩ (সি জেড এম -৪) : নদীর জলকে প্রদুষণ থেকে মুক্ত রাখা

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : সুন্দরবন এলাকায় প্লাসিটক ব্যাগের ব্যবহার বন্ধ করতে হবে								
এ-২ : সর্বসাধরণের পয়প্রণালী ব্যবস্থা নির্মাণ								
এ-৩ : সুন্দরবন-এলাকার বর্জ্য জলের নির্গমন নিয়ন্ত্রণ								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৪ (ই এন ১) : বন্যার ঘটনা হ্রাসকরণ

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : পলি সঞ্চয়ের জন্য ম্যানগ্রোভ বনসৃজন								
এ-২ : নদীর তীরবর্তী পুকুরগুলির সংরক্ষণ								
এ-৩ : নদীর একান্ত সন্নিকটে নির্মাণ কাজ বন্ধ করা								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৫ (ই এন ২) : আবহাওয়ার পরিবর্তনের আশঙ্কা হ্রাসকরণ

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : যথাসম্ভব সর্বত্রই ম্যানগ্রোভ গাছ লাগানো								
এ-২ : প্রাকৃতিক বিপর্যয় ও আবহাওয়া-সংক্রান্ত বিমার যথাযথ প্রয়োগ								
এ-৩ : আবহাওয়ার পরিবর্তনের সঙ্গে নিজের কাজকর্মকে খাপ খাওয়ানো								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৬ (ই এন -৩) : উপকুল এলাকায় ও ভূমির ক্ষয় নিয়ন্ত্রণ

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : ক্ষয়প্রবণ এলাকায় বোল্ডার ছড়ানো								
এ-২ : ক্ষয়প্রবণ এলাকা থেকে সরে যাওয়া								
এ-৩ : ক্ষয়প্রবণ এলাকায় ম্যানগ্রোভ জাতীয় বৃক্ষ রোপন করা								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৭ (ই এন -৪) : লবণাক্ত আক্রান্ত এলাকার লবণাক্ততা হ্রাসকরণ

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : বিশুদ্ধ জল সরবরাহ ব্যবস্থা গড়ে তোলার কর্মসূচী								
এ-২ : লবণক্তা আক্রান্ত ব্লকে গভীর নলকূপের ব্যবহার নিয়ন্ত্রণ								
এ-৩ : বৃষ্টির জল ধরে রাখার জন্য পুকুর ইত্যাদি								
অন্যান্য (বাধ্যতামূলক নয়) :								

টাস্ক ১৮ (ই এন ৫) : পরিবেশ সংক্রান্ত কার্যকরী দেখভাল, তথ্য নথিবদ্ধকরণ এবং রিপোটিং

				দায়িত্ব				
	পি-১	পি-২	পি-৩	স	গ্রাপ	এনজিও	জ	
এ-১ : স্থানীয় ল্যাবোরেটরি গঠন ও পরীক্ষানিরীক্ষা সুবিধা।								
এ-২ : পরিবেশ সংক্রান্ত তথ্যাদি স্থানীয় জনসাধারণকে জানানো								
এ-৩ : পরিবেশ সংক্রান্ত কাজের জন্য স্টোক হোল্ডারদের সঙ্গে পরামর্শ								
অন্যান্য (বাধ্যতামূলক নয়) :								

অনুগ্রহ করে সবচেয়ে গুরুত্বপূর্ণ ৫টি কাজকে চিহ্নিত করুন
এক থেকে এইভাবে ক্রমান্বয়ে সাজান
১ = সবচেয়ে গুরুত্বপূর্ণ

টাস্ক ১ (এস ই ২) :	জীবিকা নির্বাহের সুযোগ বৃদ্ধি/বিপিএল-এর সংখ্যা হ্রাস করার প্রয়াস	
টাস্ক ২ (এস ই ৪) :	সিদ্ধান্ত গ্রহণ প্রক্রিয়ায় জনসাধারণের অংশগ্রহণ বাড়ানোর উদ্যোগ	
টাস্ক ৩ (এস ই ৫) :	পরিবেশ ও প্রাকৃতিক বিপর্যয় বিষয়ে সচেতনতা বৃদ্ধি এবং জনসাধারণকে তার মোকাবিলার পদ্ধতি বিষয়ে প্রশিক্ষিত করে তোলা	
টাস্ক ৪ (পি এইচ ১) :	সুন্দরবন এলাকায় স্থলপথ ও জলপথে নিরাপদ যাতায়াত ব্যবস্থার মানোন্নয়ন	
টাস্ক ৫ (পি এইচ ৪) :	টেলি যোগাযোগ ব্যবস্থার মানোন্নয়ন	
টাস্ক ৬ (পি এইচ ৫) :	পানীয় জলের সুবিধার জন্য উন্নত ব্যবস্থা গড়ে তোলা	
টাস্ক ৭ (আই এন ২) :	বিভিন্ন স্টেক-হোল্ডার ও স্থানীয় জনগণের মধ্যে সমন্বয় সাধন	
টাস্ক ৮ (আই এন ৩) :	আপৎকালীন পরিস্থিতিতে দ্রুত ও কার্যকরী ব্যবস্থা গড়ে তোলা	
টাস্ক ৯ (আই এন ৫) :	প্রাতিষ্ঠানিক স্তরে সুপরিচালন ব্যবস্থা গড়ে তোলা	
টাস্ক ১০ (সি জেড এম ১) :	বাঁধ-এলাকার সমন্বয় ব্যবস্থার উন্নয়ন	
টাস্ক ১১ (সি জেড এম ২) :	ম্যানগ্রোভ বনাঞ্চলের সংরক্ষণ, রক্ষণাবেক্ষণ ও পুনরুৎপাদন	
টাস্ক ১২ (সি জেড এম ৩) :	ভবিষ্যতের জন্য জলজ জীববৈচিত্র্যের রক্ষণাবেক্ষণ	
টাস্ক ১৩ (সি জেড এম ৪) :	নদীর জলকে প্রদূষণ থেকে মুক্ত রাখা	
টাস্ক ১৪ (ই এন ১) :	বন্যার ঘটনা হ্রাসকরণ	
টাস্ক ১৫ (ই এন ২) :	আবহাওয়া পরিবর্তনের আশঙ্কা হ্রাসকরণ	
টাস্ক ১৬ (ই এন ৩) :	উপকূল এলাকা ও ভূমির ক্ষয় নিয়ন্ত্রণ	
টাস্ক ১৭ (ই এন ৪) :	লবণাক্ততায় আক্রান্ত এলাকার লবণাক্ততা হ্রাসকরণ	
টাস্ক ১৮ (ই এন ৫) :	পরিবেশ সংক্রান্ত কার্যকরী দেখভাল, তথ্য, নথিবদ্ধকরণ এবং রিপোর্টিং	

HOUSEHOLD SURVEY FOR ADAPTATION ACTION PLANNING FOR ENHANCING LIVELIHOOD RESILIENCE FOR THE FARMING & FISHING COMMUNITIES LIVING IN INDIAN SUNDARBANS

Background Information:

1) This questionnaire is a part of social survey which is intended to assess the existing livelihood vulnerability and probable adaptation options for enhancing disaster and climate resilience of Indian Sundarbans. This questionnaire has been prepared by the International Environment and Disaster Management Research Group of Kyoto University, Japan.

2) All the information retrieved from this questionnaire will be used for the purpose of academic research only and shall not given to any other party, except research team members from Graduate School of Global Environmental Studies, Kyoto University.

Name of the Responder					
Contact (Mobile Number)			Village/Block		
Age	yrs	Gender	Male (1)	Female (2)	
Educational Qualifications	Illiterate (1)	Secondary School or Less (2)	High School (3)	Bachelor or Above (4)	
How long you are living in this area?	<5 years (1)	5-10 years (2)	10-20 years (3)	>20 years (4)	
Are you registered as BPL?	Yes (1)		No (2)		
Have you enrolled in MGNREGA?	Yes (1)*		No (2)		
** Please mention the year of enrollment (e.g. 2006/2007)*					
What is your average monthly income?					

If you are a farmer, please respond to this section

1.1. Do you own any agricultural land in Sundarban Area?
No (1) Yes (2) *(If yes, answer 1.2 and 1.3)*

1.2. How much land do you possess (in *bighas*)?
<1 (1) >1-3(2) >3-5 (3) >5-10 or more (4)

1.3. What is your average yield during last four years?

2008	/bigha	2009	/bigha	2010	/bigha
2011	/bigha	2012	/bigha	2013	/bigha

1.4. Are you involved in any other livelihood activity?
No (1) Yes (2)
If yes, what kind of activity?

1.5. Did your agricultural land suffer inundation during Cyclone 'Aila'?
No (1) Yes (2)

1.6. What kind of damage you had during the past disasters or natural events such as water level rise or erosion? *(Please tick the appropriate)*

Yield Loss (1)	Livestock Loss (4)
Permanent Land Loss (2)	Financial loss (5)
Salinity Intrusion (3)	Human Life Loss (6)

1.7. What according to is the major threat for agricultural activities in Sundarbans?
(Please Rank as per the importance, 1=Less significant, 5= Highly significant)

Increase in soil salinity (1)	1	2	3	4	5
Non availability of Fresh water (2)	1	2	3	4	5
Frequent flooding and cyclones (3)	1	2	3	4	5
Temperature & Climate Variability (4)	1	2	3	4	5
Loss of cultivable land share (5)	1	2	3	4	5
Inadequate Yield in recent years (6)	1	2	3	4	5
Others (7), please specify	1	2	3	4	5

1.8. Do you grow any other crop except paddy?

No (1) Yes (2)

1.9. The following is a list of agricultural adaptation measures which might be applicable, please prioritize them as per its importance with respect to your individual understanding
(1= Less priority, 2= Somewhat important 3= Moderate Priority, 4= Important 5= Very Important)

Changing of seed sowing time (1)	1	2	3	4	5
Changing of cropping pattern (Pulse crop) (2)	1	2	3	4	5
Salinity resistance paddy species (3)	1	2	3	4	5
Home stead gardening (4)	1	2	3	4	5
Inter cropping pattern (5)	1	2	3	4	5
Crop and flood insurance (6)	1	2	3	4	5
Dual purpose use of agricultural land (7)	1	2	3	4	5
Construction of Irrigation Facility (8)	1	2	3	4	5

Soil and Water Conservation & Harvesting (9)	1	2	3	4	5
Diversification of Livelihood from Agriculture (10)	1	2	3	4	5
Migration to other places (11)	1	2	3	4	5
Others , Please specify	1	2	3	4	5

2.0. What according to you are the main barriers to promote such adaptation measures?

Lack of financial capacity (poverty) (1)	1	2	3	4	5
Lack of Technical capacity/guidance (2)	1	2	3	4	5
Lack of institutional support (3)	1	2	3	4	5
Lack of Infrastructure such as irrigation etc (4)	1	2	3	4	5
Lack of Information about climate change & disasters (5)	1	2	3	4	5
Insecure property rights (6)	1	2	3	4	5
Others, please specify (7)	1	2	3	4	5

If you are a fisherman, please respond to this section

3.1. What kind of fishing activities you are presently engaged in?

Fishing in mangrove waters (1) Deep sea fishing (2) Aquaculture (3)

3.2. If you are engaged in fishing in mangrove water or deep sea fishing, what are the changes in overall fish catches?

Increased (1) Decreased (2) No change (3)

3.3. If the overall fish production has declined, what are major causes behind such loss? (Please rank accordingly , 1: Not significant, 5: Most significant)

Loss and degradation of mangroves (1)	1	2	3	4	5
Water pollution (2)	1	2	3	4	5
Tiger prawn seed collection (3)	1	2	3	4	5
Over exploitation of fisheries resources (4)	1	2	3	4	5
Ship movement in Sundarbans (5)	1	2	3	4	5
Others, please specify (6)	1	2	3	4	5

3.4. Did your activities suffer any loss due to cyclone 'Aila'?

No (1) Yes (2)

What are the major causes of Sufferings?

Loss and damage of boats(1)	Breach of aquaculture boundary(4)
Loss of fishing gears (2)	Mixing of pollutants (5)
Loss of financial capital (3)	Other please specify (6)

In view of changing climate & disasters like cyclone 'Aila" what kind of measures would you prefer to implement in your future fishing activities?
Please Rank according to your priority (1= Less priority, 5= Most Priority)

Control of overfishing in mangrove water (1)	1	2	3	4	5
Practice fresh water pond cultivation (2)	1	2	3	4	5
Barrier plantation around aquaculture pond (3)	1	2	3	4	5
Diversify fish/prawn cultivation patterns (4)	1	2	3	4	5
Diversify livelihood (non-fisheries based) (5)	1	2	3	4	5
Migration to other places (6)	1	2	3	4	5

3.0. What according to you are the main barriers to promote such adaptation measures?

Lack of financial capacity (poverty) (1)	1	2	3	4	5
Lack of Technical capacity/guidance (2)	1	2	3	4	5
Lack of institutional support (3)	1	2	3	4	5
Lack of essential Infrastructure (4)	1	2	3	4	5
Lack of availability of fresh waters (5)	1	2	3	4	5

Notes based on personal interview

Annexure 5: Test Statistics on Choice of Adaptation

Test Statistics

Null Hypothesis: There is no significant difference between small farmers, marginal farmers and Agricultural Labors.

Threat Perception

Threats	Test	Chi-Square Value	p-value	Test Results (at 95% confidence level)
Increase in Soil Salinity	Chi Square	13.801	0.08710202	Accept Null Hypothesis
Non-availability of Freshwater	Chi Square	15.923	0.04349557	Reject Null Hypothesis
Frequent Cyclones/Disasters	Chi Square	5.539	0.6987154	Accept Null Hypothesis
Climate Variability	Chi-Square	8.426	0.3930007	Accept Null Hypothesis
Loss of Cultivable Share of Agriculture Land	Chi-Square	43.847	0.0000006	Reject Null Hypothesis
Inadequate Yield	Chi-Square	9.739	0.28382469	Accept Null Hypothesis

Adaptation Options

Adaptation Options	Test	Chi-Square Value	p-value	Test Results (at 95% confidence level)	Test	p-value	Test Results (at 95% confidence level)
Changes in Seed Sowing Time*	Chi-square	10.345	0.24164138	Accept the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.214$	Accept the Null Hypothesis
Changing Cropping Pattern	Chi-square	30.774	0.00015413	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	p =0.00024	Reject the Null Hypothesis
Salinity Resistance Paddy Cultivation*	Chi-square	7.02	0.53447636	Accept the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.375$	Accept the Null Hypothesis
Home Stead Gardening	Chi-square	12.887	0.11579718	Accept the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.088$	Accept the Null Hypothesis
Inter Cropping Pattern*	Chi-square	30.261	0.00019006	Reject the Null	Freeman Halton Extension of Fisher Exact Test	$p = 0.0002$	Reject the Null Hypothesis
Crop and Flood Insurance*	Chi-square	24.061	0.00223843	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.002$	Reject the Null Hypothesis
Dual purpose use of agricultural Land*	Chi-square	36.921	0.0000119	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.000001$	Reject the Null Hypothesis
Construction of Irrigation Facility*	Chi-square	29.758	0.00023324	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.000096$	Reject the Null Hypothesis
Soil and Water Conservation Structure	Chi-square	29.118	0.00030233	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.00011$	Reject the Null Hypothesis
Diversification of Livelihood from Agriculture	Chi-square	58.155	0.0000005	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.00044$	Reject the Null Hypothesis
Migration to other places	Chi-square	61.923	0.0000001	Reject the Null Hypothesis	Freeman Halton Extension of Fisher Exact Test	$p = 0.000000009$	Reject the Null Hypothesis

*Chi-square test conditions are not properly full filled (more than 20 percent of the *frequency* values are below 5)

Annexure 6: FGD Questions For the Survey of JFMCs

Format of the Focus Group Discussion to Assess Ecological & Economic Sustainability of Community Based Mangrove Management in Indian Sundarbans & their possible linkages with Disaster Risk Reduction

---

Background Information:

1) This study is aimed to understand the ecological, environmental & economic performance of the Forest Protection Committee & Eco-Development Committees (JFMC) under the existing Joint Forest Management Framework to identify the key opportunities and challenges in Joint Forest Management.

2) All the information retrieved from this forms will be used for the purpose of academic research only and shall not be given to any other party.

BACKGROUND INFORMATION

Name of the Committee		
Nature of the Committee	FPC	EDC
Date/Year of Formation		
Extent of the Managed Forest Areas		
Forest Category		
Forest Division / Locality		
Involvement of NGO	No	Yes, specify
Contact Person/ Designation		
Number of Members/Families Involved	Members:	
	Families:	
Main Nature of Work	Forest Protection (1)	Bio-diversity Conservation (2)
	Forest Restoration(3)	(1) + (2)

1. FGD Questions related Social & Economic Sustainability

1.1.	Number of group meeting conducted over last one year?	
1.2.	Number of voluntary works for village development done by the members in the last one year?	
1.3.	Internal conflict during the last one year?	
1.3.	What is the average income & occupation of the group members? (Non Forest Sources/ Regular Sources)	
1.4.	What is the average income of the group members? (Forest Sources due to JFM)	NWTP:
1.5.	Do any body (head) of the FPC/EDC members is also a member of political establishments?	
1.6.	What is the main Source of money for running the FPC/EDC?	
1.7.	Do you think the economic outcome from FPC/EDC is satisfactory for motivation?	
1.8.	Is there any other motivation?	

Notes on Problems mentioned by the respondents

2. FGD Questions for Monitoring & Awareness Level

2.1.	Perception of the managing committee about the condition of mangroves with or without existence of the FPC/EDC?	
2.2.	Do you consider the conservation of mangroves can greatly improve the overall livelihood and disaster resilience of Sundarbans?	
2.3.	Do you think the forest violation has increased over the years?	
2.4.	How often you have reported a forest crime in past one year?	
2.5.	Are you aware of the critical steps of CBMM such as micro-planning etc?	

Notes on Problems mentioned by the respondents

3. FGD Questions for Institutional Sustainability

3.1.	DOES your FPC/EDC get any support from NGOs?	Name: Support type:	
3.2.	How frequent the beat officer meets the committee?		
3.3.	How frequent the forest guards meet the committee?		
3.4.	How Often the key forest information is shared with the committee?		
3.5.	What is the overall attitude of the forest department?	Very Good (Friendly and supportive)	Good (Strong legal responsibility but not friendly)
		Moderate	Poor

Notes on Problems mentioned by the respondents

Notes on Problems mentioned by the respondents

4. FGD Questions for Environmental Sustainability

4.1.	What according to you the existing condition of the managed mangrove forest?	
4.2.	Is the quality of Forest has increased/decreased in last 5 years? Why?	
4.3.	Did you make any new plantation in recent years? If yes, what is the survival rate?	
4.4.	Is the managed forest suffered from other environmental problem not related to community issues?	
4.5.	Does the effective conservation have led to the improvement of livelihood of the community members? If yes, how?	
4.6.	Since the cyclone Aila does the community members are more focused in conservation?	
4.7.	Do you intend to extend the participation in developing mangrove plantation around the vulnerable areas such as embankments and erosion prone areas?	