Nature-based Solutions for Flood Management: A Case Study on Burigoalini Union, Shyamnagar, Satkhira

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Abstract

Flooding in Bangladesh is a significant and one of the frequent natural hazards, intensified by its geographical location, climate change, and socio-economic factors. Considering, Nature-based Solutions (NbS) in coastal areas like Shyamnagar upazila represent a promising and sustainable alternative to traditional infrastructure-based flood management. This research paper identifies the knowledge gaps associated with the effectiveness and societal implications of nature-based solutions for flood management in the Burigoalini Union, Shyamnagar, Satkhira. The conceptual framework known as the "Knowledge Gap" framework is used to employ focused group discussions among fishermen, farmers, and community members, along with applying thematic analysis through NVivo, to explore the relationship between NbS and society, besides to identify good practice strategies for planning and implementing NbS in flood management within the coastal zone. The findings of this study will contribute valuable knowledge to the understanding of the effectiveness of NbS in Bangladesh, also providing helpful insights for policymakers and practitioners seeking to improve flood resilience and promote sustainable development in coastal Bangladesh.

Keywords: nature-based solutions (NbS), coastal flood management, traditional infrastructure alternatives, knowledge gap, effectiveness of NbS.

Background

In recent times, changes in the environment have increased the frequency and force of extreme weather events, including floods. This results in rising global temperatures and enhanced precipitation patterns and leads to more severe storms (Milly et al., 2002). Significant increase in the frequency of traditional

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and long-duration floods globally creates various factors, including climate variability and socioeconomic changes, such as urbanization and increased exposure to flood risks. (Najibi & Devineni, 2018). Flooding in Bangladesh is a significant and frequent natural disaster, intensified by its geographical location, climate change, and socio-economic factors. The country faces severe flood risks due to its low-lying topography, high population density, and the confluence of major rivers (Dewan, 2015).

The frequency, intensity, and duration of floods in Bangladesh have increased over the past few decades, leading to significant human suffering, economic losses, and infrastructural damage (Dewan, 2015). Coastal areas are even more vulnerable to floods due to sea-level rise and existing flood control processes are inadequate, necessitating new measures to mitigate the impacts of sea-level rise on flooding (Bhuiyan & Dutta, 2012). In Bangladesh, districts like Satkhira, Chandpur, and Barisal in the Ganges-Brahmaputra-Meghna delta are extremely vulnerable due to high population density and exposure to cyclonic flooding (Bernard et al., 2022). Flooding in the southern part of Bangladesh affects millions of people and causes extensive damage to infrastructure, agriculture, and livelihoods. That part of the area is highly vulnerable to various types of flooding, including flash floods, cyclonic coastal flooding, and floods exacerbated by sea-level rise. Because of its low-lying landscape, dense population, and the meeting point of many large rivers, the nation is extremely vulnerable to flooding (Bhuiyan & Dutta, 2012). Also, the Satkhira district in Bangladesh experiences unpredictable and recorded changes in temperature and rainfall, leading to increased frequency and intensity of natural disasters such as floods, cyclones, and waterlogging. The coastal banks of Shyamnagar upazila, while providing flood protection and facilitating agricultural production, have also unprotected communities to new vulnerabilities by changing the coastal social-ecological settings. Communities there face multiple livelihood risks, including environmental hazards like floods and socio-economic challenges (Rahman et al., 2021).

NbS are strategies that apply natural processes and ecosystem services to address various environmental challenges, including flood risk management. NbS aims to protect, sustainably manage, and restore natural ecosystems in urban and rural areas, providing multiple benefits such as stormwater mitigation, biodiversity improvement, and improved human well-being (Watkin et al., 2019). NbS offers a sustainable alternative to traditional Gray infrastructure by using natural processes to manage flood risks. As Gray infrastructure involves concrete and steel constructions designed to quickly channel water away, NbS aims to utilize rainwater where it falls. This approach not only mitigates flooding but also

increases local biodiversity and ecosystem services (Watkin et al., 2019)[8]. For instance, reconnecting rivers with their floodplains can connect the natural capacity of floodplains to absorb and store floodwaters, besides reducing flood risks while also providing habitat for wildlife (Turkelboom et al., 2021).

Considering NbS in coastal areas like Shyamnagar upazila represents a promising and sustainable alternative to traditional infrastructure-based flood management. By pulling natural processes, NbS can provide multiple environmental, economic, and social benefits. However, their successful implementation requires overcoming various challenges, including the need for interdisciplinary collaboration and stakeholder engagement. Integrating NbS with traditional gray infrastructure can offer a balanced approach to managing flood risks in the face of climate change and rapid urbanization (*Frontiers | NbS in Coastal and Estuarine Areas of Europe*, 2022).

Shyamnagar Upazila sits close to the Bay of Bengal, which affects its coastal ecosystem. Rivers drop sediment that shapes the landscape changing the area's ecology and water systems. This place often sees floods and salt water coming in, which affects farming and natural homes for plants and animals (Sarker et al., 2021). Burigoalini is a union in Shyamnagar upazila found in Bangladesh's Satkhira district. It lies in a coastal spot that is easy to get hit by natural disasters like big storms and floods. Burigoalini's coastal features, like its low land and need for farming, make it easy to be affected when disasters strike. When big storms break down protective walls, it's even easier for floods and salt water to come in and cause trouble. (Tajrin & Hossain, 2017).

Effective flood management requires active involvement from the community in the management of rivers and floodplains to ensure the sustainability of these areas. Enhancing drainage systems by the removal of blockages and obstacles from rivers and connecting canals, helps in managing floodwaters more effectively, while managing tidal channels reduces sediment deposits in waterlogged areas and helps control sediment deposits to reduce the impact of flooding. Among these, the identified adaptation strategies include floating agriculture, which is particularly very important in low-lying areas that have a submergence history of several months during the monsoon season. Along with the implementation of diverse agricultural practices, a variety of development of salt- and flood-tolerant crops are highly crucial for adaptation under different flood scenarios (Ferdous & Chowdhury, 2016).

Being a low-lying delta country, Bangladesh is highly exposed to climate change in general, and specifically to flooding (Ferdous & Chowdhury, 2016). It has been suffering from regular and intense floods with huge economic losses and displacements, for which NbS may offer promising avenues to achieve

sustainable flood management. (Islam et al., 2024). These include mangrove restoration, wetland conservation, and riverbank afforestation making use of natural processes to mitigate flood risks (Mitra, 2024).

This research paper identifies the knowledge gaps related to effectiveness that are linked to NbS for flood management in Burigoalini union of Shyamnagar upazila in Satkhira district, Bangladesh. The present study also aims at understanding NbS for flood management within Burigoalini union Shyamnagar upazila. However, Bangladesh faces severe consequences related to floods in its coastal areas, such as coastal flooding and intrusion of salinity through flooding. Using the Conceptual Framework known as the “Knowledge Gap” framework, will help the study to understand the relationship between NbS and society for flood management and to determine good practice strategies for planning and implementing NbS in flood management. Overall, the study seeks to contribute valuable knowledge to the understanding of NbS for flood management in the Shyamnagar region.

Conceptual Framework

In flood management, the "Knowledge Gap" framework is vital for understanding how NbS can provide cost-effective, long-term solutions to flooding while offering additional benefits, such as improved biodiversity and reduced calamities. Concluding the knowledge gaps can help policymakers, planners, and communities design NbS that are personalized to local conditions and also integrated with existing infrastructure (Kabisch et al., 2016). The framework consists of four key components:

- **Effectiveness of NbS:**

This includes gaps in understanding how well NbS strategies mitigate floods, especially in comparison to traditional methods. Research is needed to measure and document these solutions' long-term effects, such as flood control, biodiversity enhancement, and climate change adaptation.

- **NbS and Society:**

This explores how NbS interacts with societal elements, including stakeholder engagement, public perception, and social justice. Understanding these relationships is crucial for ensuring that flood management strategies are inclusive and benefit all community members equitably

- **Design of NbS:**

It covers the technical aspects of how NbS can be effectively integrated into existing grey infrastructure, such as embankments and drainage systems.

Designing multifunctional solutions that offer multiple benefits like flood management, recreation, and climate resilience is a challenge.

- **Implementation of NbS:**

Focuses on legal, governance, and policy-related challenges, such as line up NbS with urban development plans. This component also deals with the funding process and administrative capacities needed for successful implementation.

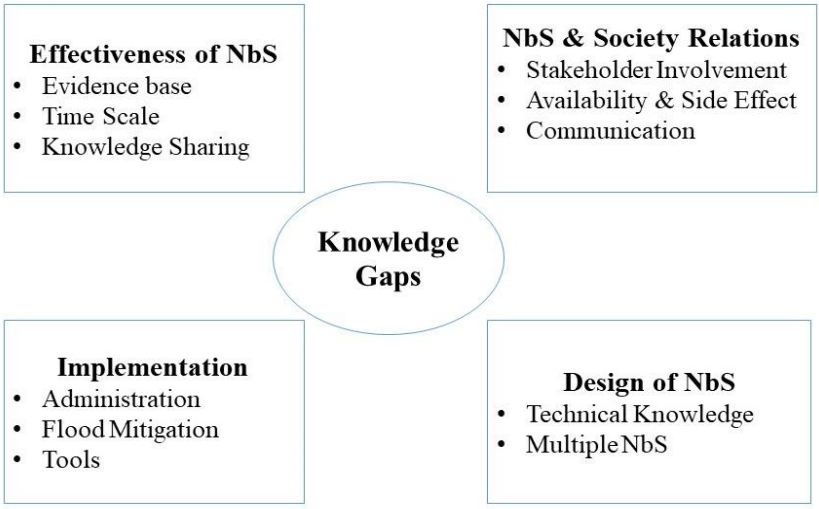

Figure 1: knowledge gap framework (Kabisch et al., 2016)

By addressing these factors through research, outcomes could include more sustainable, cost-effective, and equitable flood management systems. Furthermore, the research would build a strong evidence base that supports widespread adoption of NbS for flood control, while also providing social and ecological co-benefits.

Methodology

Study Area

Shyamnagar upazila, Satkhira is located in the southwestern coastal region of Bangladesh, which is highly vulnerable to natural disasters due to its proximity to the Bay of Bengal and its low-lying topography. The area is

significantly affected by coastal floods, cyclones, and tidal surges, particularly in the Burigoalini and Gabura Unions, which are identified as the most disaster-prone areas (Shaibur et al., 2017).

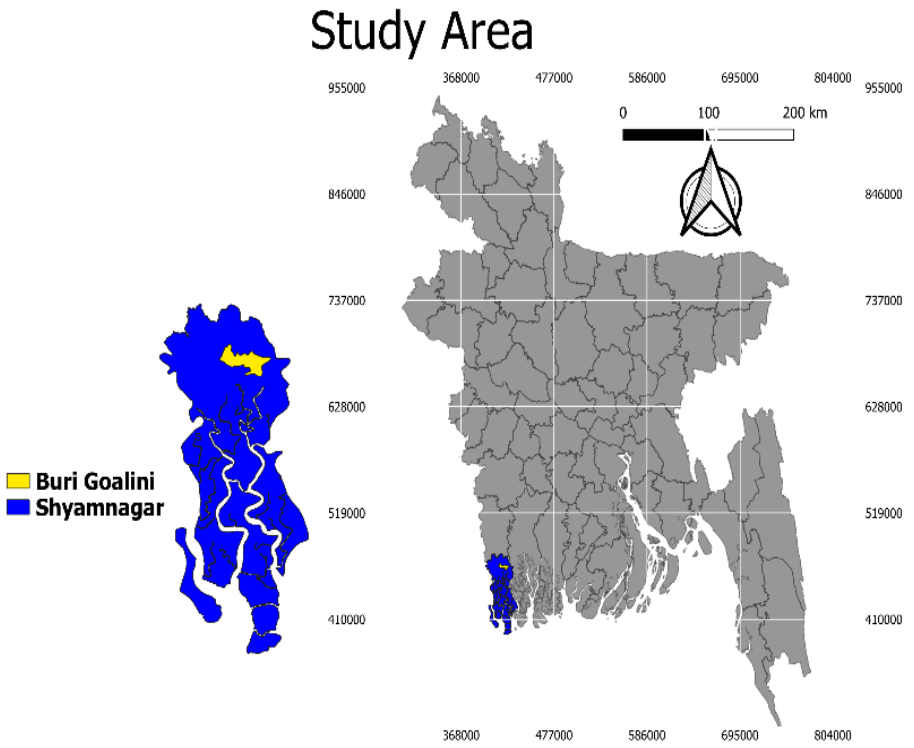

Figure 2: study area map

Burigoalini Union was chosen for this study area due to its critical vulnerability to climate-induced natural disasters, making it a representative case for understanding the broader impacts of climate change in coastal Bangladesh with a 24,913 total population (*Shyamnagar Upazila - Banglapedia*, 2011). Also, The Integrated Coastal Zone Management Plan highlights the importance of this region in addressing flood risks (Shaibur et al., 2017).

Study Design

From the Burigoalini Union, three focus group discussions were conducted for this study. The participants included farmers, fishermen, and

general community members, chosen based on their geographical location and exposure to livelihood challenges to capture diverse perspectives on NbS adoption across different livelihoods. The majority of people in this area are involved in fishing and agriculture, making them key stakeholders in understanding the impact of their environment on their livelihoods.

The sampling methods used were snowball sampling for focused group discussion and non-random purposive sampling for selecting experts. These techniques were employed to ensure a diverse relevant selection of participants and their direct exposure to flood risks and NbS practices. Additionally, an expert sampling was conducted to include key informants such as the Union Disaster Management Officer, NGO workers, Forest Officers, and Agriculture Officers, whose specialized knowledge was crucial to further enrich the research.

For ethical considerations, participants were briefed on the research's objectives and provided informed consent before data collection. All responses were anonymized to protect participant identities.

Study Tool

A preliminary qualitative questionnaire was developed following previously conducted research and a thorough literature review. The design of the questionnaire was framed around the Knowledge Gap Framework, which helped to focus on addressing gaps identified in prior studies. This framework guided the design of the questionnaire, ensuring a focused investigation of identified gaps such as the long-term effectiveness of NbS and its societal implications. For example, the section on the effectiveness of NbS in the questionnaire directly addressed gaps in documented outcomes of NbS interventions. A pilot study was conducted among 10 participants to validate the questionnaire. After incorporating the necessary changes, the final version was ready for implementation. The questionnaire featured open-ended questions, was collected manually, and divided into five key parts: socio-demographics of the community, the effectiveness of NbS, the relationship between NbS and society, design of NbS, and implementation. Each of these parts contained specific questions targeting these themes.

The integration with the Knowledge Gap or Conceptual Framework plays a crucial role in this study of NbS for flood management. The framework is designed to address the gaps in current knowledge about how NbS can be effectively implemented in rural areas like the Burigoalini Union. It explores various dimensions such as the effectiveness of NbS, the relationship between

NbS and society, design, and implementation challenges. For instance, one of the identified knowledge gaps is the effectiveness of NbS in adapting to climate change and managing environmental challenges like flooding (Kabisch et al., 2016).

Data Analysis

The data analysis for this research followed a structured qualitative approach, using **NVivo** software to facilitate the organization and exploration of data. Thematic analysis is applied to identify, analyse, and report patterns or themes within the data collected through focus group discussions and interviews. The analysis proceeds as follows:

- **Data Organization**:

  All transcriptions from focused group discussions and key informant interviews were uploaded to NVivo. Each transcript is coded based on recurring themes, patterns, and categories related to the research objectives, such as the effectiveness of NbS, their impact on livelihoods, and climate variability.

- **Thematic Analysis**:

  Using NVivo, open coding was used to identify initial themes followed by essential coding to establish connections between categories. As patterns emerge, the codes are refined and categorized into broader themes that align with the study's objectives. Later themes are analysed to understand how they address the research questions. This involves an iterative process of reviewing and refining themes to ensure they accurately represent the data. Both manifest and latent content were examined to derive deeper insights.

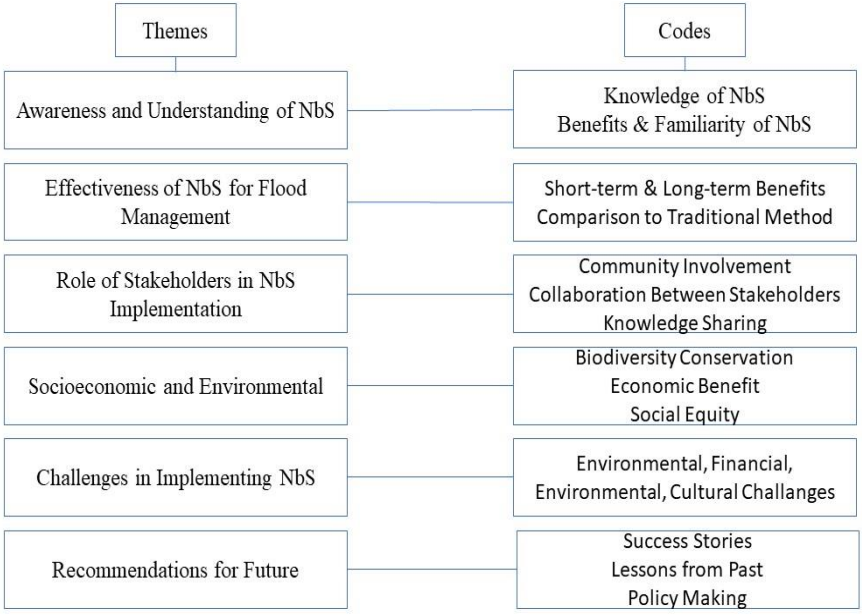

Figure 3: themes & codes for analysis

- **Data Validation**:

Information from key informants and a literature review are used to validate the findings. This cross-referencing ensures the credibility and accuracy of the thematic analysis results.

- **Result Interpretation**:

Finally, the identified themes are interpreted in the context of the study's aim to assess NbS for flood management. The analysis provides insights into community perceptions, challenges, and the effectiveness of NbS interventions in the case study area.

Results and Findings

Thematic Concepts

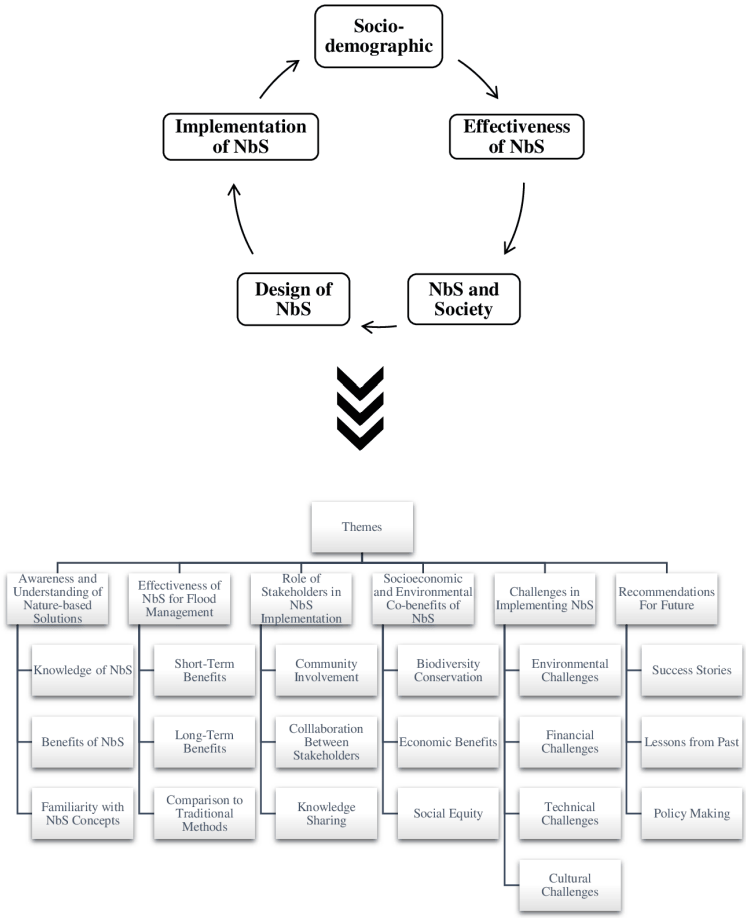

Figure 4: thematic analysis process

Focused Group Discussions

As part of this research, three Focused Group Discussions were conducted among distinct occupational groups of around 26 people in the Burigoalini Union: fishermen, farmers, and the general population. The FGDs revealed notable variations in the participants' knowledge and familiarity with

NbS concepts, reflecting differences in occupational experiences and environmental interactions according to the framework.
Different kinds of themes based on different components are described below –

Theme 1: Awareness and Understanding of NbS

The FGDs reflected varied levels of awareness and understanding of NbS across the respondents with different occupational backgrounds, inclusive of fishing and farming. Generally, there is recognition of NbS, though at a largely varied level of understanding.

- *Knowledge of NbS:*

Participants appeared to hold the concept of NbS, though this was often described in practical rather than technical terms. For example, fishermen mentioned that while they might not be familiar with the terminology, they knew what NbS practices involve, such as planting of mangroves and restoration of wetlands, well understood within their context of flood management. Farmers also understood that NbS uses natural processes in rebuilding ecosystems, giving a basic understanding of the same concept.

- *Benefits of NbS:*

Participants listed a number of benefits of NbS and emphasized how NbS has been particularly successful in flood management and trying to reduce its impacts. They underlined that these initiatives, such as planting mangroves and digging canals, help save agricultural lands from saltwater intrusion and erosion, hence protecting their livelihoods. The community recognizes that such solutions add value not only to flooding but also to biodiversity and general ecosystem health.

- *Familiarity with the NbS concept:*

While some respondents had association with NbS principles, especially those applied to practical uses, others tended to be less aware of the theoretical underpinning. The fishermen showed a basic awareness related to how NbS can function in flood management, whereas farmers are open to learning more about these approaches, which will better position them to adapt to environmental changes.

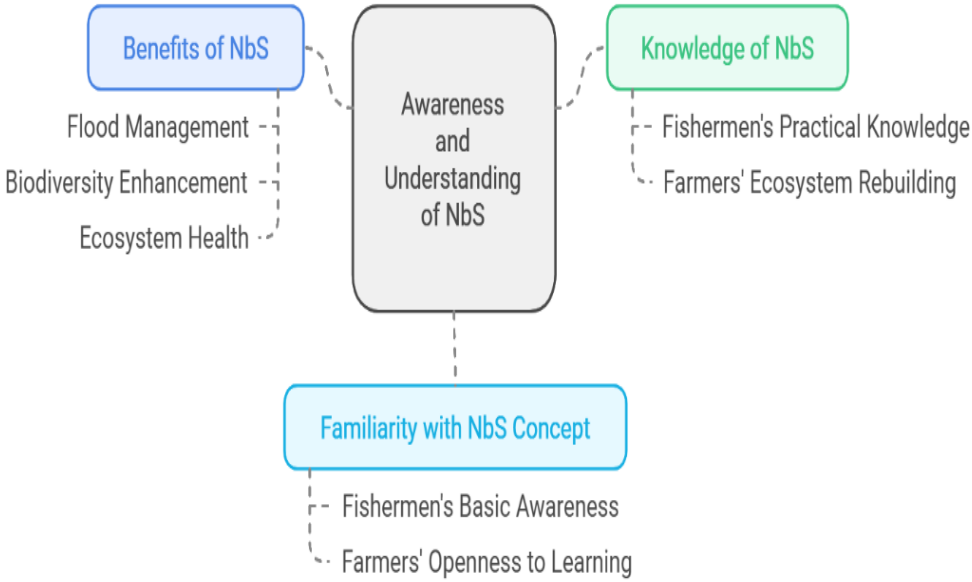

Figure 5: theme 1 - awareness and understanding of NbS

Theme 2: Effectiveness of NbS for Flood Management

Results from the three FGDs showed diverse views on the effectiveness of NbS for flood management. Participants shared views on the short-term and long-term effects of these approaches.

- *Short-Term Benefits:*

Participants observed that some NbS practices, like planting mangroves and creating wetlands, begin to show positive effects in the short term. Fishermen and farmers noted that these solutions help reduce soil erosion, protect agricultural land, and slow down water flow. However, immediate gains might be less because it takes a while to achieve the maturity of ecosystems. In the short run, green embankments, plantation of trees, and digging of canals were to some extent useful to reduce flood impacts during heavy rainfall.

- *Long-Term Benefits:*

In all FGDs, participants mentioned that the effectiveness of NbS over the longer term is significant. For example, mangroves serve as natural barriers at full growth and contribute to flood and erosion protection, adding to overall ecosystem health. The farmers especially mentioned that flood-resistant agriculture and diversified fisheries contribute to livelihoods that are resilient in the longer term. The mixed-occupation group also highlighted that NbS

approaches contribute to biodiversity and soil health, thus improving the sustainability of the resources locally over time.

- *Comparison to Traditional Methods:*

There was agreement from across the FGDs that NbS offers more sustainable and cost-efficient solutions than hard infrastructure, such as embankments. Although people recognized that traditional approaches provide quicker protection, these were less adaptive in the longer term such as wetland restoration for environmental changes. The NbS approach has the added advantage of improving ecosystem resilience, which makes it preferable in the long run over just solely addressing flood hazards.

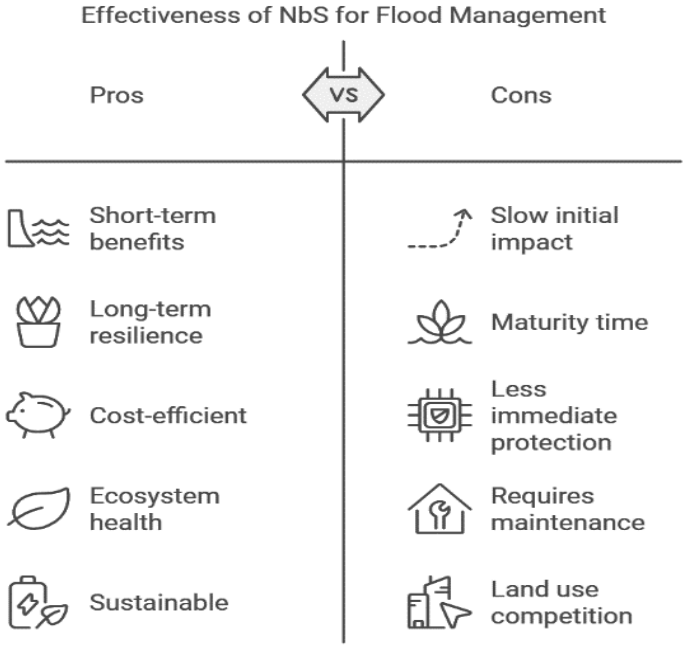

Figure 6: theme 2 - effectiveness of NbS

Theme 3: Role of Stakeholders in NbS Implementation

The theme role of stakeholders in the implementation of NbS (NbS) for flood management is critical, with a focus on community involvement, collaboration, and knowledge sharing.

- *Community Involvement:*

Community involvement has been rebounded time and again among all three focus groups. Indeed, the valid responses from participants who are fishermen, farmers, and those from mixed occupations indicated that the successful NbS initiatives involve local communities from the very start of implementation up to maintenance. Many participants reasoned that communities involved right from the start would show a greater level of ownership, which normally would increase the likelihood of long-term success. This sense of responsibility encourages people to take care of and protect the natural infrastructure, like mangroves and wetlands.

- *Collaboration Between Stakeholders:*

These FGDs also established that effective NbS flood management requires cooperation at large scales, from the local community to government agencies, NGOs, and other environmental groups. As has been pointed out, such cooperation allows for much better coordination of resources, knowledge, and efforts toward NbS project implementation. However, contributions from government authorities were not particularly effective; this view came out in contributions from some participants, especially in the second FGD, and impeded the overall success of such initiatives.

- *Knowledge Sharing:*

The other significant message related to information sharing and lessons learned from previous NbS projects is that stakeholders indicated knowledge sharing among diverse stakeholders through community meetings, local media, or workshops forms the foundation upon which flood management strategies could be optimized. Such knowledge sharing not only educates the community on the diverse set of benefits of NbS, but it makes the community understand how to implement such solutions into practice in daily life to increase resilience in flood-prone areas.

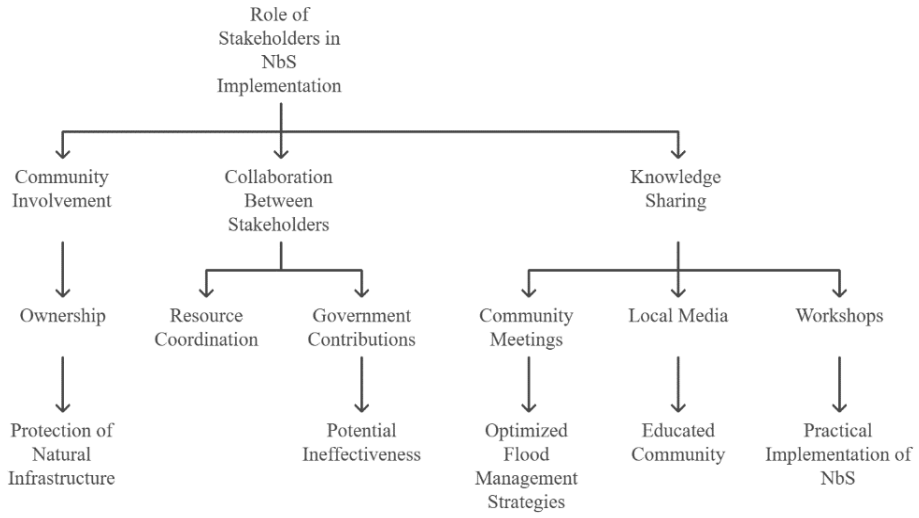

Figure 7: theme 3 - role of stakeholders in NbS implementation

Theme 4: Socioeconomic and Environmental Co-benefits of NbS

The most important socio-economic and environmental co-benefit of NbS regarding flood management focuses on biodiversity conservation, economic benefits, and social equity.

- *Biodiversity Conservation:*

All the participants in the FGDs reiterated that NbS not only reduces floods but also contributes to protecting and restoring biodiversity. The fishermen and farmers acknowledged that these NbS, like the restoration of mangroves, wetlands, and other ecosystems, enhance the conservation of local flora and fauna. This biodiversity conservation would then reinforce the environment's resilience against future floods, hence making it a sustainable solution for flood management. Participants also agreed that this would help in the restoration of nature, to which their livelihoods are strongly attached.

- *Economic Benefits:*

One of the leading themes that cut across the FGDs was the economic aspect of NbS. The participants agreed to the fact that NbS projects, if well implemented, have the potential to introduce new jobs to the local communities. For example, maintenance of natural infrastructures like mangrove replanting or ecosystem monitoring. Moreover, it has been revealed by farmers that NbS applied in agriculture and fisheries can potentially assure more sustainable and productive practices to ultimately ensure economic benefits sustainably.

Importantly, flood management through NbS helps minimize the economic loss associated with floods, which is a major concern for locals.

- *Social Equity:*

Another leading theme was social equity as promoted by NbS. NbS projects involving all community members both in planning and implementation to ensure benefits accruing from the project are equitably shared. In this respect, participants argued that fair involvement in decision-making processes, coupled with provision for training opportunities, are indeed methods of uplifting marginalized groups so that all benefit from these initiatives. This, in turn, will create a more inclusive community that can be resilient enough to adapt to future challenges.

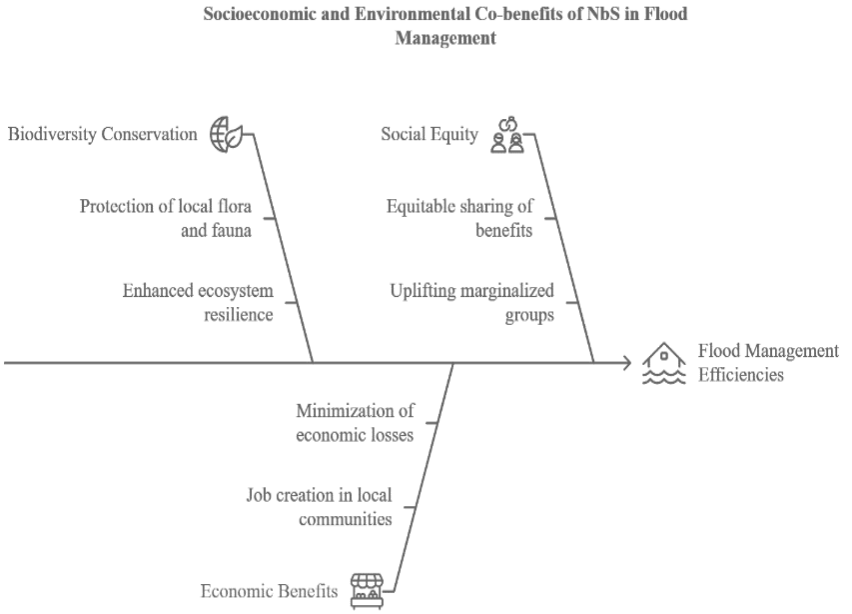

Figure 8: theme 4 - socioeconomic and environmental co-benefits of NbS

Theme 5: Challenges in Implementing NbS

In the Satkhira coastal area, some challenges were identified in flood management through NbS, such as environmental, financial, technical, and cultural challenges.

- *Environmental Challenges:*

Environmental challenges are huge because of the lack of awareness in the community about the importance of NbS. Sometimes, these illegal activities

involve the cutting down of mangroves, thereby weakening natural flood barriers and reducing the effectiveness of such solutions. Other problems, like soil erosion and wetland degradation, further complicate efforts to sustain these natural infrastructures.

- *Financial Challenges:*

It also critically inhibits NbS implementation. Results from FGDs showed that a lack of funding, most of which is exacerbated by corruption and mismanagement, makes it hard to sustain the projects in the long term. Lacking financial support for training, resource allocation, and how to keep these natural infrastructures going means the initiatives fail.

- *Technical Challenges:*

There is lack of expertise and technical abilities necessary in the design process and implementation of NbS. According to participants, developing sustainable solutions requires knowledge at the local and expert levels. Various projects have also been hindered by a lack of access to technical ability, and there is generally an absence of regular training programs.

- *Cultural Challenges:*

The local community aspect was pointed out to date because some of the community resisted the adoption of NbS due to unfamiliarity with its conceptual framework. Community involvement in planning and decision-making is of utmost importance over such resistance but faces barriers in culture for full participation and understanding of the long-term benefits of NbS.

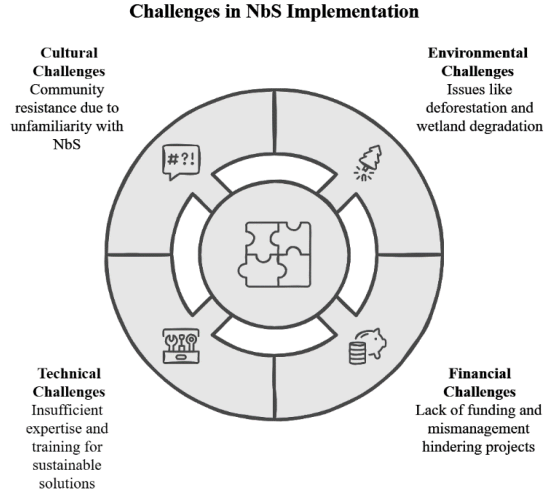

Figure 9: theme 5 - challenges in implementing NbS

Theme 6: Recommendations for the Future

Participants suggested their recommendations regarding the future of NbS in flood management, based on success stories, lessons from past experiences, and policymaking.

- *Success Stories:*

NbS provided direct benefits to different communities in Burigoalini, particularly in the planting of mangroves and restoration of natural barriers. Such success stories also demonstrate how NbS can significantly reduce flood impacts, protect livelihoods, and help the local economy by supporting biodiversity, such as creating fish habitats.

- *Lessons from Past:*

The importance of community involvement in planning and implementing NbS is emphasized by the participants. As participants explain, NbS projects are more effective and sustainable if communities are active in their participation. For instance, conserving local mangroves has reduced the destruction caused by flooding and helped in improving the socio-economic status by offering additional means of livelihood, such as clean water and habitat for wildlife. This shows that combining traditional knowledge with technical expertise may be the key to better NbS projects.

- *Policy Making:*

The participants also included in their recommendations to policy-making the following- increasing funding, more effective application of the law in the protection of natural barriers, and deeper education of communities about the NbS benefits. They further recommended periodic knowledge-sharing platforms that would help the local practitioners in NbS to learn from best practices and emerging techniques so that NbS projects are responsive to environmental and socio-economic changing conditions. Above all, policymakers are encouraged to pay attention to long-term planning and investment in training programs for developing local capacity.

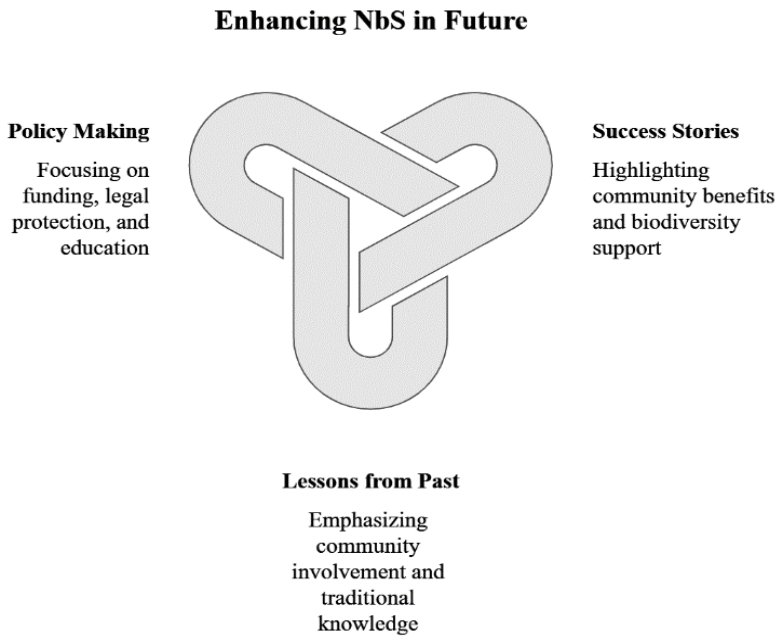

Figure 10: theme 6 - recommendations for future

Discussion

These FGDs were representative of the varied occupation levels, which ranged from fishing to farming. The most obvious trend emerging from these FGDs was the level of awareness and comprehension of NbS among respondents. While NbS is generally known conceptually, it lacks a detailed technical definition from the respondents' perspective. This conceptual understanding points to a gap in technical knowledge, suggesting a need for structured educational programs on NbS practices. Such programs could further empower local communities, aligning their everyday practices with broader ecological goals, thereby enabling a more comprehensive application of NbS beyond their immediate experiences. For instance, it is pointed out that fishermen know practices like mangrove planting and wetland restoration, though the specific terminology of NbS is unknown to them yet they relate the two measures above with flood management in their everyday lives. Again, farmers recognized that NbS uses natural processes in rebuilding the ecosystems, hence they have a basic understanding of NbS. Some direct and indirect benefits related to NbS were found among the participants, such as how NbS was able to successfully minimize recent floods. As well as Natural Flood Management, directly aims to

reduce flood risks through various interventions, enhancing the resilience of ecosystems and communities (*WIREs Water - 2023 - Thaler - Natural Flood Management Opportunities to Implement Nature-based Solutions on Privately.Pdf*, 2023.). They shared that mangrove planting and canal digging were effective techniques for protecting their agricultural lands from saltwater intrusion and erosion to save their livelihoods. Also, local agriculture officer Riazul Islam mentioned that local people are using these traditional techniques as early techniques. This observation reveals an opportunity to balance traditional techniques with NbS practices, creating hybrid approaches that build on both local knowledge and ecological strategies. It was further recognized by the community that NbS addresses not just flooding but biodiversity and ecosystem health, too. Whereas some of the respondents became familiar with NbS principles through practical works, others-especially farmers-showed a need to be more informed on theoretical aspects for better adaptation to changing environmental conditions (Kabisch et al., 2016).

The range of views on the effectiveness of NbS for flood management varied, and both short-term and long-term benefits were identified. As participants pointed out, some NbS practices, such as planting mangroves and creating wetlands, start to show positive effects in the short term. According to the fishermen and farmers, these measures will have numerous benefits, including a reduction in soil erosion, protection of agricultural land, and reduced flow velocity of water. These short-term benefits might be small because ecosystems need time to develop. In the short term, mitigation of flood impacts could be achieved in some ways during heavy rainfall, by green embankments, tree plantations, and canal digging (Thaler et al., 2023). Over the longer term, participants consistently underlined the very important benefits arising from NbS. Participants also acknowledged NbS as a critical component in adapting to climate change. They recognized that mangrove forests, flood-resistant crops, and diversified fisheries are vital for building resilience against more frequent and severe weather events, positioning NbS not only as a reactive solution but as an adaptive measure to future climatic shifts. Also, protect Mangroves, against flooding and erosion from a high-water table while further enhancing ecosystem health (Moraes et al., 2022). As a result, farmers emphasized livelihood resiliency over time with flood-resistant crops and diversified fisheries. NbS approaches also enhance biodiversity, improve soil health, and ensure resource-use management is sustainable over time. According to Pintu Kumar Guha a Project Officer at the Center for Natural Resource Studies, while these approaches are more rapid compared to traditional methods, such as hard embankments, participants commonly concluded that NbS offers more

sustainable, adaptive, and cost-efficient solutions that contribute to ecosystem resilience for better long-term outcomes.

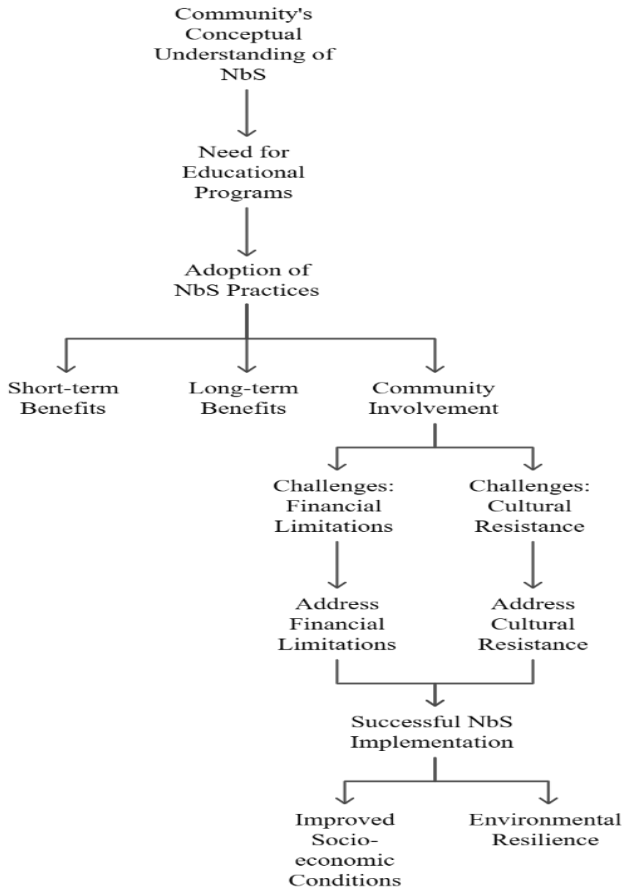

Figure 11: steps of successful NbS implementation at the community level

All groups shared that when NbS initiatives involved local communities from the outset, such communities took ownership of projects and thus contributed to their sustainability. Specific statements were made by fishermen and farmers that natural infrastructure such as mangroves and wetlands are better protected if communities are involved in implementation and maintenance. Collaboration among the local communities, government agencies, NGOs, and environmental groups was also seen as essential (Ferreira et al., 2020). The other

important attribute was knowledge sharing where the participants highlighted the essence of information sharing within community meetings, through local media, and during workshops. Such an approach allows learning not only about the knowledge base of NbS but also provides practical experience within a community regarding how to implement such solutions, thereby making them more resilient to floods in general (Ferreira et al., 2020).

NbS was widely recognized as offering socio-economic and environmental co-benefits, emphasizing the potential of supporting biodiversity conservation, economic benefits, and social equity (Kabisch et al., 2016). The participants have spoken of NbS-like mangrove restoration and wetland regenerations that have helped in mitigating floods and have been responsible for strengthening the local biodiversity among fishermen and farmers. Also, Jahir Akon, Forest Officer on that range added that this ecosystem's restoration would add to the resilience of the environment, which is important in response to sustainable flood management and directly linked to their livelihood. Economically, the result says that NbS initiatives may also provide new jobs within the community to take care of and monitor the ecosystem. Farmers then expanded on how NbS enhances those sustainable agriculture and fisheries practices that control the long-term economic impacts of floods and thereby improve the local economies, as also agreed by the agriculture officer. To further the initiative of NbS adoption, some participants recommended economic incentives, such as tax reductions or subsidies, for those actively engaged in NbS practices. This approach could not only support livelihoods but also encourage more community members to contribute to local NbS projects, thereby enhancing environmental responsibility and economic stability. Socially, the respondents also pointed out that NbS provides social equity through decision-making and actual project implementation by every group of people in the community, and Fazal Ahmed Local Disaster Manager at the union level added that it empowers marginalized communities to participate in their own development.". As reported, they considered equal participation and even training opportunities for marginal groups to be a just distribution of benefits, thereby helping to build an inclusive resilient community. Overall, participants decided that NbS can holistically enhance both the environmental and socio-economic resilience of flood-prone communities such as the Shyamnagar coastal area (Moraes et al., 2022).

Various challenges were identified during the implementation of NbS in flood management in the Satkhira coastal area. Because of the lack of awareness at the community level about NbS benefits, various environmental challenges mentioned by the Forest officer, such as harmful mangrove-cutting practices,

reduce the effectiveness of natural barriers against flooding, soil erosion and degradation of wetlands are also other problems that further undermine such efforts. Participants suggested the establishment of accessible funding mechanisms or community-based funds that would directly support local NbS initiatives. By facilitating direct access to funds, communities can prioritize projects based on immediate needs, reduce delays due to administrative processes, and strengthen long-term NbS viability. No NbS project exists without finances available for training, resources, and maintenance (Seddon et al., 2020). Technical challenges include a lack of expertise or access to required technical skills both at local and expert levels (Nelson et al., 2020). The participants were reminded that regular training programs should be imparted to build the capacity that is needed in designing and implementing sustainable NbS projects. Last but not the least, cultural challenges arise from community resistance to adopt NbS due to the unfamiliarity with its concepts. Greater involvement of communities in the processes of planning and decision-making overcomes this resistance, however, due to cultural barriers, full participation and understanding of the benefits offered by NbS as a long-term option are still hampered. NbS projects should also consider cultural practices and values when introducing new ecological approaches, making efforts to involve community leaders, and respected and expert personnel in the advocacy of NbS. This socially sensitive approach can bridge understanding, reduce resistance, and foster a more inclusive and supportive environment for NbS adoption. These challenges highlight the complexity of effectively implementing NbS in the region (Seddon et al., 2020).

Based on success stories, learned lessons, and suggestions for policymaking, one of the striking examples of successful mangrove planting and restoration of natural barriers in Burigoalini directly highlighted some benefits offered by NbS in reducing flood impacts through livelihood protection and local economic boosts because of biodiversity support, such as the creation of fish habitats. Participants emphasized, from their experience, that NbS projects should involve an active community during both the planning and implementation stages since a mixture of traditional knowledge with more technical information produces better results. Additionally, ongoing monitoring and evaluation were noted as crucial for adapting NbS practices to evolving environmental and social contexts. Participants highlighted that regular assessments would allow communities to address any challenges, modify practices as needed, and ensure that NbS efforts continue to meet their resilience and sustainability goals effectively. For example, local activities related to the conservation of mangroves reduced flood damage, improved socio-economic conditions, and supplemented resources such as clean water and habitats for

wildlife (Pontee et al., 2016). Regarding the policy recommendations, participants called for increased funding, better enforcement of laws protecting natural barriers, and more community education about NbS benefits. Moreover, they suggested relevant knowledge-sharing platforms to keep practitioners updated on the latest best practices and new techniques to make NbS projects resilient to changing environmental and socio-economic conditions. Lastly, long-term planning and investment in local capacity-building through training programs were stressed as indispensable for the sustainability of any effective NbS undertaking (Anderson & Renaud, 2021).

Conclusion

The research highlights the transformative potential of NbS in flood-prone coastal regions, demonstrating their dual role in enhancing ecosystem resilience and community livelihoods of Burigoalini Union, Shyamnagar, Satkhira. From the participants, it can be understood that while the local population has a fairly good idea of NbS, there is still a gap in knowledge relating to more technical aspects and long-term effectiveness. By addressing flood resilience through NbS, this research supports SDG 13 (Climate Action) and SDG 15 (Life on Land), highlighting the potential for NbS to serve as adaptable solutions in other coastal regions facing similar challenges. Also, this research advocates for a hybrid approach that combines NbS, such as mangrove restoration, with traditional embankments (traditional practices). Such integration including scientific techniques enhances resilience by holding the strengths of both approaches, offering a comprehensive strategy for managing floods in coastal regions. Community involvement in the entire planning to implementation process has been identified to create more resilient and adaptive outcomes that are favourable for the environment and livelihoods like community ownership. This study also emphasizes that culturally sensitive approaches, which respect and incorporate local practices, are crucial for the success of NbS.

Future studies should focus on assessing the long-term effectiveness of NbS in adapting to climate variability. Comparative studies across different ecological and socio-economic contexts can provide a deeper understanding of how NbS strategies can be customized for diverse environments. Success stories in this region include the restoration of mangroves that establish how NbS may protect against flooding and bring in such socio-economic co-benefits as job creation and ecosystem restoration. In addition, offering economic incentives for community members involved in NbS projects, such as stipends for mangrove maintenance or subsidies for flood-resistant crops, could enhance community participation and ensure sustained efforts. If policymakers desire accessible and sustainable

approaches, their focus should shift toward increasing funding, better enforcement of laws, and capacity building at the local level through continuous training programs. Equally, importance should be given on the establishment of ongoing monitoring, adaptive management frameworks, regular assessments, and community feedback mechanisms which would allow NbS projects to be modified and optimized over time, for changing environmental and socio-economic conditions. To support the continuous evolution of NbS, the establishment of knowledge-sharing platforms such as training, workshops, and media uses are recommended, where community members, environmental experts, and policymakers can exchange best practices and lessons learned. In an era of escalating climate risks, NbS offer a transformative pathway to sustainable flood management. By encouraging collaboration among stakeholders and integrating NbS into policy and practice, we can build resilient communities capable of adapting to future uncertainties against flood.

References

Anderson, C. C., & Renaud, F. G. (2021). A review of public acceptance of nature-based solutions: The 'why', 'when', and 'how' of success for disaster risk reduction measures. *Ambio*, *50*(8), 1552–1573. https://doi.org/10.1007/s13280-021-01502-4

Bernard, A., Long, N., Becker, M., Khan, J., & Fanchette, S. (2022). *Bangladesh's vulnerability to cyclonic coastal flooding*. https://doi.org/10.1016/j.wace.2014.11.001

Bhuiyan, Md. J. A. N., & Dutta, D. (2012). Analysis of flood vulnerability and assessment of the impacts in coastal zones of Bangladesh due to potential sea-level rise. *Natural Hazards*, *61*(2), 729–743. https://doi.org/10.1007/s11069-011-0059-3

Dewan, T. H. (2015). Societal impacts and vulnerability to floods in Bangladesh and Nepal. *Weather and Climate Extremes*, *7*, 36–42. https://doi.org/10.1016/j.wace.2014.11.001

Ferdous, M. M., & Chowdhury, A. H. (2016). *Study on the adaptation capacity and practices of the villagers in the water logged area of Satkhira, Bangladesh*. https://doi.org/10.13140/RG.2.2.11750.96322

Ferreira, V., Barreira, A. P., Loures, L., Antunes, D., & Panagopoulos, T. (2020). Stakeholders' Engagement on Nature-Based Solutions: A Systematic Literature Review. *Sustainability*, *12*(2). https://doi.org/10. 3390/su 12020640

Islam, Md. J., Abdullah, M. S., & Alam, M. (2024). Flooding crisis in Bangladesh: Urgent measures required. *Biodiversity*, *25*(2), 95–98. https://doi.org/10.1080/14888386.2024.2330385

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2), art39. https://doi.org/10.5751/ES-08373-210239

Milly, P. C. D., Wetherald, R. T., Dunne, K. A., & Delworth, T. L. (2002). *Increasing risk of great ¯oods in a changing climate*. *415*.

Mitra, D. (2024, August 28). *Nature-based solutions a must for flood control* -. https://www.dml.or.id/nature-based-solutions-a-must-for-flood-control/

Moraes, R. P. L., Reguero, B. G., Mazarrasa, I., Ricker, M., & Juanes, J. A. (2022). Nature-Based Solutions in Coastal and Estuarine Areas of Europe. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.829526

Najibi, N., & Devineni, N. (2018). Recent trends in the frequency and duration of global floods. *Earth System Dynamics*, *9*(2), 757-783. https://doi.org/10.5194/esd-9-757-2018

Nelson, D. R., Bledsoe, B. P., Ferreira, S., & Nibbelink, N. P. (2020). Challenges to realizing the potential of nature-based solutions. *Current Opinion in Environmental Sustainability*, *45*, 49–55. https://doi.org/10.1016/j.cosust.2020.09.001

Pontee, N., Narayan, S., Beck, M. W., & Hosking, A. H. (2016). Nature-based solutions: Lessons from around the world. *Proceedings of the Institution of Civil Engineers - Maritime Engineering*, *169*(1), 29-36. https://doi.org/10.1680/jmaen.15.00027

Rahman, M. A., Dawes, L., Donehue, P., & Rahman, M. R. (2021). Cross-temporal analysis of disaster vulnerability of the southwest coastal communities in Bangladesh. *Regional Environmental Change*, *21*(3), 67. https://doi.org/10.1007/s10113-021-01797-9

Sarker, M., Haque, S. A. U., Rahman, M., Akter, M., & Ali, S. (2021). Integrated use of remote sensing, GIS and GPS technology for monitoring the environmental problems of Shyamnagar. *Journal of Environmental Science and Natural Resources*, *12*(1-2), 11-20. https://doi.org/10.3329/jesnr.v12i1-2.51979

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to

climate change and other global challenges. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Shaibur, M. R., Khan, M. H., & Rashid, M. S. (2017). *Climate change may cause natural disasters in Shyamnagar, Satkhira: The southwestern parts of Bangladesh*. *32*. https://doi.org/10.5194/esd-9-757-2018

Shyamnagar Upazila, *Banglapedia*. (2011). https://en.banglapedia.org/index.php/Shyamnagar Upazila

Tajrin, M. S., & Hossain, B. (2017). *The Socio-Economic Impact Due to Cyclone Aila in the Coastal Zone of Bangladesh*. https://doi.org/10.13140/RG.2.2.11750.96322

Thaler, T., Hudson, & Green. (2023). *Natural flood management: Opportunities to implement nature-based solutions on privately owned land—Thaler—2023—WIREs Water—Wiley Online Library*. https://wires.onlinelibrary.wiley.com/doi/10.1002/wat2.1637

Turkelboom, F., Demeyer, R., Vranken, L., De Becker, P., Raymaekers, F., & De Smet, L. (2021). How does a nature-based solution for flood control compare to a technical solution? Case study evidence from Belgium. *Ambio*, *50*(8), 1431-1445. https://doi.org/10.1007/s13280-021-01548-4

Watkin, L. J., Ruangpan, L., Vojinovic, Z., Weesakul, S., & Torres, A. S. (2019). A Framework for Assessing Benefits of Implemented Nature-Based Solutions. *Sustainability*, *11*(23), 6788. https://doi.org/10.3390/su11236788