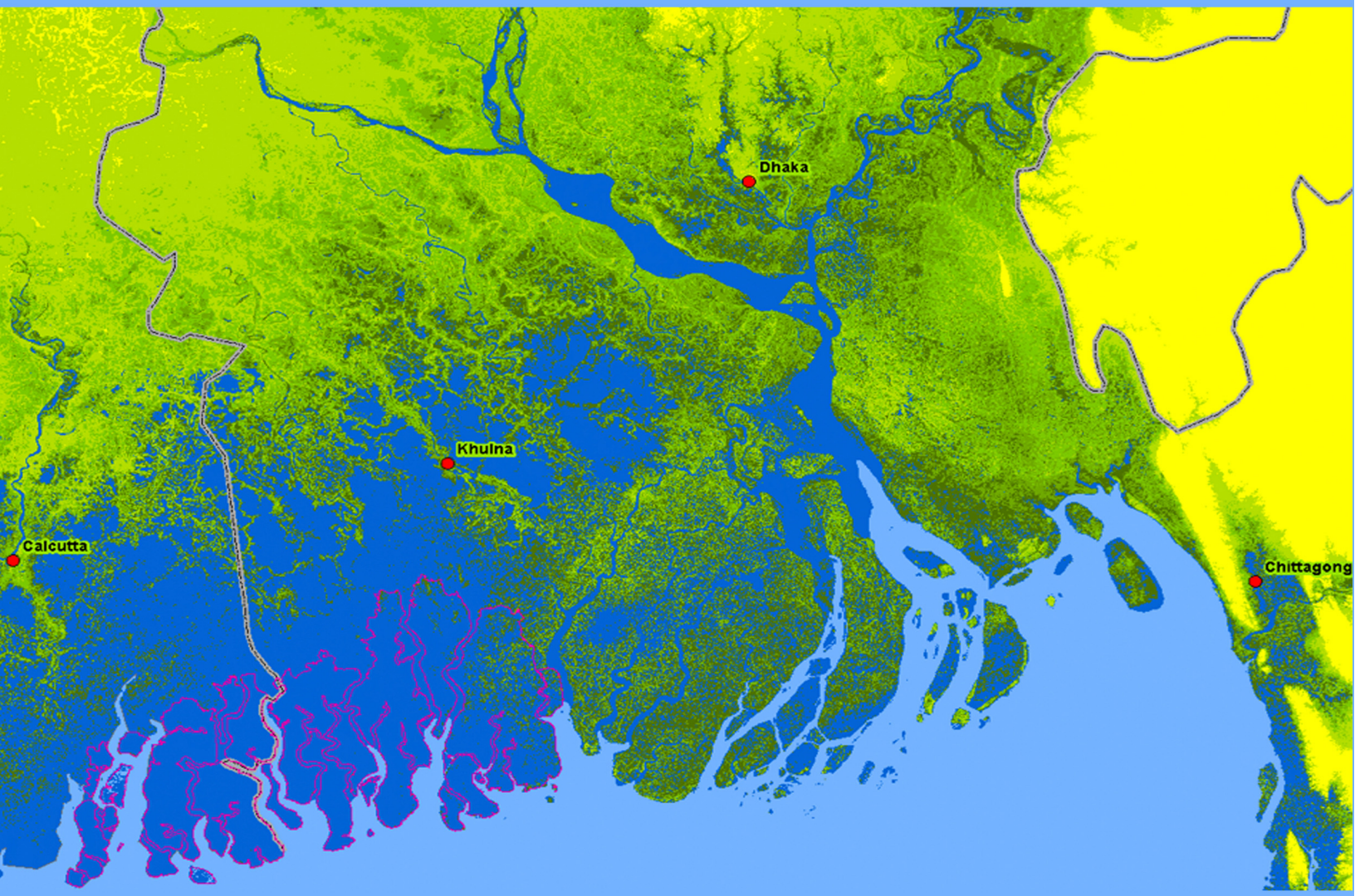
JOURNAL OF BANGLADESH STUDIES



Special volume on 20 years of
BEN-Bangladesh Environmental Network

Volume 20
Number 2
Year 2018
ISSN 1529-0905

BDI
Bangladesh Development Initiative

JOURNAL OF BANGLADESH STUDIES (ISSN 1529-0905)

Volume 20, Number 2, 2018 - Published in October 2020

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FROM THE EDITOR

This issue of JBS addresses what may be referred to as forays into the soul of a nation: its all-encompassing environment. The reader is presented with a compendium of authoritative views on various environmental matters to suggest how Bangladesh ought to prioritize its options to ultimately deliver environmental justice. Importantly, I hope this issue will bring a modicum of realization to key stakeholders that when a nation's soul is destroyed, in slow but sure steps, willfully or otherwise, it assuredly destroys what the soul inhabits —- humanity in its diversity, culture, harmony with nature, livelihoods, aspirations, and much more.

Environmental degradation is reflected in various human activities that harm nature (the damming of rivers to reclaim land for construction, dumping toxic waste in waterbodies, air pollution from coal-fired power plants and brickfields, etc.). Often such activities place the aspirations of one group of people in direct conflict with another (clean air vs. need for electricity; clean water vs. dyeing operations in the RMG trade) and raise the specter of whose worldview will have the final say and whose must be sacrificed. Consciously or sub-consciously, embedded in the discourse is the interplay between the perspectives of a functionalist society which is problem-oriented in nature and directed at providing solutions to practical problems and a radical humanism perspective of the Young Hegelians —- Marx, Feuerbach, Lukacs, Gramsci —- concerned with "seeking to reveal society for what it is, to unmask its essence $\cdots$ and to lay the foundation for human emancipation through deep-seated social change" (Burrell and Morgan 1985 p.284).

Whether this tussle between different interest groups should end up in a zero-sum game or whether alternative outcomes can be envisaged is something researchers and academics ought to contemplate further. Not only is this important at the national level; such matters constantly come up in international affairs also. For example, according to Schoenbaum (1992), "The GATT is under attack by some in the environmental community who charge that international free trade blindly fosters the exploitation of natural resources. The GATT is depicted as a sinister charter that allows 'big business' a free hand to plunder the bounty of the natural world." Some environmentalists insist how free trade has led to destroying the environment, including threats to certain species. Schoenbaum indicates how environmentalist lobbyist have joined together to disrupt free trade in its present avatar.

If the problem emerges as a power game, continuing conflict can dissipate much intellectual, emotional and physical energy with neither side backing down. Such conflict can be protracted and debilitating. Thus, instead of a zero-sum approach, perhaps the need of the day is to involve various stakeholders and invoke the need to negotiate an optimal outcome.

Banning two-stroke engine vehicles and re-imposing a ban on plastic bags is certainly desirable: but what of the vested interests? Can the enactment of various environmental laws devise alternative modes of sustenance for those who anticipate being displaced? The 2019 high court verdict that "A river is a living entity, a legal person and a juristic person," is a clear need of the day: no question. But what of those (leather and garment industry) who have few alternatives within a reasonable cost framework? Can some arrangements (including viable locations and technological solutions such as wastewater treatment) be negotiated so that their operations can continue profitably and unhindered? The coal-fired power plant in Bagerhat, Khulna, threatens the Sundarbans and it would be a shame to lose, over time, the mangroves and the protection it affords to various entities. Yet, power demand has been growing in leaps and bounds as the nation marches from lower middle-income status to higher aspirations. Could some alternatives be devised by domestic and international environmentalists in concert with other major stakeholders? The Rooppur nuclear powerplant also raises similar questions — of costs and benefits: who pays, who benefits?

In the arcane world of politics, where the environment is a political hotbed (unfortunately), saving face is a huge issue, especially when egos of key stakeholders are embroiled. Under the circumstances, the question is whether it is better to have behind-the-door negotiations within some give-and-take framework among the feuding parties instead of staking out claims and counter claims in public, proving each other wrong, and propagating one's point-of-view in no uncertain terms as widely as possi-

ble. Also important is instead of seeing several matters — trade liberalization, jobs and economic growth, climate change, carbon sequestration, preservation of species — as separate issues, could they be brought together in one forum to examine and explore the benefits and costs for the human race?

I do not pretend to have answers; I merely seek to explore possible alternate scenarios in the constant struggle that I term "the clash of interests." My point here is to stress that it is not important to win a battle here and there but to win the wa $\cdots$ for humanity! That means safeguarding the environment, a major source of human sustenance, especially within our fragile ecosystem, while looking out for jobs and economic growth. When ideas clash and interests diverge, it is important to disengage from the battle of egos and transition to another paradigm — the exchange of wisdom — to safeguard the human species. It also entails not just figuring out "what" we need to do but also "how" to approach the vexing problems. I believe the human race must become better at negotiating its future instead of succumbing to baser instincts of power, politics, ego, and who wins today.

Congratulations are due to our *special editor*, Ahmed Badruzzaman, for taking literal pains to put together this illuminating collection of essays for JBS. Thanks are also due to the authors for making a strong case for protecting the soul of the nation, actually the soul of the planet. It is likely that the struggle will continue between the profiteers and the planet-preservers. Let us hope that research, the generation of new knowledge, a rational perspective, and concern for humanity will prevail to avert a doom that is hard to envisage.

Syed S. Andaleeb
Editor in Chief

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FROM THE SPECIAL EDITOR

The idea of this special volume of the JBS on Bangladesh environmental issues arose following the 20th Anniversary celebration of the formation of the Bangladesh Environmental Network (BEN) in July 2018. In its 20 years, BEN a global network of Bangladeshi diaspora (http://ben-global.net) has attempted to help redress the myriad environmental challenges that Bangladesh faces as the country's economy grows. BEN has done its work through projects, fruitful dialog with successive governments irrespective of political affiliation, research-based position papers, in-country international conferences, and activism in collaboration with partners on the ground, such as the Bangladesh Poribesh Andolon (BAPA).

The six papers in this special volume provide only a glimpse into this multi-faceted effort. The reader will note an underlying vein through all six papers—preservation of rivers and water bodies of Bangladesh is closely related to saving the country's environment, and the need for all to be cognizant of this as economic growth is pursued. We hope that the reader will also notice a common thread across the papers weaving the message of the UN's sustainable development goals (SDG's): a developing country with a fragile ecosystem can simultaneously strive for a sustainable economic growth and responsible environmental safeguards.

The first paper, *Bangladesh Environment Movement — Achievements and Challenges*, by Nazrul Islam, provides an overview of the history, successes and challenges of the movement. The paper starts with a brief tutorial on the theory behind the environmental movement contained in two concepts. One involves the dynamic relation that exists between the level of economic development and the quality of the environment in a country. The second concept is the postulation that pollution level initially increases with economic growth and then declines after a country achieves a high level of growth. This theory can help navigate the environmental journey and inform policy decisions. The author then walks the reader through the formation of the environmental movement in Bangladesh, its onward journey, its partnership with successive governments leading to policy successes, such as the ban on Two-stroke Engine Vehicles, re-imposition of the ban on plastic bags, and the enactment of various pro-environmental laws. The author also notes the inevitable divergences that tend to arise with policy makers resulting in challenges in getting policy directives fully implemented, for example, those on river protection that BAPA/ BEN faced, and how the movement has striven to overcome such challenges. The author highlights the salient features of the successful and resilient environmental movement. These include collaboration between Bangladeshis resident in the country and those in the diaspora, as well as the movement's distinctive feature of financial self-reliance that has prevented vested-interests from influencing it and preserved its politically non-partisan character.

The second paper, *Endangered Delta and the People's Movement for Its Survival*, by Sharif Jamil, illustrates one of the major challenges the first paper talks about. The author analyzes the state of the country's river systems and associated wetland. These areas form a vital source of life and livelihood in the Bengal Delta, the world's largest active delta. The author analyzes the threats Bangladesh's rivers systems face from river-grabbing by powerful interests, mega industrial projects being implemented, construction of structures often on rivers, and almost unmitigated dumping of industrial waste into the streams and rivers. One example of a mega industrial project is the Rampal Coal Power Plant being built in the vicinity of the Sundarbans, with limited or no appropriate environmental impact assessment. The author notes the people's movements that have grown in various parts of the country to protect her rivers and wetlands, and the success they have achieved. He highlights both beneficial partnerships with certain government entities to safeguard the rivers, as well as hindrances placed by other governmental entities in this effort. The author notes the very laudatory role courts in Bangladesh have played in attempting to beat back the assault underway on the country's water systems, including the 2019 high court verdict that declared, "A river is a living entity, a legal person and a juristic person," and poses the question, 'will the court's decision be implemented and that too in a timely manner?'

The third paper, *A Critical Look at the Environmental Impact Assessment (EIA) for Rampal Power Plant,* by

Wahida Rashid, uses the standard norms utilized in writing and reviewing EIAs for public projects in the US to examine the Rampal EIA that the Bangladesh government used to approve the project. The Rampal project, also noted in Jamil's paper above, is a coal-fired power plant under construction in Bagerhat, Khulna, in very close proximity of the Sundarbans, the world's largest mangrove forest and a UNESCO World Heritage site. The project has been opposed by domestic and international environmentalists, including BEN and BAPA, but the plant remains under construction. The author finds the Rampal EIA lacking in multiple aspects and recommends a more complete EIA using international standards. Several of the issues raised in Rashid's assessment are similar to the objections UNESCO has raised in opposing the Rampal project, which threatens the Outstanding Universal Value (OUV) of the Sundarbans and its inscription on the World Heritage List. The OUV denotes the exceptional cultural or natural significance of a site that transcends national boundaries, making it of 'common importance for present and future generations of all humanity,' and thus accords it the necessary protection through the inscription.

The fourth paper, *Underlying Causes of Early Floods in the Haor Region*, by Md. Khalequzzaman, examines the unprecedented floods that occurred in four districts in Bangladesh in the haors (vast wetlands) in 2017, in late March and early April and a somewhat smaller but still a large flood in 2019 in the same period. The author uses publicly available 100-yr rainfall data from Sunamganj and the adjacent Meghalaya State of India to make a prediction of increased rainfall in April, compatible with reports by the Intergovernmental Panel on Climate Change. He warns that the flooding is being compounded by multiple factors, such as reduced carrying capacity of Bangladesh's rivers due to human interference and infrastructure building on them, and the resulting siltation that Jamil's paper above described. The author reiterates the value of haors in the Bangladesh economy and ecosystem. He recommends steps to increase the carrying capacity of rivers, starting with collection of modern digital data to better understand the flow patterns of the rivers and wetlands, and then develop suitable plans to manage the country's water systems, especially in the haor regions.

The fifth paper, *Sedimentation Rates Versus Sea-level Rise at the Bangladesh Coast*, by Dipen Bhattacharya, illustrates the importance of understanding whether the sedimentation rate can counter the accelerated sea-level rise due to the rapid climate change initiated in the 20th century. Based on his own and others' research on the effect of sea-level rise on the Bangladesh coastline, the author states that the current sedimentation rates in the Bengal Delta may have been underestimated. He concludes that the current sedimentation at the coast is sufficient to compensate for the sea-level rise at this time, but will not suffice in view of the accelerated sea-level rise. Bhattacharya emphasizes that unhindered sedimentation is essential in maintaining the equilibrium relative to sea-level rise. He also warns that the building of barrages, embankments and polders included in the Bangladesh Delta Plan 2100 prepared with input from Dutch experts runs counter to this. Finally, he calls for building a better sedimentation model for the entire Delta to manage water body governance in Bangladesh in a holistic manner.

The sixth paper, *Bangladesh Energy/Climate Nexus Part I- Quest for Energy Fix and a Trailblazing Rural/Household Sector*, by Ahmed Badruzzaman, notes energy use in Bangladesh and its history. The author surveys the country's difficulty in developing and providing access to modern energy sources. The author notes the dual nature of the country's energy scene, in terms of energy sources and utilization. While energy plans at the level of the state have been mixed and uncoordinated, there has been much recent progress in the often neglected rural/household energy sector. The key element in the progress is a multi-component energy system for clean cooking, advanced biogas use and CO_2-free solar-based off-grid/micro-grid home electrification outside the purview of the often unreliable national grid. This trailblazing growth engendered by domestic ingenuity is in congruence with multiple SDG's, the paper notes. The associated success in this sector can possibly inform the energy planners to consider options that are similarly suited to the country's terrain, societal aspirations, and economy, as they develop plans for the urban/ industrial/ commercial energy sector, instead of blindly considering options that arise out of the past of the developed world and are informed by choices crafted by external experts.

Prior to the twenty first century, economic growth was hailed as the overriding objective in developing countries such as Bangladesh. Environmental issues were considered to be redistributive—my enterprise gains at the expense of your pond's degradation. There was scant environmental regulation and an effective Department of Environment was not created until 1989. In fact, certain vested interests often proposed the choice of growth vs. environment. The arguments for this false choice became moot earlier this decade as countries subscribed to SDG's set up through the United Nations. The SDGs are an urgent call to shift the world onto a more sustainable path with the understanding that there is not necessarily a contradiction between environmental sustainability and economic growth. We hope the reader gets a sampling of the monumental challenge an endeavor to navigate this apparent contradiction poses, however, and the extraordinary efforts underway by Bangladeshi environmentalists, resident and non-resident, to navigate this challenge, through research, activism, and partnership.

The poet Khalil Gibran so lovingly noted, "Everything in nature bespeaks the mother." As the papers in the present volume indicate, much harm has already come to the Mother, but all is not lost. Perhaps new research-driven information and insights, such as those in these papers, will allow us to "reexamine ethically what we have inherited, what we are responsible for, and what we will pass on to coming generations," as the Dalai Lama urges, in order to fashion an all-inclusive environmental movement to benefit us all.

Ahmed Badruzzaman (Paper 1–5)
Farida Khan (Paper 6)

Bangladesh Environment Movement: Achievements and Challenges

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Abstract

This paper provides an overview of the history, achievements, and challenges of Bangladesh environment movement. It uses the Environmental Kuznets Curve to explain the rationale of the environment movement and informs about its features, scope, and potential for a broader significance. It highlights the importance of cooperation between resident and non-resident Bangladeshis in forming and propelling forward the environment movement in Bangladesh. It reviews the considerable success achieved in adoption of pro-environment policies and identifies lack of proper implementation as the main current challenge. The paper discusses the main reasons for inadequate implementation and points to the ways in which these could be overcome and the role that the environment movement could play in this regard. The paper ends by noting the possibilities of vicious and virtuous cycles that the environment movement faces and the need to ensure that it is the latter that materializes.

1 Introduction

Bangladesh's environment started to deteriorate sharply beginning with the 1980s, as the pace of industrialization gathered steam. For some time, the response to this deterioration was limited to government circles and non-government and environment-related consultancy organizations, who were prompted to a large extent by foreign stimuli. However, an indigenous civic environment movement emerged in late 1990s and solidified with the formation of *Bangladesh Poribesh Andolon* (BAPA) in 2000. Non-resident Bangladeshis (NRB), who had set up Bangladesh Environment Network (BEN) in 1998, played a crucial role in founding BAPA, and since then BAPA-BEN cooperation has remained the bedrock for Bangladesh environment movement. In fact, BAPA-BEN cooperation has emerged as a model for RB-NRB cooperation, in general, for voluntary civic effort for the betterment of the country.

Thanks to the efforts by BAPA, BEN, and other pro-environment organizations, the environment movement achieved considerable success in getting many pro-environment policies adopted. However, implementation of the adopted policies remains a challenge. There are both knowledge-related and material interest-related obstacles to proper implementation. In some cases, perverse implementation has resulted in worsening of environment.

The environment movement therefore now stands at a crossroads. On the one hand, dissatisfactory implementation may cause demoralization and weakening of the environment movement, thereby creating the scope for further harm to the environment, leading to a vicious cycle. However, there is also the possibility that the sorry state of implementation will galvanize the people, persuade them to join the environment movement in larger numbers, and thus strengthen the environment movement and force the government to take steps toward proper implementation. As a result, a virtuous cycle may ensue. It is a duty of all to ensure that the environment movement does not fall into the trap of the vicious cycle and instead moves forward to the virtuous cycle.

The new government formed following the election of December 2018 seems to be more earnest in implementing pro-environment policies, such as the policy of freeing the rivers from encroachment. This is encouraging. If sustained and widened to other areas of environmental protection, this changed stance of the government may trigger the virtuous cycle in the environment movement and prove to be the beginning of a new stage in the struggle to save Bangladesh's environment.

The discussion of the paper is organized as follows. Section 2 provides the theory behind the environment movement, using the concepts of Income-Environment Relationship (IER), in general, and Envi-

ronmental Kuznets Curve (EKC), in particular. Section 3 discusses the formation of and successes achieved by the environment movement. Section 4 explains the scope of the environment movement, while Section 5 discusses its salient features and its potential broader scope in Bangladesh. Section 6 informs about BEN activities abroad. Section 7 presents the success of the environment movement in getting pro-environment policies adopted. Section 8 discusses the implementation challenge, noting its various causes. Section 9 considers ways to overcome the implementation problems, and Section 10 discusses the role of the environment movement in this regard. Section 11 presents the challenges of the future, including the possibility of a vicious cycle as well as of moving to the virtuous cycle. Concluding comments are collected in the last, Section 12.

2 Theory Behind the Environment Movement

To present the theory behind the environment movement, it may be useful to introduce the concept of *Income-Environment Relationship (IER)*, which refers to the *generic* dynamic relationship between the level of economic development and the quality of environment in a country. A particular proposition about the nature of this relationship is the *Environmental Kuznets Curve (EKC)*, postulating that the pollution level in a country will first increase with economic growth and then decrease after the country reaches a high level of income.[1] With per capita income level on the horizontal axis and pollution level on the vertical axis, the EKC will therefore have an inverted-U shape (Figure 1).

Sometimes EKC is used to suggest *policy irrelevance* and thereby *policy-inaction*. This is because EKC may be viewed as promoting a sense of *inevitability* and *automacity*. For example, the *rising part* of the EKC curve may suggest that increase in pollution is an *inevitable* outcome (by-product) of economic growth, prompting countries not to do much to curb pollution. The *falling part* of the curve on the other hand may suggest that after reaching a relatively high level of income (the threshold level, Y^*, in Figure 1, the level of pollution will decrease *automatically*, without requiring policy action.

A closer look however shows that the above interpretation of EKC is not correct. Even proponents of EKC point out that the declining part of EKC embodies policy action and is not an automatic, guaranteed outcome. For example, once a country reaches a high level of income, there is a greater demand for environmental quality and hence for pollution curbing policies. Also, at a higher income level, a country acquires greater financial and technological resources and institutional capability necessary to curb pollution. Thus, both the demand and supply side factors can play a potential role in bringing down pollution level. However, to what extent this potential will be realized depends on conscious action, including appropriate government policies. Similarly, EKC allows policy influence on its rising part too. For example, countries witnessing economic growth may use policies to *flatten* the rising portion of the curve. In particular, policies are necessary to ensure that environmental deterioration does not cross the *threshold level*, beyond which the damages become irreversible (P^* in Figure 1. As a result, it is possible to have a *policy-modified EKC*, with lower gradient in the rising part, lower peak, and quicker descent in the falling part, as compared to the relatively spontaneous, *unmodified EKC* (Figure 1). Thus, instead of suggesting policy inaction, EKC actually allows environmental policies to play a significant role *at all stages* of economic growth.[2]

The role of policies in determining environmental outcomes is also clear from the empirical evidence showing that the IER in practice does not always conform to EKC. It is noticed that, while EKC held true for some of the pollutants, it did not do so for many other pollutants. The IER has also been found to *differ* across regions and time periods. These variations suggest that there is no *iron law* that pollution has to first increase before decreasing. Instead, the research suggests that the main role in determining the shape of the actual IER belongs to policies.[3] That is why it is important for a country to have a strong environment movement, which can exert pressure on authorities to adopt and implement pro-environment policies.

3 Environment Movement: Formation and Achievements

The environment movement, in its modern sense, began in Bangladesh in the 1980s. Its beginnings were, to a certain degree, aided by some international stimulus. Several non-government organizations (NGOs) working in Bangladesh took interest in environmental issues. A few research-cum-consultancy organizations arose with focus on environmental issues.[4] The National Environment Management Action Plan (NEMAP) was formulated in 1995 through cooperation among the Government of Bangladesh, United Nations Development Programme (UNDP), Association of Development Agencies in Bangladesh (ADAB), and Bangladesh Centre for Advanced Studies (BCAS).[5] The United Nations Development Programme (UNDP) in Bangladesh launched its Sustainable Environment Management Programme (SEMP) in 1997 to support the implementation of NEMAP.[6] SEMP had twenty-one sub-projects assigned to roughly as many, so-called, Sub-Implementation Agencies (SIA). SEMP spawned new consultancy and advo-

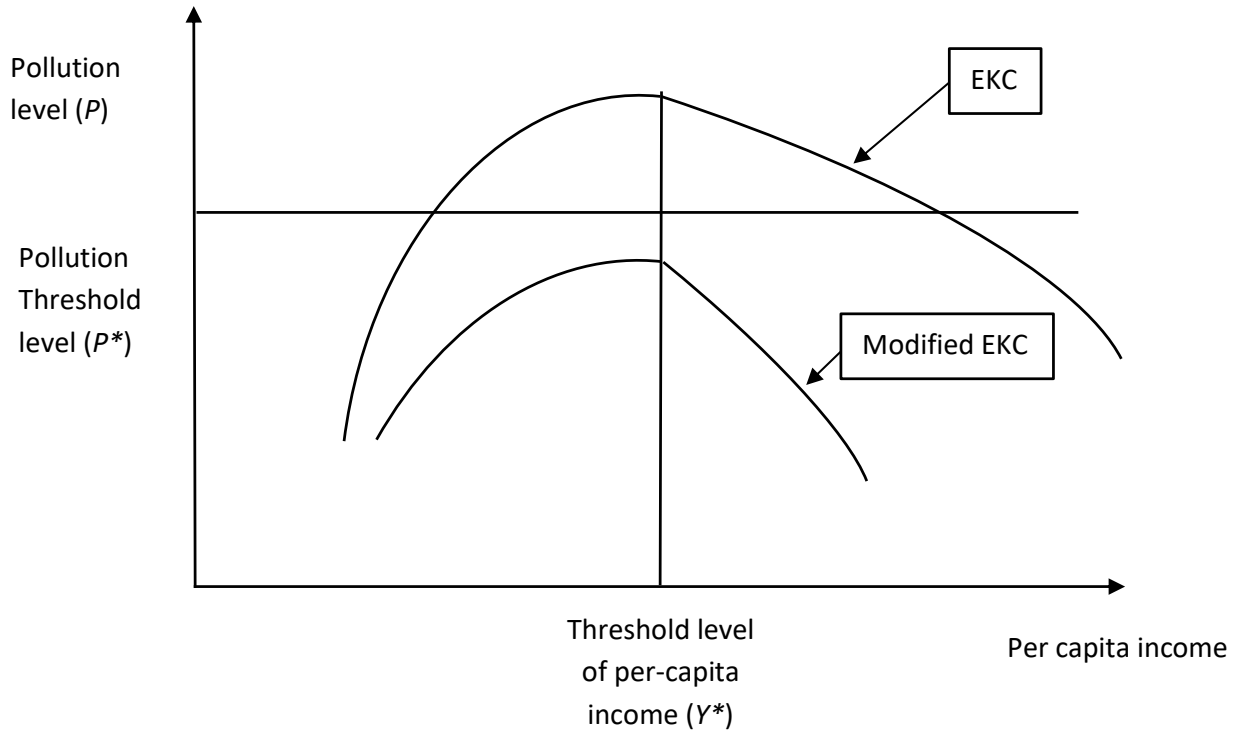

Figure 1: Environmental Kuznets Curve.

cacy organizations, eager to participate in SIAs of SEMP. The cooperation between NGOs and the government was a novelty at that time. However, these activities in the 1980s and early 1990s were, to a large extent, donor-driven and government-oriented; they were not citizens' own initiatives.

The situation in this regard started to change in the latter half of the 1990s. By that time, environmental problems had become more acute, and concerned citizens started to feel the necessity of citizens' organized efforts for protection of environment, instead of leaving the entire responsibility and initiative to the government. It is this realization that led to the formation of the pro-environmental civic group POROSH (*Poribesh Rokkhya Shopoth*) by prominent resident Bangladeshis (RB) in Dhaka. Several issue-based civic movements also emerged, such as the one protesting against proposed cutting of trees in the Osmany Udyan in order to construct a new convention hall for holding the Non-Aligned Movement (NAM) Summit.

Meanwhile, the awareness about environmental problems and the necessity for citizens' collective action spread among NRB's too. In 1998, they took the initiative to form Bangladesh Environment Network (BEN), as a global network to help RBs protect Bangladesh environment. In 1999, BEN put forward the proposal of holding a comprehensive conference on Bangladesh environment to bring together pro-environment forces of the country, who until then were working mostly separately and thus did not attain the critical mass necessary to be effective.

POROSH responded to the BEN proposal positively, and the two organizations reached out to other pro-environment organizations, all of which supported the proposal. Over time, the proposed conference developed into the first International Conference on Bangladesh Environment (ICBEN), held on January 13–14, 2000 (Ahmed 2000). POROSH, BEN, Bangladesh University of Engineering and Technology (BUET), and the Coalition of Environmental NGOs (CEN) served as the main organizers of this conference and more than fifty pro-environment organizations joined the effort as co- and associate organizers.

ICBEN-2000 proved to be a huge success and led to the formation of *Bangladesh Poribesh Andolon (BAPA)* in July of that year, raising the environment movement in Bangladesh to a new level. Since then, BAPA and BEN have been working closely together for protection of Bangladesh environment. Other organizations that have been also playing an active role in the environment movement include Bangladesh Environment Lawyers Association (BELA), Poribesh Bachao Andolon (POBA), Work for Better Bangladesh (WBB).

Thanks in large part to the environment movement's campaign, several important achievements were made. Prominent among these are:

- Imposition of the ban on Two Stroke Engine Vehicles;
- Introduction of unleaded gasoline;
- Re-imposition of the ban on plastic bags;
- Formation of the Task Force, and more recently of the National River Conservation Commission;
- Removal of cross-dams from the Baral River;
- Adoption of Building Rules requiring more space to be left between buildings, etc.

Following the spirit of first ICBEN (of 2000), second and third ICBEN were held in 2002 (Ahmed, Tanveer and Badruzzaman 2002) and 2010, respectively. Apart from these comprehensive ICBENs, BAPA and BEN, in association with other pro-environment organizations, have been holding specific issue-based special conferences almost on an annual basis, as can be seen from the list below.

2020: Special Conference on Political Effectiveness of Environment Movement in Bangladesh: Challenges and Remedies

2019: Special conference on Bangladesh Delta Plan 2100

2018: Special conference on floods, waterlogging, and landslides

2017: Special conference on Sustainable Development Goals and Bangladesh Environment

2016: Special conference on coastal and marine environment

2015: Special conference on environmental acts and policies implementation problems

2014: Special conference on environment movement and organization

2013: Special conference on water resources of South Asia: conflict to cooperation

2011: Special conference on traffic jam, urbanization, and Bangladesh environment

2010: Third International Conference on Bangladesh Environment (ICBEN-3)

2009: Special conference on climate change and the tasks for Bangladesh

2007: Special conference on indigenous peoples and Bangladesh environment

2006: National convention on rivers and energy

2004: International conference on regional cooperation on transboundary rivers

2002: Second International Conference on Bangladesh Environment (ICBEN-2)

2001: Special conference on the Sundarbans

2000: First International Conference on Bangladesh Environment (ICBEN-1).

These conferences have become an important event for the environment movement and civic collective efforts in general. Apart from influencing actual policies, BAPA and BEN made a huge contribution to the documentation, analysis, and formulation of recommendations regarding various environmental problems of the country. At ICBEN-2000, a comprehensive *Dhaka Declaration on Bangladesh Environment* was adopted, containing the summary of the analyses and recommendations presented in the papers and discussions of the conference, covering all major environmental problems of the country. The *Dhaka Declaration* was updated at ICBEN of 2002 and 2010. Similarly, following each of the special conferences above, BAPA and BEN brought out volumes containing the papers, resolution, and other pertaining materials. These volumes, together with the ICBEN volumes, have now become a valuable source of information, analyses, and suggested policies on all major environmental problems of the country. Students, teachers, researchers, policymakers, and all interested are benefiting from these volumes. Through this documentation and analyses, BAPA and BEN have been able to raise the discussion of environmental issues of Bangladesh to a qualitatively higher level.

The selfless, dedicated work of BAPA and BEN has earned appreciation from all corners of the country. The media holds it in high esteem and the Dhaka City Corporation awarded BAPA the *Nagar Padak* (City Award) in 2007, and the Government of Bangladesh awarded BAPA the *Jatiyo Poribesh Padak* (Environmental National Award) in 2010. In fact, Bangladesh is quite unique to have a nation-wide, robust civic environment movement. Not many developing countries, at similar per capita income level as Bangladesh, can claim the presence of such a movement. In this respect, Bangladesh can take some pride in the international arena.

4 Scope of the Environment Movement

The goal of the environment movement is clear. It is to stop the process of environmental degradation in Bangladesh and to repair the damage that has already been done. However, the environment movement does not view itself as just a pressure group, whose goal is to put up demands on the government. Instead of such a narrow and reductive view, the environment movement of Bangladesh takes a broader view of its task. This was made clear in the *Dhaka Declaration* adopted at ICBEN-1 that identified the following three distinct levels of pro-environment efforts:

- *Individual level:* People can do much at the individual level to protect environment, beginning with caring for environment in one's own home and immediate surroundings. He or she can also refrain from environmentally harmful consumption and can teach the value of good environment to the children, relatives, and friends. These types of pro-environmental activities on the part of an individual do not always require governmental or community's help.
- *Community or local level:* Much can be done at the community and local level without help from the government. For example, people in a given community can band together to save trees, water bodies, open spaces, etc., in their locality.
- *National level:* The major sources of environmental deterioration are often rooted in government policies at the national level. It is therefore necessary to influence national policies in order to protect the environment.

There are important connections among efforts at these three different levels. First, it would be irrational on the part of citizens to demand pro-environment measures from their government unless they themselves take similar measures at levels that are under their direct control, namely the individual and community levels. For example, if people want the government to stop deforestation, then they themselves should protect trees in their own homesteads and localities. Second, government policies cannot be successful if individuals and local communities do not back up those policies with their own actions. For example, the government policy to ban the use of plastic bags cannot work fully unless citizens themselves refrain from using these bags.[7] Third, unless people are sensitized about their duties at individual and community level for protection of environment, they are also not likely to come forward to participate actively in campaigns to influence national policies. In this sense, pro-environment efforts at local and community levels are a pre-requisite of pro-environment efforts at the national level.

However, the connections run in the opposite direction too. For example, pro-environment measures at the national level may help raise general awareness about the necessity of environmental protection at individual and community levels. Similarly, pro-environment initiatives at the community level may induce people to be attentive to environmental protection at the individual level. These two-way connections show that the scope of the environment movement needs to be conceived broadly.[8] The important question is how Bangladesh environment movement can hope to succeed with such a broad mission. In answering this question, it is first necessary to take note of some of the salient features that Bangladesh environment movement has displayed so far.

5 Salient Features of the Environment Movement and It's Broader Significance

5.1 Salient Features of the Environment Movement

The environment movement of Bangladesh, as represented by BAPA and BEN, has displayed several appealing features, including unity, RB-NRB cooperation, financial self-reliance, non-partisan character, consensus decision making, and volunteer spirit to work unitedly for the greater benefit of the country. These principles have helped them to strive for achieving the goals of the broad mission described above.

Unity: Broad unity has been the birthmark of BAPA. As mentioned earlier, about fifty pro-environment organizations and institutions of Bangladesh joined hands to organize ICBEN of 2000, the founding gathering of the Bangladesh environment movement. These included major universities and research institutions of the country, government environmental agencies, major pro-environment NGOs, media organizations, socio-cultural organizations, etc. It is rather rare for Bangladesh to have so many organizations come together to do something positive. BAPA has been holding up this unity, always trying to work in cooperation with all pro-environment forces of the country.

RB-NRB cooperation: RB-NRB cooperation remains, as already noted, the bedrock of the Bangladesh environment movement. A notable aspect of Bangladesh environment movement is the involvement of Non-resident Bangladeshis (NRB). Bangladesh Environment Network (BEN), the organization of pro-environment NRBs, played the initiating role in convening ICBEN and founding BAPA. BAPA-BEN cooperation has become a model for RB-NRB cooperation for civic effort for the betterment of Bangladesh.

Financial self-reliance: The most important distinctive feature of Bangladesh environment movement is financial and intellectual self-reliance. Both BEN and BAPA rely on their members' contributions for financing their activities. This financial independence makes it possible for these organizations to make objective assessment of various environmental problems and their proposed solutions and to evaluate critically government's environmental policies and the way these are implemented. The financial self-reliance also allows BAPA and BEN to be independent of views and prescriptions of foreign donor agencies and be critical of them, if

necessary. Environmental problems always involve vested interests. Donor financing of environmental projects often adds an additional layer of vested interest influences. A self-reliant environment movement can cut through these different layers, reach the essence of the problems, and take correct positions regarding their solutions. Thus, financial self-reliance also leads to self-reliance of the views and positions of BAPA and BEN regarding the environmental problems of the country and not be affected unduly by either the government or the donors or other vested interests.

Volunteer spirit: A companion (of 'self-reliance') feature of Bangladesh environment movement is its volunteer spirit. Since BAPA and BEN do not accept donor financing, their financial resources are meager, and hence they cannot depend on paid work for their functioning. The environment movement of Bangladesh therefore relies on voluntary labor of its members. It appeals to the noble sense of responsibility of the citizens towards their country and urges them to play an active role in protecting the environment of their country. The revival of voluntary work by the environment movement is helping this spirit to spread in other areas of civic engagement.

Non-partisan character: The environment movement of Bangladesh is non-partisan. It is very much aware of the role of politics and political parties in protecting environment and engages with them to persuade them to adopt and implement pro-environment policies. However, it stays away from party politics and appeals to people of all parties to join the environment movement. It further feels that party politics should not hinder people of different political leanings from coming together and working for common national interests.

Consensus decision making: Decisions in BEN and BAPA are taken largely through consensus and rarely through division and vote. The operation through consensus becomes possible because BAPA and BEN are free from vested interests. It is therefore easier for BAPA and BEN members to reach agreement through reasoning and discussion.

Forward looking: The environment movement is primarily a movement for the future. It aims at leaving the earth for future generations in a better condition than it otherwise would be.[9] This spirit was captured well by the Brundtland Commission's definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987)." However, the current generation needs to be educated on what has to be done and how it can be done. As Bangladesh industrializes, the importance of environmental issues and hence of the environment movement will only increase. However, the current generation needs to be motivated to do their duty to the future generations. This requires explaining to them what is needed to be done, in other words, why an environment movement is needed. It is not surprising that environment movement is the first social movement in Bangladesh in which RB-NRB cooperation came to fruition, because NRBs, particularly those living in advanced industrial countries, are more likely to be tuned to such future issues.[10]

5.2 Broader Significance of the Environment Movement in Bangladesh

The salient features of the environment movement noted above also create for it the potential to have a broader significance in Bangladesh. This is because the traditional political parties and social organizations are often failing to meet the expectations of the people. As a result, there is a vacuum in effective representation of people's interests.

Among the features above, self-reliance and volunteer spirit are proving particularly appealing because there has been a serious decline of both among social organizations of the country in recent decades. The rise of Non-Government Organizations (NGO) and assumption by them of various developmental and social functions have undercut the role of civic volunteer work. Similarly, funding of NGOs by foreign donor agencies and sponsorship by commercial establishments of various socio-cultural activities has undermined the tradition of self-financing, based on contributions of people.

In the above backdrop, the volunteer spirit and financial self-reliance of BAPA and BEN are resonating well with the expectation of the people. More people are attracted by the new BAPA-BEN model of voluntary and self-reliant social work. This may help to revive the culture of self-reliant, voluntary social work in Bangladesh. As a result, the environment movement can have a broader social role in Bangladesh and not be limited to environmental protection only.

6 BEN Activities Abroad

Apart from working together with BAPA inside Bangladesh, BEN has been undertaking a variety of activities abroad. Some dimensions of this work are noted below.

6.1 BEN Campaigns

A particular dimension of BEN activities abroad comprises campaigns that BEN conducts on various environmental issues of Bangladesh, particularly those having an international character. Climate change is surely one of them. As is well known, Bangladesh is one of the countries that are worst affected by climate change, though it had practically zero contribution to its creation. Climate change is clearly a global challenge and Bangladesh needs to work with the international community for its mitigation and also for adaptation. BEN therefore considers mobilizing international action for climate as an important task. For example, BEN organized, in 2009 the "Global Day of Action against Climate Change." The main event of the Day was a rally held in front of the United Nations Headquarters in New York. Similar events were held in Australia, Japan, Germany, and Bangladesh. BEN is an active participant of the Peoples' Climate March. It took part in the New York march in 2015 and the Washington march in 2017. In fact, BEN is the only organization that participated in these marches with a country banner. Another issue on which BEN is conducting international campaign concerns India's River Linking Project, aimed at diverting water of international rivers away from Bangladesh. BEN organized a rally in front of the UN Headquarters in 2012 to protest against this project.

6.2 Different Chapters of BEN

One of the important activities of BEN abroad is to sustain and expand its reach among NRBs. For this purpose, it formed BEN chapters in different cities, states, and countries. In the USA, the most active BEN chapter is in the Tri State area of New York, New Jersey, and Connecticut. There are also BEN chapters and groups in the mid-Atlantic area, state of Georgia, New England, mid-West, state of California, and the Pacific Northwest. Outside the USA, BEN has chapters and groups in Australia, Canada, Japan, Germany, and the United Kingdom. BEN-Australia regularly holds rallies and other events on various environmental issues, both global and specific to Bangladesh. BEN-Japan held several International Conferences on Environmental Aspects of Bangladesh (ICEAB), with participation of scholars from Japan, Bangladesh, Australia, and other countries. It also brought out volumes containing papers and resolutions of these conferences. BEN-Germany organized several international conferences focusing on energy and climate change issues. All chapters of BEN participated in BEN's campaign on climate change and other issues.

6.3 Other BEN Activities

Environment Newsletter: An important activity of BEN is publication of the internet-based weekly, the "Environment Newsletter" which presents important news items concerning the state of both Bangladesh and global environment and regarding activities of BEN and BAPA. It helps to disseminate BAPA-BEN views on environmental issues and the solutions that they recommend. Both BEN and BAPA members find this newsletter useful, and it serves as a regular connection among them.

BEN Internship: BEN arranges environment-related internship program for members of the second generation NRBs. BEN helps them to be placed in environment-related research or advocacy organizations in Bangladesh. This program helps young students to fulfill their academic requirements and also be informed on the environment movement, to help and join it.

BEN fellowship: BEN provides fellowship to environmental activists in Bangladesh. This is to help deserving activists who are foregoing income to devote more time to environmental activism

Research collaboration: BEN helps RB scholars and has promoted RB-NRB collaboration in research on environmental issues. For example, BEN helped air samples to be tested in modern US labs to determine the quantities of different pollutants. BEN experts collaborate with RB scholars working on areas of common interest.

Action projects: BEN undertook several action projects too. One of these was the Solid Waste Aerification and Disposal project. Under this project, the organic part of the household waste is separated and converted into organic fertilizer by aerification using community labor. The project thus helps to get fertilizer, dispose waste, create employment—all at the same time. This project was implemented on a pilot basis in two locations, namely Vashantek slum area in Dhaka city and the National University campus in Gazipur.

6.4 BEN Expert Panels

To facilitate research and formulation of policies concerning various environmental issues of Bangladesh, BEN has formed panels focusing on particular issues. Among these are the panels for: (i) River and water resources; (ii) Energy: (iii) Climate change: (iv) Urbanization; (v) Arsenic; (v) Household, industrial, medical, and electronic waste; and (vi) Economic, legal, and management issues. These panels work in collaboration with Program Committees that BAPA has formed in Bangladesh on the similar issues. The work by BEN panels on water and energy served as the basis for formulation of the BAPA-BEN resolutions on rivers and energy, respectively.

7 Policy Related Challenges Faced by Bangladesh Environment Movement

Having reviewed the organizational development of the environment movement, we now turn to issues of policies and their implementation. In Section-2, we already mentioned some of the policy achievements of Bangladesh environment movement. These took the form of laws, regulations, rules, directives, orders, declarations, etc. The following provides a more detailed list, grouping the policy measures under various dimensions of environment.

- River and surface water bodies
  - Enactment of the Wetlands Protection Act;
  - Issuance of the High Court directive to demarcate river boundaries by installing pillars;
  - Directive of the Prime Minister to stop constructing unnecessary river intervention structures and instead to learn to "live with floods";
  - Initiative to create circular waterway around Dhaka city;
  - Step to remove pollution from the bed of the Buriganga River;
  - Formation of the River Task Force and the National Commission on Protection of Rivers.
- Urbanization
  - Formulation of the Dhaka city Master Plan and the Detailed Area Planning;
  - Promulgation of the new rules regarding building and construction;
  - Imposition of the ban on Two-stroke Engine Vehicles (TSEVs).
- Industrial pollution
  - Directive to install Effluent Treatment Plant (ETP);
  - Decision to transfer the tanneries from Hazaribag to Savar site, equipped with Central Effluent Treatment Plan (CTP);
  - Directive to ensure safe and healthy work environment in the factories;
  - Ban on setting up of industrial enterprises in forest areas;
  - Adoption of policy regarding energy and other minerals extraction and use;
  - Commitment not to engage in open-pit coal mining at Phulbari;
  - Prime Minister's declaration not to establish mines in lands that are under multiple cropping;
  - Decision to use and develop national capability in energy exploration and extraction;
  - Decision to substitute wood by coal as the fuel in brick manufacturing;
  - Decision to use in brick manufacturing chimneys that are taller and equipped with scrubbers.
- Forests and biodiversity:
  - Adoption of forests policy;
  - Ban on plying of oil tankers and ships containing hazardous materials through the Sundarbans;
  - Adoption of policy to preserve bio-diversity.
- Other areas:
  - Re-imposition of ban on the use of plastic bags;
  - Ending the use of leaded gasoline and introduction of unleaded gasoline.

Despite the achievements above, Bangladesh environment movement has a long way to go. Challenges remain with respect to both policy formulation and implementation. There are many broad areas still awaiting pro-environment policies. It may be noted in this regard that policy making in Bangladesh continues to be heavily influenced by foreign funding and thinking, despite the fact that the country is financially much more self-reliant now than it was in the 1980s. Not surprisingly, foreign thinking often fails to take appropriate note of the domestic conditions and the indigenous ideas and practices that are more suitable for the country. Inappropriate (foreign) philosophies often combine with vested material interests of domestic as well as foreign actors to create serious barriers to proper policy formulation. As a result, policies adopted often end up being counter-productive, as can be seen in the areas of, for example, water development, transportation, and urbanization, to be discussed later.

8 Implementation Challenges Faced by Bangladesh Environment Movement

More daunting however are challenges that Bangladesh faces regarding implementation of pro-environment policies. It is therefore important to note the state and nature of implementation problems, their causes, and possible ways of overcoming them.

8.1 Policy Implementation Cycle

To understand the implementation problems, it is appropriate to start from the analytical scheme presented in Figure 2. It shows that the implementation process starts from social pressure for adoption and implementation of pro-environment policies by various policy making bodies, such as the parliament, ministries, departments, etc.

The role of implementation of the adopted policies belongs to implementing agencies, such as the directorates, departments, etc. The last step in this process is the implementation outcome, which has a feedback effect on the social pressure for adoption of pro-environment policies, thus completing the cycle.

The previous sections discussed the first step of the process, namely generation of social pressure. BAPA and BEN and the environment movement, in general, are part of the social pressure for adoption of pro-environment policies. We saw that, as a result of this pressure, a number of pro-environment laws, rules, regulations, etc. have been adopted. However, their implementation has been far from satisfactory.

8.2 Problematic Implementation

Surveying the implementation scenario, it is possible to distinguish the following four types of situations:

- Good implementation
- Partial implementation
- Non-implementation
- Perverse implementation

The following provides a brief review of each of these types of implementation.

Good implementation: Good implementation is the situation when appropriate steps are taken to follow up on the policies adopted and these steps yield the desired results. A prominent example is provided by the decision to ban the two-stroke engine vehicles (TSEV) in Dhaka and Chittagong cities. It is estimated that more than fifty thousand of these vehicles were plying in Dhaka city alone in the late 1990s. Not having a catalytic converter (which converts unused carbon mono-oxide into carbon dioxide), these vehicles were spewing poisonous carbon mono-oxide in the form of black smoke. Since gasoline used during that period contained lead, the exhaust fumes were a deadly mixture of several types of poisonous gases. Following the ban, TSEVs were replaced by three wheelers running mostly on compressed natural gas (CNG). As a result, the quality of air in Dhaka and Chittagong cities improved significantly.

Partial implementation: Partial implementation is the situation when only half-hearted measures are taken to follow up on adopted policies and these measures fail to yield results to the desired extent. An example of partial implementation is provided by the directive to industrial enterprises to install effluent treatment plants (ETP). Due to the lack of enforcement, many enterprises are yet to install ETP. Moreover, enterprises that have installed ETP, often do not operate them in order to save expenses.

The situation regarding the ban on the use of plastic bags may be characterized as somewhere between good and partial implementation. Open use of the plastic bags is less frequent, which can be taken as an indication of good implementation. However, reports continue to appear about clandestine use of plastic bags, suggesting only a partial implementation. Also, many shop owners have shifted to using bags made of plastic *nets*, thus subverting the intent of the law. Moreover, the use of plastic in packaging of products has become so ubiquitous and is generating so much of plastic waste, that the original intent of the ban on the use of plastic bags is getting largely nullified.

Another example of partial-implementation is provided by the situation with the Baral River of North Bengal. Responding to many years' of campaign by BAPA, BEN, and many other pro-environment groups, the River Task Force decided to free up the Baral River by removing the sluice gates and earthen cross dams that were built earlier on this river. The implementing agencies, particularly the Bangladesh Water Development Board (BWDB), dragged their feet as much as they could. Ultimately, under pressure of the local population and the environment movement, the earthen cross-dams were removed, but the concrete sluice gates, which started the process of killing the Baral River are yet to be removed.

Non-implementation: This is the situation when good pro-environmental policies are simply ignored and not implemented. A prominent example is provided by the Detailed Area Plans (DAP) that were prepared as way of implementation of the Master Plan for the Dhaka city. Though the DAPs were gazetted after the Awami League-led government came to power in 2009, these have been mostly ignored. Another example of non-implementation can be seen regarding the decision not to allow setting up of industrial enterprises in Gazipur forest area. This decision is generally ignored. Examples of non-implementation are ubiquitous.

Perverse implementation: Most alarming is perverse implementation of pro-environmental policies. This happens when well-meaning laws and decisions are implemented in a way that produces results which are opposite to what were intended for and thus harm the environment rather than improving it. A prominent example of perverse implementation is provided by the directive issued by the High Court to demarcate river boundaries through installation of pillars. The intention of this directive was to prevent encroachment of river foreshores. However, the way this directive was implemented actually promoted further encroachment of rivers.

It is well-known that river flows in Bangladesh fluctuates tremendously across seasons. During the rainy (summer or peak) season, rivers reach their brim and often overflow onto the adjacent floodplains. On the other hand, during the dry (winter or lean) season, river flows

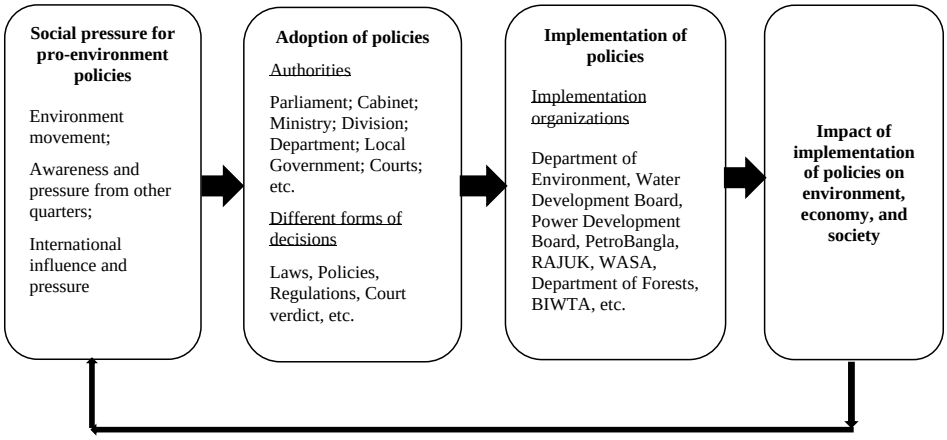

Figure 2: Anatomy of the Implementation Problem.

diminish and recede to a very narrow part of the channels. Clearly, the true boundary of a river is given by its flow during the rainy season, and not by its flow during the dry season. Unfortunately, in the name of implementation of the High Court directive, the district administrations of Dhaka and Gazipur have installed pillars along the lean-season flow of the Buriganga and Turag Rivers. During the rainy season, these pillars now lie in the middle of the rivers, protruding through the water and creating a new danger to the boats and ships plying these rivers. Thus, through perverse implementation, the district administrations have subverted the High Court directive and produced results that are exactly opposite to what was intended. Instead of protecting the foreshore from encroachment, they have now made it official that the foreshore is not a part of the river (i.e. does not fall within the river boundary), thus encouraging people to encroach whatever remains of it. Another pervasive example can be seen in construction of structures meant to mitigate flood but ending up aggravating flood.

Overall, instances of non- and partial implementation are more common and instances of good implementation are rather rare. What is encountered mostly is partial, non-, and perverse implementation. That explains why—despite the adoption of pro-environmental policies—the environment of Bangladesh continues to deteriorate. Improving implementation is therefore the main challenge that the environment movement now faces. To find out how to improve implementation, it is necessary to know the reasons why the state of implementation is generally poor.

8.3 Reasons for Poor Implementation of Pro-environment Policies

Among the reasons for poor implementation of pro-environment policies in Bangladesh, the following four types may be distinguished.

- General weakness of governance in Bangladesh
- Non-specificity and intangible character of many environmental goals
- Weaknesses in the formulation of environmental laws, regulations, directives, etc.
- Problems of philosophy, attitude, approach, and material interests

The following sections provide a brief review of these problems, which are interconnected, as shown in Figure 3.

The general weaknesses of governance in Bangladesh are well known and have been discussed in more detail in Islam (2016).[11] It shows that governance has two sides, namely (a) political leadership and (b) civil administration. While the political leadership takes the decisions, it is the civil bureaucracy that implements them. (The civil bureaucracy also plays a vital role in aiding the political leadership in reaching the decisions.) Thus, these two sides are interdependent, and the performance of one depends on that of the other. However, the primacy in this relationship belongs to the political leadership. A good political leadership can undertake reforms of civil administration if its quality is not satisfactory. However, the converse is generally not true. It is difficult for a good civil bureaucracy to rectify a bad political leadership, though it can ameliorate the ill effects of the latter for a while. Both sides of governance—political leadership and civil administration—suffer from weaknesses in Bangladesh. These general weaknesses of governance affect formula-

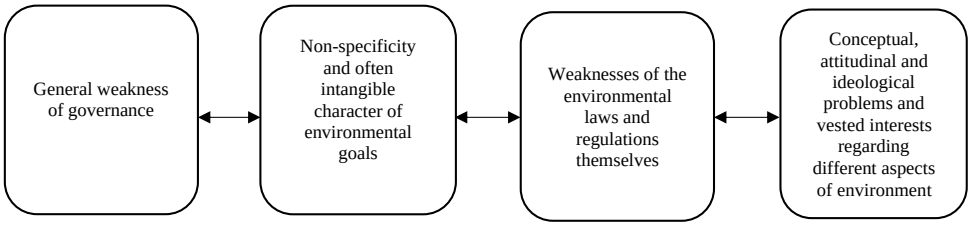

Figure 3: Reasons for poor implementation of pro-environment policies.

tion and implementation of policies in all spheres of national life of the country, including of environment.

The extent of corruption and degeneration of the civil bureaucracy came to fore during the 1/11 government,[12] when law enforcement officials raided the apartment of Mr. Gani, the then Chief of the Forest Department, and found cash money obtained through bribe-taking stashed in pillows and mattresses. No wonder that with such forest chiefs, the forests of Bangladesh are disappearing fast. Similarly, it is alleged that the government rule requiring Environment Impact Assessment (EIA)—before any major project is approved—has created a lucrative "business" opportunity for many in the environment agencies. The traditional form of the malpractice is taking bribes before approving EIAs prepared by others (individual consultants or consulting firms). The other form is more entrepreneurial, whereby the officials themselves set up, clandestinely, consultancy firms to which they then direct the contracts for preparation of EIA reports. In either case, the purpose of the EIA reports gets compromised, and these reports end up being just a formality, instead of a genuine scrutiny of the environmental impact of particular projects.

8.4 Problem of Non-tangibility of Many Environmental Problems and Objectives

The implementation problems in the environment sector are aggravated by the fact that many of the environmental problems and objectives are not that tangible. To understand the issue, we may first note that environmental problems and objectives can be classified into two types, namely

- Tangible
- Intangible

Tangible problems are those that can be easily visualized, readily understood, and accurately quantified. By contrast, intangible problems are not easily visible and quantifiable. True that the classification of environmental problems into tangible and intangible categories is not always clear cut. Often it is a matter of gradation, and there are environmental problems that have elements of both tangibility and intangibility. In short, it is not a black-and-white situation, and there are many grey areas.

An example of environmental problems that are more tangible is provided by Two-stroke engine vehicles (TSEVs), mentioned earlier. It is easy to see whether these vehicles are plying or not and, if yes, how many of them. It is also possible to calculate how much poisonous gases they are spewing. Similarly, plastic bags present a relatively tangible problem. Plastic bags are physical objects, which can be quantified, and it is easy to see whether they are used. However, unlike the TSEVs, plastic bags can be used clandestinely, making their exact quantification relatively more difficult. This shows how elements of tangibility and intangibility can coexist in the same problem.

Examples of relatively more intangible problems include, for example, the problem of river boundaries. Earlier, we noted the problem created by seasonal fluctuations in the river flow. There is also the issue of year-to-year variations of river flow, so that even the high season flow may differ across years, making determination of the exact boundaries difficult. In absence of unvarying physical evidence, one has to resort to official land records, which are not always available to the public. In fact, the problems of land records in Bangladesh are proverbial. There is also the issue of which cadastral survey is to be followed—the original Cadastral Survey (CS), the Revised Survey (RS), or the more recent survey conducted by the Bangladesh government. Thus, the good intention of demarcation of river boundaries often loses its way in the maize of land records.

Needless to say, it is easier to deal with environmental problems that are tangible. That is why we see that more progress could be made with respect to the problems of TSEVs and plastic bags. By contrast, it is proving difficult to demarcate river boundaries properly and to prevent rivers from being encroached.

8.5 Problems of Philosophy, Approach, and Material Interests

A special type of problem that affects implementation of environmental policies concerns the philosophy and approach towards environmental issues. Often this problem gets linked with the problem of material interests. Sometimes, these two problems become so intertwined that even the protagonists fail to realize which of the two is motivating their actions. In the following, we present three examples to illustrate these problems:

- Cordon vs. Open approach to rivers;
- Urbanization strategy and the dual role of Rajuk;
- Transportation problem and the private-car model.

8.5.1 Cordon approach to rivers:

One of the main reasons for lack of implementation of the pro-environment policies regarding rivers and other surface water bodies is the dominance of the Cordon approach in water-related government agencies of Bangladesh.[13] According to this approach, the floodplains are to be cordoned off from neighboring rivers to protect them from river overflow. The approach was imposed on Bangladesh by the International Engineering Company (IECO) that was hired—following Krug Commission's report in late 1950s—to formulate a water development strategy for the country. The IECO prepared a Master Plan, containing scores of cordon projects. Since then, Bangladesh has been spending about twenty percent of its development budget on implementation and servicing of these projects. The Cordon approach is a concrete version—applicable for deltas—of the more general Commercial approach to rivers, according to which "any river water that passes to the sea is a waste" and hence all river water has to be used up for various commercial purposes (such as irrigation and urbanization) before the river reaches the sea.

While yielding some initial positive benefits in terms of expansion of controlled irrigation in the initial periods, these Cordon projects over time started to reveal their negative consequences. Among these are (i) expansion of below-flood-level-settlement; (ii) aggradation of riverbeds; (iii) deterioration of water bodies and soil quality inside the cordons; (iv) disruption of open capture fisheries; (v) diminution of waterways; (vi) subsidence of the floodplains; and (vii) spread of waterlogging. In many places, waterlogging has become perennial.

The right approach to rivers in a deltaic country such as Bangladesh is the *Open approach*, which is a concrete version—applicable for deltaic countries—of the more general, Ecological approach that discourages major interventions in the volume and direction of river flows. The Open approach emphasizes the organic links between river channels and floodplains and advocates preservation and enhancement of these links, instead of severing them, as is done under the Cordon approach. The Open approach thus (i) discourages below-flood-level settlement, (ii) facilitates distribution of sediment over the floodplains and thus prevents aggradation of riverbeds and subsidence of floodplains; (iii) preserves waterbodies inside floodplains and their soil quality; (iv) promotes open-capture fisheries; (v) preserves and extends waterways; (vi) mitigates flooding and prevents waterlogging.

Experience has made it amply clear that Bangladesh needs to abandon the Cordon approach and adopt the Open approach. The Prime Minister of Bangladesh, Sheikh Hasina, has also called—in her own way—for the Open approach. She asked to give up the goal of "preventing" flood and to accept the reality and advantages of "living with" floods. She criticized the practice of Bangladesh Water Development Board (BWDB) engineers to build unnecessary embankments and sluice gates. Unfortunately, despite the clear lessons from the water development experience of the past six decades and the directives from the Prime Minister, the water-related government agencies keep on clinging to the Cordon approach and are taking up and implementing more Cordon projects.

One reason for the tenacity of the Cordon approach is of course the belief of the engineers and other water related professionals that Cordon approach is the right approach. They have been trained in this approach through the education in western universities and national universities following the western curricula.

However, in addition to the ideological conviction, there is also the issue of material interests. Water-related professionals and the personnel of the water-related government agencies have a material stake in big-budget Cordon projects. As a result, they find it difficult to turn away from the Cordon approach even if they see its pitfalls. This combination of philosophy and material interests make it difficult for water-related government agencies to implement pro-environment laws, regulations, and directives—including the directives issued by the Prime Minister—regarding rivers and other surface water bodies.

8.5.2 Urbanization strategy and the dual role of Rajuk[14]

Another example of philosophy and material interests becoming a problem in the way of implementation of pro-environment policies can be seen in the area of urbanization. As noted above, a Master Plan was prepared for long-term development of Dhaka city, and Detailed Area Plans (DAP) were formulated as a way to implement the Master Plan. Though the DAPs were gazetted during

the Awami League-led government formed in 2009, these have been now effectively abandoned.

There are many reasons for this sorry outcome. One of these is the dual role played by Rajuk—the organization responsible for Dhaka city's planning and development. The main mandate of Rajuk is to serve as the *regulator*. It is supposed to guide the development of Dhaka city. In particular, it is supposed to ensure that the development of Dhaka city follows the Master Plan, by implementing the DAPs.

However, Rajuk has also taken on the role of a *developer*. This duality of role has been a characteristic of Rajuk from the very beginning, i.e. even during the Pakistan period, when it was first established and named as Dhaka Improvement Trust (DIT). Since then it took up many large land and housing development projects, one after another. Beginning with Dhanmondi, Banani, and Gulshan, Rajuk's land development projects now extend far and wide to Jhilmil in Keraniganj—on the other side of the River Buriganga—and Purbachal—on the other side of the River Balu. In carrying out these land development projects, Rajuk itself appears to be violating many pro-environment laws and regulations. For example, it is widely alleged that in implementing the Uttara and Purbachal projects, Rajuk filled up many waterbodies, violating the Wetlands Protection Act. As a consequence, Rajuk's role as the regulator has been largely compromised. It is difficult for Rajuk to prevent other developers from filling up water bodies when it itself has been doing the same.

The question is, why did Rajuk take on the *developer-role,* which conflicted with its *regulator*-role? One reason again concerns the urbanization philosophy. According to Rajuk's prevailing philosophy, it falls upon itself to acquire land of the common people, develop it using government funds, and then distribute it at minimal price among select members of the elite. In other words, Rajuk is guided by an elite-oriented urbanization philosophy. It is due to this philosophy that Rajuk acquired the dual role that hindered implementation of DAP and the Master Plan.

However, in addition to the wrong philosophy, material interests have played an important role here. Rajuk could not have big budgets had it limited itself to the regulatory role only. By contrast, land development projects mean big budgets, creating a lot of legal and illegal opportunities of enrichment for Rajuk and other related agencies and individuals both during the implementation of the projects and distribution of plots once the projects have been completed. The above story applies equally to *housing* projects, under which Rajuk not only develops the land but also builds multi-storied buildings for distribution later-on. It is because of these strong material interests that it is difficult to prevent Rajuk from taking up land and housing development projects.

Thus, a combination of philosophical problems and material interests is making it difficult for Rajuk to give up its developer-role and limit itself to the regulator-role. The consequence is that pro-environment policies regarding urbanization, such as the DAPs, couldn't be implemented.

8.5.3 Transportation strategy based on the private car model

A similar combination of wrong philosophy and vested material interests can be seen obstructing implementation of pro-environment policies regarding transportation.[15] An acute consequence of the misguided transportation policies is the unbearable traffic jam of Dhaka city. Traffic jam is spreading to other cities and towns and highways of Bangladesh too.

The government is primarily looking for infrastructural solutions for the traffic jam problem. It is building flyovers and elevated expressways. Unfortunately, flyovers constructed so far have not provided lasting and expected relief from the traffic jam problem. It is difficult to believe that the elevated expressway will change the situation radically.

One of the reasons for this disappointing situation is the dominance of the philosophy that views private car as the ideal mode of transportation. There is an all-out encouragement on the part of the government as well as the private sector for acquiring and using private cars for transportation. By comparison, mass transportation modes are neglected. Yet, in the context of the extremely high density of population of Bangladesh—and its cities, in particular—private cars are not the appropriate mode of transportation. Bangladesh needs to adopt public transportation—such as buses, trams, commuter trains, underground railway (metro) etc.—as the dominant mode of transportation.

Bangladesh is also an ideal place for walking and biking. The distances are short and the land is flat. Unfortunately, what is happening is just the opposite. The practice of biking in Dhaka and other major cities is declining. This is happening at a time when in Europe and Japan, more people are using bikes for transportation. In Denmark, for example, bicycle trips now comprise about one-third of all trips. However, the elite and policymakers of Bangladesh appear to be transfixed on North America, particularly the United States and Canada, where private car is the dominant mode of transportation. They fail to see that the land-to-human ratios of the North American countries are entirely different from that of Bangladesh. Bangladesh simply does not have enough physical space for private cars to ply, if a significant portion of the popu-

lation does indeed switch to private cars, as they are currently encouraged to do, and they will indeed do so under the current policy environment, as the income level increases. There is hardly a better example of "fallacy of composition" than provided by the current traffic situation in cities of Bangladesh. People buy car to move around faster, and yet as more people buy car, the speed at which they can move around becomes slower. In Dhaka city, sometimes walking gets one to the destination faster than by car! Bangladesh thus is a classic case where the individual interest not only conflicts with the interests of the community, but ultimately proves harmful for the individual itself.

Apart from bad philosophy (belief in the superiority of private car as the mode of transportation), there are also vested material interests preventing Bangladesh from switching to a more pro-environment transportation strategy based on mass transit, biking, and walking. Just as was the case with water development and urbanization strategies discussed above, large infrastructure projects are favored in the case of transportation too, because they generate large budgetary allocations. Politicians, bureaucrats, consulting and construction firms—all can hope to benefit from these budgets. In addition, car importers act as a powerful interest and lobbying group. Currently, each member of the Parliament is allowed to import a car duty free. Since import duties on cars are high (ranging upwards from 200 percent), this provides an easy and lucrative opportunity for the MPs to enrich themselves. Is it a surprise that these MPs and a government formed by them encourage the private car model?

There are many other examples of wrong philosophy and vested material interests combining to create a barrier to implementation of pro-environment policies. The question is what can be done to overcome this barrier and other implementation problems?

9 Ways to Overcome the Implementation Problems

A multidimensional effort is needed to overcome the problems of implementation of pro-environment policies in Bangladesh. As noted above, general governance weaknesses are an important reason for poor implementation of pro-environment policies. Islam (2016) provides a detailed analysis of Bangladesh's governance problems and suggests several political and administrative reform proposals for mitigating these problems. On the political side, it suggests switching to the proportional system of election (from the current majority-system) and reducing the government-term from the current five years to four years. Regarding administration, it suggests rationalization of the size and salary of the civil service, increase in people's participation in judging the performance of the officials, etc. Due attention may be given to these reform proposals.

Environmental courts can play an important role in implementation of pro-environment policies. Setting up of these courts has been a good step. However, their numbers still remain inadequate. Also, for a long time, the right to file suits in these courts was limited to officials of the Department of Environment. This has been changed recently, allowing members of the public affected by pollution to bring law suits against polluters. However, environmental courts are yet to display their effectiveness. Public awareness and enthusiasm about the environmental courts remain low. A big push is therefore necessary to make the environmental courts an effective tool for fighting against pollution.

One of the special problems regarding implementation of pro-environment policies arises, as noted above, from the fact that many environmental problems are intangible. Overcoming this problem requires more careful formulation of the environmental laws, regulations, and decisions, making them as *detailed* as possible. As the saying goes, "The devil lies in the details!" As seen above, the district administrations of Dhaka and Gazipur used the absence of details in the High Court directive regarding river boundary demarcation to implement it in a perverse way, thus subverting the very intention of the directive. They could not have done so if the High Court directive had specified that the boundary of the rivers has to be based on their historic highest peak season flow, as corroborated by records contained in the original Cadastral Survey. In other words, special efforts need to be made to close all possible loopholes that may be used for perverse or lack of implementation of environmental laws, regulations, and decisions.

More difficult is the task of overcoming the barriers arising from the combination of wrong philosophies (regarding various environmental issues) and vested material interests. So far as wrong philosophies are concerned, the main task is to reveal their flaws and put forward the alternative, correct philosophies. This however requires research, publication and dissemination in different forms. In-depth studies can be presented in the form of books and journal articles, which will be more helpful in influencing the views of experts in relevant fields. Shorter versions, containing the conclusions and recommendations, can be prepared in the form of pamphlets, Op-Ed pieces, and leaflets, which will be more useful for the general public.

Debunking wrong philosophies can help to reduce the influence of vested interests too. It can remove the ideological cover under which many people hide, when they are actually driven mainly by material interests. Second, the debunking can energize people to rise up against the influence of vested interests.

The task of overcoming the obstacles to proper implementation of pro-environment policies is not easy. However, with a concerted, multi-dimensional effort it should be possible to improve the implementation situation.

10 Role of Environment Movement in Overcoming Implementation Problems

The main responsibility for implementation of pro-environment policies belongs to the government. However, can the environment movement play a role in overcoming the problem? Will its role be limited to drawing attention to the implementation problem and urging the government to solve the problem? Or, it has a more active role to play?

For example, drawing attention of the public and the government to the implementation problem is an important task. The environment movement can perform this task by monitoring and evaluating the implementation situation carefully. However, its role should not be limited to advocacy of policy adoption only. In fact, without being engaged in policy implementation, the environment movement cannot gauge what adjustment in current policies and introduction of what new policies are needed. In short, environment movement has an important role in policy implementation too. The following notes some of the ways in which the environment movement can play a more advanced role in mitigating the implementation problems.

- *First,* the environment movement can work together with other social movements in overcoming the general governance problems that affect implementation of policies in all areas, including environment.
- *Second,* the environment movement can help to ensure more effective utilization of the environmental courts. It can make people aware of the opportunities created by the environmental courts and provide people technical help to file suits in these courts. This will entail helping people with documentation, evidence gathering, and performing adequately at hearings. A few cases of success can go a long way in popularizing the use of environmental courts for protection of environment.
- *Third,* the environment movement can help to deal with the intangible character of many environmental issues. It can scrutinize more closely the drafts of environment related laws, regulations, directives, and decisions and point out the lack of details, as and where necessary. Also, it may play a more proactive role in pointing out the policies as these are revealed in the implementation process.
- *Fourth,* the environment movement can play an important role in countering the problems created by the wrong philosophy about various environmental issues. For this purpose, it may mobilize the pro-environment experts and academics to conduct necessary research and publish the findings in the form of books and articles. It can prepare pamphlets and leaflets based on these findings for wider dissemination. It may also mobilize the media to publicize materials, dispelling the wrong philosophies, approaches, and attitudes.

It is encouraging to note that BAPA, BEN, and other pro-environment organizations are indeed playing an important role along all the dimensions above. For example, BAPA played a crucial role in exposing the perverse implementation of the High Court directive regarding demarcation of river boundaries. Similarly, BAPA has developed a strong movement for implementation of the decision of the River Task Force regarding opening up the Baral River.

The extent to which efforts by the environment movement can be fruitful in overcoming the implementation problems depends significantly on the government itself. It is good that the government is often including representatives of the environment movement in various environment-related committees. However, formal opportunities will not be enough. The government needs to truly value the recommendations that the environment movement offers. [16]

11 Challenges of the Future

Formation of a nation-wide, robust environment movement has been a great achievement of Bangladesh. This movement has succeeded in getting many pro-environment policies adopted. However, the movement now faces formidable challenges too. The following notes some these interrelated challenges.

First, despite the success, it has not yet been possible to bring about a general reversal of the country's environmental degradation process. Pro-environment policies are yet to be adopted in many areas. More importantly, the state of implementation of adopted pro-environment policies is highly unsatisfactory.

Second, while there has been much increase in environmental awareness among different parts of the society, the general public are yet to take to streets to fight for environmental protection. As a result, the number of people participating actively in the environmental campaigns remains small. In other words, environment movement is yet to become a *mass* movement. This remains a serious weakness of the environmental movement, and it is this

weakness that allows vested interests to perpetuate and even increase their anti-environment activities.

Third, the successes achieved in recent years have been less visible and categorical than those achieved at the beginning of this century. For example, formation of the Task Force and the newly formed Commission on rivers are successes. However, the effects of these steps are less perceptible than, say, removal of TSEVs, introduction of unleaded gasoline, or prevention of open-pit coal-mining at Phulbari. To make situation worse, there have been some perceptible failures, such as the failure to prevent the Rampal coal-fired power plant from getting constructed near the Sundarbans and the failure to preserve the public character of the Dhanmondi park of Dhaka city. The danger is that these failures may trigger a *vicious cycle*. The lack of appreciable success may dampen the enthusiasm in the environment movement, lessening the pressure on the government and even less success in protecting environment and further dampening of the environment movement (Figure 4).

What is instead necessary is a virtuous cycle, whereby success in protection of environment will create enthusiasm in the environment, draw more people to it, make it more assertive, generate more pressure on authorities, leading them to more pro-environmental action, which then will strengthen the environment movement further (Figure 5).

Fourth, lack of perceptible progress in protecting environment becomes a particularly important obstacle to mobilizing NRBs for protection of Bangladesh environment. Progress that is imperceptible inside Bangladesh can be even more so to NRBs who are many thousands of miles away.

Fifth, another challenge is that faced by BEN in drawing the second generation NRBs to the struggle for protection of environment in Bangladesh. There are contradictory processes at work here. On the one hand, children growing up in developed countries receive more education regarding environment in schools, and hence they more aware about the importance of environmental protection. This can encourage them to get involved with this effort and join BEN, and some indeed do so. On the other hand, unlike first generation Bangladeshis, whose hearts lie in Bangladesh, the second generation NRBs do not feel that kind of attachment with Bangladesh and hence can be less concerned about its environment. This works against their joining BEN. The latter can be a grave challenge, because the continuity of BEN depends on whether the second generation of NRBs will care for Bangladesh environment.

Sixth, drawing the youth to the environment movement is an important task for BAPA too. As noted earlier, the environment movement is a movement for the future. The younger generations have a greater stake in protection of environment. They should be instinctively drawn to the environment movement. However, it seems that there are forces working against this from happening.[17] One of these is the spread in the society and the youth of the culture of self-aggrandizement and aversion toward working for greater cause. As a result, the youth does not feel the necessity to get engaged in the collective action aimed at a greater cause like that of protecting environment. Yet, enlisting the participation of the youth is vital for BAPA and the environment movement. An important task for the environment movement is therefore to reach out to the youth, using many innovative ways, such as more energetic use of social media. There are hopeful signs. The large participation of students of various universities in recent BAPA-BEN conferences shows that, with proper outreach, it is possible to draw the young to the environment movement. The same can be seen in the success of the Green Voice, an organization of pro-environment movement.

12 The Way Forward

Bangladesh now has a robust, nation-wide environment movement, based on strong theoretical and scientific foundations. A sound organizational structure has been put in place. BAPA-BEN cooperation has been the bedrock of the environment movement in Bangladesh.

BAPA-BEN cooperation has emerged as a model for RB-NRB cooperation. BEN-BAPA principle of financial self-reliance is helping to bring back the culture of self-reliant social work that used to prevail in Bangladesh in the past. Many concrete achievements have been made in protecting environment. Through a slow process of knowledge creation and organization building, the ground has been prepared for many more achievements to be made in the future. A leap is now necessary, so that the environment movement can blossom into a mass movement and realize the potential that has been created, and a general reversal of environmental degradation can be achieved.

The environment movement was launched at the turn of the century with high hopes. It was anticipated to have a broader significance in Bangladesh in view of the prevailing vacuum in effective representation of public interests. The current development strategy, despite the increase in per capita income, has not led to a beautiful and comfortable Bangladesh. On the other hand, the *Dhaka Declaration*, adopted by BAPA and BEN, provides a well-rounded direction for sustainable development in Bangladesh. The scope for materialization of this broader significance may still exist in Bangladesh despite significant changes in the political landscape of the country.

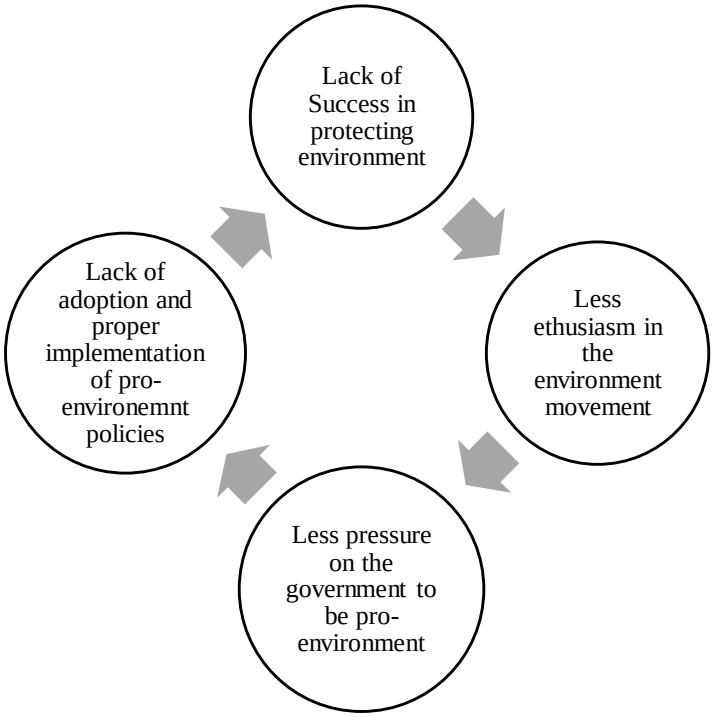

Figure 4: Vicious cycle between lack of success of environment movement and its weakening.

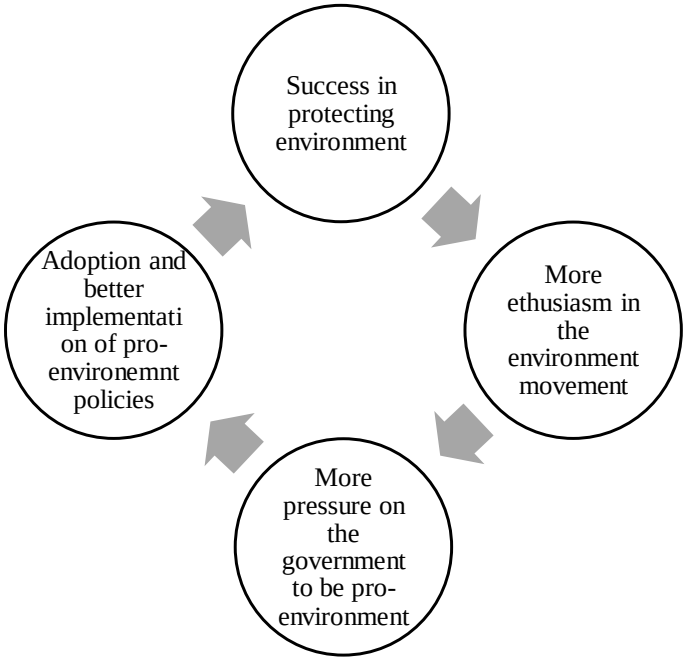

Figure 5: Virtuous cycle between success of environment movement and its vigor.

The previous section noted the possibility of a vicious cycle. However, it is also possible to transform the possibility of a vicious cycle into a virtuous cycle, through a process shown in Figure 6. According to this process, the lack of progress in protecting environment leads to more civic discontent, prompting more people to get engaged with the environment movement, which then becomes a mass movement, leading to a reversal of Bangladesh's current slide toward environmental deterioration and to a renewal of Bangladesh's development strategy toward sustainable development.

This positive transformation will not come about automatically. BAPA, BEN, and other pro-environment forces will have to work hard for it. However, the situation may be getting ripe for such a resolution. The overall environmental situation continues to deteriorate. For example, the single-minded focus on the structural approach is failing to solve not only the river-related problems but also problems of transportation. Waterlogging has become ubiquitous. Dhaka is routinely ranked as one of the most unlivable cities in the world. The environment movement will have to reach the masses with its solutions. Once the masses know about these solutions and be convinced about their merit, they may rise up to be the force that is necessary for the long awaited environmental and social renewal.

Abbreviations

ADAB: Association of Development Agencies in Bangladesh
BAPA: Bangladesh Poribesh Andolon
BCAS: Bangladesh Centre for Advanced Studies
BELA: Bangladesh Environment Lawyers Association
BEN: Bangladesh Environmental Network
BUET: Bangladesh University of Engineering and Technology
BWDB: Bangladesh Water Development Board
CEN: Coalition of Environmental NGOs
CTP: Central Effluent Treatment Plan
CNG: Compressed natural gas
CS: Cadastral Survey
DAP: Detailed Area Plans
EIA: Environment Impact Assessment
EKC: Environmental Kuznets Curve
ETP: Effluent Treatment Plant
ICEAB: International Conferences on Environmental Aspects of Bangladesh
ICBEN: International Conference on Bangladesh Environment
IECO: International Engineering Company
IER: Income-Environment Relationship
KC: Kuznets' Curve
MP: Member of Parliament
NAM: Non-Aligned Movement
NEMAP: National Environment Management Action Plan
NGO: Non-governmental Organization
NRB: Non-resident Bangladeshi
POBA: Poribesh Bachao Andolon
POROSH: Poribesh Rokkhya Shopoth
RB: Resident Bangladeshi
RS: Revised Survey
SEMP: Sustainable Environment Management Programme (launched by the UNDP in Bangladesh in 1997
SIA: Sub-Implementation Agencies
TSEV: Two-stroke Engine Vehicles
UNDP: United Nations Development Programme
WBB: Work for Better Bangladesh

Endnotes

1. It draws its name and inspiration from the Kuznets' Curve (KC) hypothesis regarding the relationship between economic growth and income inequality. According of KC, the inequality will first worsen, as the economy grows, and then improve after the economy has reached a high level of per capita income. For discussion on Income-Environment Relationship (IER), Kuznets Curve, and Kuznets Environmental Curve, see Islam (1997) and Islam, Vincent and Panayotou (1999).
2. See Panayotou (1995) and others for related discussion.
3. See Islam (1997) for the relevant analysis.
4. A prominent among them was Bangladesh Centre for Advanced Studies, formed in 1986. See http://www.bcas.net/?fbclid=IwAR2Rvr-_r-XQtT4c7mk-W QcFXY7doWrnfoXkqHqbbxd 3WCu5HVXusE8rXAQ
5. See MoEF (1995) for details regarding NEMAP. As it puts it, "NEMAP is an environmental planning exercise of the Government of Bangladesh carried out by the MOEF with assistance from UNDP (p. 14)." It further informs that "A National NEMAP Committee was established to oversee the consultative phase. The Committee consisted of the Coalition of Environmental NGOs (CEN), Association for Development Agencies in Bangladesh (ADAP), Bangladesh Centre for Advanced Studies (BCAS), and Bangladesh Forum for Environmental Journalists (FEJB) and others (p. 19)." See also http://documents.worldbank.org/curated/en/329001468741610744/pdf/multi-page.pdf

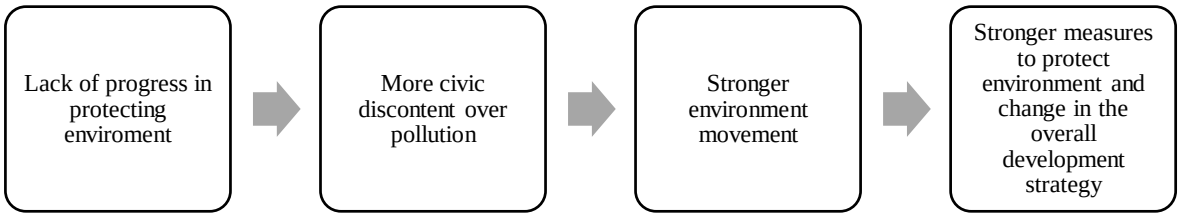

Figure 6: From vicious to virtuous cycle of environment movement.

6. https://info.undp.org/docs/pdc/Documents/BGD/00011488_Sustainable%20Environment%20 Management%20 Programme%20(SEMP).pdf
7. Similarly, government policy to protect wetlands cannot be successful entirely if communities fill up surface water bodies in their own localities.
8. Often the national governmental policies are initiated and sustained by vested interests, and it not possible to overcome the resistance of these interests without strong mobilization of the people. Such mobilization can only come about if people are sensitized about environmental issues in general, including environmental initiatives that they can take at individual and community level.
9. This spirit was captured well by the Brundtland Commission's definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."
10. This also means that NRBs can serve as a conduit for the flow of advanced technological processes and ideas that are necessary to confront environmental problems of Bangladesh.
11. See also Khan (2015) for a perceptive discussion of governance problems in Bangladesh.
12. This is the military-backed government that came to power in 2007, led by Lt. Gen Moenuddin (Army Chief), Mr. Fakhruddin (Chief Adviser of the Caretaker Government), and Dr. Iazuddin (the President).
13. For discussion of the Cordon Approach to rivers and its alternative, the Open Approach, and their relative merits and demerits for Bangladesh, see Islam (1997; 2018), Islam et al. (1999) and also Islam (2016).
14. For a discussion of Rajuk's dual role and its pernicious effects, see BAPA and BEN (2010) .
15. For an analysis of Bangladesh's transportation policies and their effects, see BAPA and BEN (2010).
16. Unfortunately, this is not always happening. An egregious example is provided by the illegal structure built by the Saiham Group of industries on the Sonai River in Habiganj. The River Task Force is not being sincere regarding removal of this structure, despite repeated helpful efforts on the part of BAPA.
17. See Hoque (2018)

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Endangered Delta and the People's Movement for Its Survival

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Abstract

Bangladesh has one of the largest river systems in the world. Known as the Ganges Delta, it is also the world's largest delta and empties into the Bay of Bengal. For centuries this has been the lifeline of people who built villages, towns and cities surrounding these water bodies which support economy of the population depending largely on transportation, fishing and agriculture.

This paper analyses the current state of the Bangladesh river systems and its wetlands. It examines the role of the custodians of these resources, the state and business interests, the mega projects being launched, and the impact these activities will likely have on the environment and the rich biodiversity that still exists in these water bodies. The analysis demonstrates that the aquatic life in Bangladesh river system and wetland is reducing, the wetland-based ecosystem is threatened, and the living condition of people living around these systems is deteriorating. The paper notes how popular movements have repeatedly called for environmental impact studies of these projects, and implementation of environment-friendly and cost effective projects using global quality standards to safeguard the Ganges delta, a unique water system of great beauty and importance. But these calls have been met with only limited action. However, as the paper relates, the recent verdict from Bangladesh courts in favor of these movements giving legal rights to all the rivers and wetlands of Bangladesh have raised the hopes of water advocates around the globe.

1 Introduction

The Bengal Delta, created by the Ganges, the Brahmaputra, and the Meghna Rivers and their distributaries, spreads across Bangladesh and the Indian state of West Bengal (Allison 2012, SANDRP 2017). It is the world's largest active delta, at the head of the Bay of Bengal. Human settlement and urbanization took place here along the banks of the rivers. Peoples' livelihood, economy, communication, transportation, food security, culture, heritage, social stability, and politics are directly influenced by the health of these rivers. Figure 1 displays the major and minor river systems in Bangladesh.

There are controversies regarding the precise number of rivers that flow through Bangladesh. Figure 1 illustrates the origin of the controversy. A survey (Wikipedia 2019*a*) by the Bangladesh Water Development Board reported 310 rivers in the country, among which 175 are in miserable conditions, with 80% lacking proper depth. Recently, an independent researcher noted names of 1,182 rivers in Bangladesh in his book (Haque 2017). However, BAPA-BEN,[1] through the National Convention on Rivers in 2006, found only 230 separate, identifiable rivers in the country. Among the 57 government-recognized transboundary rivers, 53 enter Bangladesh from India, three from Myanmar and one flows into India from Bangladesh. A recent study by the Center for Environment and Geographic Information Services (CEGIS 2020) identified 16 additional transboundary rivers between Bangladesh and India (Biancamaria, Hossain and Lettenmaier 2011). The report on the study was submitted to Bangladesh Government, which then requested India for recognition of these rivers as trans-boundary rivers (Siddique 2016). However, there has been no report so far about any reply from their Indian counterpart. Separately, the newly formed National River Conservation Commission (NRCC) has identified 405 rivers in its recent initiative to update the inventory on Bangladesh's rivers. It is in the process of further updating the inventory of (Bangladesh Rivers) and has already engaged responsible government agencies to gather the needed information; the inventory is expected to be published. The government has documented that Bangladesh had more than 24,000 km of waterway in 1971, at the time of Bangladesh's independence (FAO 2016). However, 40 years later, only about 3,800 km remain (Dhaka Tribune 2019*a*).

Regardless of disagreements on the precise number of rivers in Bangladesh, there is no dispute that Bangladesh is dependent on four major river systems, namely 1)

Figure 1: Bangladesh Major and Minor Rivers. Banglapedia, Rivers of Bangladesh, National Encyclopedia of Bangladesh, http://en.banglapedia.org/index.php?title=River

the Ganges-Padma, 2) the Brahmaputra, 3) the Barak-Meghna, and 4) the Karnaphuli. Therefore, the health of this largest active delta in the world is highly influenced by the activities undertaken by the people and governments of the five countries that share all or some of these basins. These countries are Bangladesh, Bhutan, China, India, and Nepal.

Due to ill-motivated and shortsighted activities, both externally in upstream countries and internally in Bangladesh, there has been serious degradation of the country's rivers and wetlands. As a result, the ecology, environment and people of this riverine country are now highly endangered. In response, people in different parts of the country are gathering and organizing social movements to protect the rivers and the wetlands (Ashoka 2019, Bhuiyan 2013, Waterkeepers 2017*a*;*b*; 2018). These movements are likely to intensify and spread in the future, if the degradation continues and the government does not adopt pro-people and pro-environment approaches to rivers.

2 Existential Threats to Rivers and Wetlands

The first post-independence government led by Bongobondhu, the founding father of Bangladesh, clearly understood the importance of rivers and the need to attend to their unhindered flow. Consequently, the country's very first planning document included provisions for dredging of rivers (GOB 1973). Following Bongobondhu's unfortunate demise in 1975, these appeared to have been abandoned. Instead, recommendations by Dutch and other experts for the cordon approach (i.e., creation of polders) for flood control and river management, and its embrace

by vested interests at both bureaucratic and political levels became the norm. It is only recently that dredging of rivers has been of interest (Dhaka Tribune 2018; 2019*b*, Khan 2019). This, however, appears partly related to connecting Indian States on the east of Bangladesh to West Bengal on the west of the country as noted elsewhere (Sharma 2017).

In the intervening years, projects of polders, embankments, barrages and sluice gates were implemented, instead of dredging the rivers, which carry more than a billion tons of sediment to Bangladesh each year. As a result, the wetlands and canals were disconnected from the main river channels, and small rivers began to die. People encroached on the dried-up river beds and other wetlands for cultivation and settlement (Zahur 2010). Administrative and legal frameworks were also created to facilitate such destructive policies. In the name of establishing the road communication system, roads and highways were built from east to west whereas the rivers mainly flow from north to south. Short-length and low-height bridges and culverts killed navigational waterways encouraging river encroachment all over the country.

During the last two decades, reckless encroachments of rivers and public lands have increased alarmingly, facilitated by the Cordon approach-inspired projects. Rivers flowing by cities and towns have become too narrow to drain all the untreated pollutants. Government revenue collectors were not following the legal instructions about managing rivers, ignoring even the Land Management Manual they were supposed to follow. In some cases, to derive unethical benefit, flowing rivers were wrongfully reclassified as "degraded wetlands" to allow legal leasing of the river's land (Abbas 2010, Byomkesh, Nakagoshi and Shahedur 2008, CEGIS 2020, Islam and Rashid 2011, Islam 2012, Rahman 2019). For example, an allocation of three crores (30 million) taka[2] was made to dredge the Gugalichora River in Baralekha Upazila in Moulvibazar district. However, downstream in Kulaura Upazila, the same district administration changed the class of this river to a degraded wetland to lease out the river to be impounded and used for farm fishing.

When the National Environment Policy was drafted, BAPA were also part of the drafting processes on behalf of the civil society. The group suggested to the government to revise the legal framework that empowers the Land Ministry to be engaged in such leasing through the Upazila Nirbahi Officers (UNO), Deputy Commissioners (DC), and Divisional Commissioners[3] (Akhtar 2009, Islam 2019). This could be done by incorporating a policy clause disallowing reclassification of a natural wetland. Unfortunately, the suggestion was not accepted. As a consequence of this inaction, rivers and wetlands are disappearing all across the country (Khan 2018*a*, Maliha 2019, Rashid 2018). A prominent example of this process is encroachment of Adi Buriganga (2nd Channel) right beside the capital Dhaka city (Buriganga Riverkeeper 2016, Khan 2018*b*). It is now filled and occupied by structures from Chunarchar in Keraniganj to Lalbag Lohar Pool near Sadarghat. These activities have continued despite public dissemination by BAPA of extensive information and data on this issue since 2012 (Buriganga Riverkeeper 2016). Figure 2 illustrates the encroachment (Khan 2018*a*).

The damage has become so extensive that the Buriganga River, which originally flowed from both the Dhaleshwari and Turag rivers, now is fed only by the Turag River, with the connection with the Dhaleshwari River choked by encroachment (Akhtar 2009, Ali 2019). Furthermore, in a front-page expose, the Daily Prothom Alo reported on a power plant completely blocking the mouth of the Buriginaga River in Bosila where it meets Turag (Protham Alo 2019). The plant was owned by a ruling party parliamentarian.[4] However, no action was taken. Similarly, a significant portion of the remaining flowing channel of the Buriganga River is being filled up in the name of another well-connected group. BAPA prepared video documentation of this atrocious encroachment and showed it to the government's Task Force for rivers, but no remedial measure was taken. All the canals flowing through the entire floodplain of the Buriganga, Turag and Balu Rivers and connecting them have been filled up over the last several years (Ali 2019). However, identifying the responsible culprits is a challenge, because it is widely suspected that senior politicians and high officials in the government are directly behind the encroachment and they themselves are likely occupying the land.

The Honorable High Court of Bangladesh gave a clear verdict in 2009, mandating formal demarcation of rivers around Dhaka city, eviction of illegal occupants, protection of the recovered lands, and increased flow to the city's rivers. But faulty implementation of the verdict, in fact, aggravated encroachment. The demarcation pillars and walkways constructed by the government along the rivers, in the name of their protection, actually legalized illegal encroachments and expedited grabbing of the remaining foreshore and riverbanks. BAPA repeatedly opposed such permanent destruction of the rivers and compelled the Task Force to form inquiry committees to properly survey the river area and relocate the demarcation pillars. The first inquiry committee was established under the authority of the DCs.

BAPA immediately protested this step due to the obvious conflict of interest, because it was the DCs who were responsible for puting up the noncompliant demarcation pillars. In face of BAPA's protest, another inquiry committee was established just for the Turag River, headed by a Deputy Secretary of the Shipping Ministry. The report

Figure 2: A photo taken from Kamrangirchar Jora Bridge (inset) in the capital: A boat struggles to ply the water of once vibrant but now stagnant old channel of the River Buriganga which sees thick growth of water hyacinth from encroachment and dumping of waste. Photos: Nabiulla Nabi (Adopted from: Khan, 2018: http://www.theindependentbd.com/post/168708.)

issued by this committee, despite its relative accuracy, was not accepted by the Task Force. Instead, it formed another inquiry committee headed by a Joint Secretary of the Ministry of Land. This third committee also found that none of the demarcation pillars was erected in full compliance with the court verdict. It also identified the illegal occupants, and presented some good recommendations about how to rectify the situation. Unfortunately, as was the case with the previous report, this report was buried and the Taskforce again gave the responsibility to the DCs to review the pillars and hand those over to the Bangladesh Inland Water Transport Authority (BITWA). As a result, the rivers around Dhaka have permanently lost significant part of their foreshores and bank areas.

In another example demonstrating the Taskforce's reluctance to serve its core function of protecting the rivers of Bangladesh, the NRCC during the tenure of its first chairman gave a fully biased inquiry report in favor of an encroacher of the Sonai River at Madhabpur Upazila in Habiganj, and the Task Force gave indemnity to the encroacher to construct Saiham Future Complex right in the middle of the Sonai River, disregarding BAPA's "note of dissent" at the meeting. Recently under the second and current chairman of NRCC, there was another inquiry and field visit conducted by the commission. The Chairman of NRCC after the field inquiry gave letter to the district administration of Habiganj to evict Saiham Future Complex but the district administration did not take any step so far.

Every time the question of legal interpretation of river demarcation arises, the government officials at almost all levels appear to misinterpret the directives intentionally. The High Court directive regarding demarcation of Dhaka rivers clearly stated that the demarcation was to be done using the CS (Cadastral Survey) or the RS (Revised Survey), whichever would make the rivers wider, to ascertain the original position of the rivers. The High Court directive further stipulated that the complete area of a river must include the riverbed, foreshore and riverbank. But

the government administration officials insist on using the RS only, leading to restricted demarcation and loss of river lands. Whether by corruption or ignorance, it appears that government officials are interested in leasing out river lands for sand extraction and other detrimental activities that destroy the water bodies. Following CS or RS are necessary to locate the river. But to determine the area of a river, three basic components of the river are important to be identified practically on ground. A river when she mingles herself during monsoon with any floodplain area, the legal framework of the country gives clear directives to protect the floodplains as well as.

Further complicating the river situation inside Bangladesh is the fact that most of the rivers of the country depend on transboundary flows (Baten and Titumir 2016). As a result, unilateral water withdrawal projects in upstream countries have tremendous impacts on the river morphology and dynamics in Bangladesh. The ill-motivated Farakka water diversion barrage and other structures on the upstream reaches of the Ganges River in India killed dozens of rivers and wetlands in Bangladesh (Kawsar and Samad 2016). The Sundarbans World Heritage Site and the people of the Ganges Basin inside Bangladesh are struggling to meet their fresh water needs and face threats to their very existence. The Gajoldoba Barrage in India killed the downstream Teesta River in Bangladesh. The Brahmaputra River in Bangladesh is under similar threat. By constructing unilateral water diversionary barrages, India has effectively changed the structure of the rivers downstream in Bangladesh. In the lean period, the water flow is completely shut off to Bangladesh causing accumulation of sediment in the riverbeds. This encourages encroachment and agriculture on land that should be under water. During the monsoon, however, huge volumes of water flow suddenly, washing away villages and people every year. This flood-and-drought cycle has significantly changed the structure of rivers downstream.

In a worrisome recent development, India has proposed plans to connect its West Bengal state with Assam and Tripura states using the rivers of Bangladesh but without any impact assessment (Arora and Sharma 2018, Chakraborty 2015, IWAI 2019, Sharma 2019, The Hindu Businessline 2018). Funds have been committed by India to dredge a portion the Brahmaputra and Meghna Rivers, with the remaining corridor from Mongla to Ishwardi to be dredged by the Bangladesh government for transportation of equipment to be installed at the Rooppur Nuclear Power Plant in Ishwardi (Wikipedia 2019*b*). Meanwhile, a huge express highway construction project is underway by the bank of the Brahmaputra (Anand 2017). Clearly, no adequate and transparent assessment has been done about the possible impacts of these multiple mega projects on the riverine country. The people are completely unaware of the fate of hundreds of rivers, canals and wetlands that are entirely dependent on the Ganges, Brahmaputra and Meghna (GBM) river system.

3 Pollution and Water Quality Issues

In addition to the threat of disappearance, rivers and water bodies in Bangladesh face the additional threat of pollution and degradation of water quality. This is well documented (Hasan, Shahriar and Jim 2019, World Bank 2018*b*). Before we discuss these further, let's briefly consider the country's environmental regulatory framework.

The Department of Environment (DoE) within the Ministry of Environment and Forest (MoEF), is responsible for the control and abatement of water pollution in Bangladesh. Broadly, the DoE is mandated to set and enforce environmental regulations for all forms of pollution. Bangladesh has developed a legal framework and a set of standards to meet to prevent water pollution (ECR 1997). The DoE has, by law, a strong enforcement mechanism at its disposal. All industrial units or projects must obtain "Environmental Clearance" from the DoE. Rules specify waste discharge quality standards for all industrial units and projects. However, several toxic materials such as copper, cobalt and aluminum are not specified in the waste quality standards (Clemett 2006).

Despite the regulatory framework, non-compliance, a challenging enforcement environment, and absence of meaningful monitoring scenario have resulted in a significant pollution of the country's water bodies. We describe a number of instances of this next. A recent World Bank study noted "In low-flow winter months, all rivers surrounding Dhaka are designated as ecologically critical areas, as they are almost completely unable to sustain life" (World Bank 2018*a*).

Tannery and textile/dyeing pollutants are two major sources of industrial pollution of rivers (Chowdhury n.d., Mondol, Asia, Chamon and Faiz 2017). A process to relocate 155 industries from Hazaribag Tannery Area in Dhaka city to the newly-developed Tannery Estate in Harindhara of Savar was initiated in 2003. However, the timeline of this relocation was repeatedly revised, and the relocation began only in 2016. By this time, the number of industries in Hazaribag Tannery Area grew to more than 230.

While this move was intended to alleviate river pollution, the project is plagued with problems. The Central Effluent Treatment Plant (CETP) in Savar is inadequate to properly treat the waste not only due to negligence and corruption but also due to the fact that the CETP design itself was faulty from the beginning. As a result, the tannery enterprises that relocated to Savar are now polluting

Dhaleshwari River and the entire surrounding floodplain. The Chrome Separation Plant is yet to be set up, and no arrangement is in place to treat the salts that are used for tanning. The Biological Treatment Plant does not have the capacity to hold the amount of effluent produced by the original 155 factories, let alone the additional more than 80 tannery factories that didn't get a plot allocation in the original plan for the Savar site. Thus, the relocation of Hazaribag Tannery is just relocating the pollution further upstream. Furthermore, there has been no discussion on impact on and plans for the tannery workers and their families or the hundreds of small and medium cottage industries that operate on the byproducts or leftovers from the tanneries. Thus, the relocation is causing many social and other economic problems.

About one hundred dyeing factories are discharging untreated wastes directly into the Buriganga River from Shyampur area. Hundreds of textile and spinning mills are polluting Bongshi, Turag, Balu, Shitalakhya and other rivers, without any meaningful monitoring by the Department of Environment (DoE). The acceptance standards set by the DoE for pollutant parameters, particularly for waste disposal from large industries, are also unacceptably high.

Government institutions, such as City Corporations and sewage authorities, are carrying untreated waste from city dwellers directly to the rivers. Naval vessels are throwing all possible wastes, including burnt fuel, directly to the rivers. The rivers in Bangladesh are treated as the dumping ground for all kinds of waste and pollutants.

In the name of food security for the nation, the agricultural sector is allowed to use excessive chemical fertilizer and pesticides all over the country. Through canals and small rivers, agricultural run-off ultimately reaches the main river flow as well as.

The planned construction of a large number of coal plants, including the one at Rampal near the Sundarbaans, World' a largest mangrove forest and a UNESCO World Heritage Site that has been controversial, would also degrade the water systems. In preparation for infrastructure development related to these plants, the industries are filling up canals and wetlands, destroying the navigational network and causing huge riverbank erosion. Dredging of the Pashur river (also denoted as Passur river in some literature, such as UN Environmental Program documents) to import coal for Rampal is underway. The quantity of fish eggs in the Pashur River near Mongla and Rampal has decreased to one-third of the egg population prior to 2010. A recent report noted that the Rampal plant could emit high levels of mercury, a potent neurotoxin that damages children's brains and nervous systems, and it could be sufficient to further aggravate the fish egg issue. The eggs would be unsafe to eat over an area of approximately 70 sq. km around the power plant (The Daily Star 2017). The report also stated, "Additionally, 10,000kg of mercury discharged over the life of the plant could end up in the coal ash pond, which is subject to flooding and poses further risks to aquatic food chain of the Sundarbans and Bay of Bengal." This could impact millions of people who eat the fish, the report stated.

Kalapara and Taltali Upazila, where construction of at least seven coal-based power plants and of multiple coal terminals are planned near the Payra Sea Port, is a critical migration route for the pollution-sensitive Bangladesh national fish, the Ilish (Hilsa) fish. In 2017, 38 thousand metric tons of hilsa fish landed to Kalapara from the Bay of Bengal through the Rabnabad and adjacent channels. With the construction of coal-based industries along the hilsa's migratory corridor, Bangladesh will lose about Tk 4 billion[5] every year in fish catch (Roy and Hossain 2019).

Similarly, the planned construction of a number of coal plants in Matarbari and Moheshkhali will severely pollute the Koheliya River and the Cox's Bazar beach, the longest beach in the world (EP 2019). The coal plants in Moheshkhali and Matarbari will highly impact the salt and dry-fish production of Bangladesh.

Transboundary pollution by upstream countries making water unsuitable for use in the downstream is also a big concern for the rivers and wetlands of Bangladesh (Ahmed 2013). This concern will grow into a major challenge with uranium and coal mining and mineral extraction underway in northeastern India and with many kinds of waste products crossing international boundaries into Bangladesh waterways.

4 People's Movements

Degradation of the rivers and wetlands in Bangladesh has already triggered mass movements in many affected areas of the country. For example, a longstanding movement to free Baral River mobilized thousands of people to form a human-chain along its 200 km long bank (The Daily Star 2012). BAPA led civil society organizations to make numerous trips from the capital Dhaka to the Baral River valley to participate and to help in organizing the Baral movement, motivating the local people to come forward to save the Baral River, and in helping the Coordinator of "Save Baral Movement" in many other ways.

Early on, a movement, named "Save the Khowai River Movement" was developed to save Habiganj town from severe waterlogging. Over time, it turned into a mass movement. In 2008, about ten thousand people staged a procession, demanding demolition of the illegal structures constructed on the old Khowai River. On a different occasion on 27 February 2016 more than 20 thousand people gathered to protest pollution from a factory in Ektiarpur of

Madhabpur Upazila in Habiganj (Jamil 2016). Similarly, hundreds of people took part in a hunger strike to save the Ratargool Swamp forest in Sylhet. Thousands of villagers gathered to recover Gugalichara River in Moulvibazar.

River movements are spreading in other parts of the country too. For example, on 17 April in 2017 in Dakope of Khulna district more than five thousand people protested against setting up of industries around the Mongla port and pollution of the Pashur River (Jamil 2017). Hundreds of people gathered to protect the Jamuna and Brahmaputra Rivers in Sirajganj, Bogra, Gaibandha, and Kurigram. There are many other examples of people coming forward *en masse*, when it becomes a question of their survival and when they get proper information and see competent leadership.

The Bangladesh High Court gave specific verdicts to protect the rivers and wetlands of Bangladesh recently and assigned responsibility to the National River Conservation Commission (NRCC) to implement and coordinate the instructions of the court. In a landmark decision on January 29, 2019 the Court declared, 'A River is a living entity, a legal person and a juristic person' (Chandrasekharan 2019). The question is: how well will the court's decisions be implemented and that too in a timely manner?

5 Conclusion

Common people in villages and small towns in Bangladesh are acute victims of all forms of degradation of the deltaic character of this land (Islam 2012). But environmental activists of the country continue to hope for the better, as the government's Task Force on rivers and NRCC continue to invite their participation in river-related decision-making processes. Many organizations, groups and individuals are working for the protection of rivers and wetlands in many places in Bangladesh. National and local media houses, including social media platforms, are sensitizing the population to the importance of protecting the environment. Although the goal of a common organizational framework for the management of GBM basins together by the five riparian countries has not materialized, people-to people efforts in this direction have already started. It may not be a far-fetched dream that one day people will gather everywhere to save the rivers and wetlands, to save the delta, and to save their very existence. What is needed is just to support good initiatives and build stronger networks to realize the power of working together to protect environmental rights and a sustainable future for all.

Abstract Wetlands are a vital link between land and water in Bangladesh. A majority of the people of Bangladesh are critically dependent on wetlands. In this paper, the values of wetlands, causes and effects of wetlands degradation, as well as the present wetlands management approach, are analyzed and recommendations for wetlands management are suggested based on participatory rural appraisal (PRA), field visit, personal experience, and existing literature and information. Wetlands play a crucial role in maintaining the ecological balance of ecosystems, but wetlands habitat of Bangladesh is under constant threat due to increase of population, intensive agriculture, overfishing, siltation, pollution, ill-planned infrastructures, lack of institutional coordination, lack of awareness, etc.

As a result biodiversity is reducing, many species of flora and fauna are threatened, wetlands-based ecosystem is degenerating, and the living conditions of local people are deteriorating as livelihoods, socioeconomic institutions, and cultural values are affected. Wetlands management is not addressed separately in water management activities of Bangladesh. In order to balance human needs and wetlands conservation, a mainly community-based wetlands management approach has been taken in Bangladesh, but this is not enough to prevent the degradation of wetlands. Therefore, Bangladesh now needs a comprehensive strategy combining political, economic, social, and technological approaches to stop further degradation.

Abbreviations

BAPA: Bangladesh Poribesh Andolon
BEN: Bangladesh Environmental Network
BITWA: Bangladesh Inland Water Transport Authority
CEGIS: Center for Environmental and Geographical Information Service
CETP: Central Effluent Treatment Plant
CS: Cadastral Survey
DC: Deputy Commissioner (district administrator)
DoE: Department of Environment
ECR: Environment Conservation Rules
GBM: Ganges-Bramhaputra-Meghna
GOB: Government of Bangladesh
MoEF: Ministry of Environment and Forest
n.d.: no date (in several references cited from the web)
NRCC: National River Conservation Commission
RS: Revised Survey
UNO: Upazila Nirbahi Officer (Upazila (sub-district) administrator)

Endnotes

1. BAPA, Bangladesh Poribesh Andolon, is an environmental organization based in Bangladesh; BEN, Bangladesh Environmental Network is a global

network of non-resident Bangladeshis to facilitate communication about Bangladesh's environmental problems. BEN and BAPA are partners.

2. Approximately, USD 375,000 @80 taka/USD
3. Bangladesh is divided into increasingly larger administrative units, Upazilas (sub-districts), Districts, and Divisions, administered, respectively, by UNO's, DC's, and Division Commissioners.
4. This would be the "Politician- Polluter connection," detrimental to environmental compliance that Islam notes in 'Environment Policy in Bangladesh,' https://www.academia.edu/12548737/ Environment_Policy_in_Bangladesh.
5. Approximately, USD 50 million at a nominal exchange rate of Tk. 80/USD.

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A Critical Look at the Environmental Impact Assessment (EIA) for Rampal Power Plant

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Abstract

The paper reports on a critical review of the Environmental Impact Assessment (EIA) for the Rampal Power Plant that was approved by the Department of Environment of Bangladesh in 2013. The review was conducted utilizing definitions and standard norms for preparing and reviewing EIAs for Public Projects in the United States. These include examination of the process flows, transparency, public engagement, assessment of environmental impact to the resources in and adjacent to the proposed project site, and consideration of alternative sites. All appear inadequate in the Rampal EIA, especially the consideration of alternative sites in view of the close proximity of the project site to the Sundarbans, rendering the EIA incomplete and insufficient. The EIA was examined for the necessary impact assessment of coal transport through the Passur River ecosystem and of power plant operation. None was found in the EIA. This step was left to an external entity which had not performed this key assessment at the time the project was approved.

1 Introduction

A coal-based thermal power plant proposed by Bangladesh Power Development Board (BPDB) and approved by the Department of Environment (DoE) of Bangladesh is under construction in Sapmari Katakhali, Rampal in Bagerhat near a highly sensitive environmental boundary known as the Sundarbans. An Environmental Impact Assessment (EIA) was approved for the power plant by the DoE on August 5, 2013 (Rampal EIA 2013). However, the controversy around the project and its location continues (Rahman 2016). Many in the general public of the country, local and international environmentalists, special interest groups, landowners, Non-Governmental Organizations (NGOs) and media have objected to the proposal of the project with the belief that it will jeopardize the ecosystem of the internationally acclaimed mangrove, the Sundarbans. The present paper assesses the Rampal EIA.

2 What is an EIA?

Before we dive into the Rampal EIA, let's discuss the background and processes to understand the EIA practice in Bangladesh. An EIA is an environmental planning document that analyses, discusses and discloses environmental impacts for a proposed project and develops and defines mitigation measures to protect and preserve the environment. For any proposed public project where public funds will be invested, an environmental document must be prepared as part of the project approval process. An environmental document is prepared to comply with environmental laws, regulations, guidelines and rules to protect the environment for the greater good.

In Bangladesh, the primary source of guidance in preparation of an environmental document comes from the Environmental Conservation Act (ECA) of 1995 (ECA 1995) and Environmental Conservation Rules of 1997 (ECR 1997). The enforcer of these laws and rules is the DoE of Bangladesh (DoE 1997). The ECR, 1997 guidance protects and conserves environmentally sensitive areas and provides guidance to be followed to protect environmental resources for a proposed project. Per ECR, 97 proposed projects are categorized according to potential for adverse impact to the environment. There are four categories for industrial projects; they are Green, Orange A and B, and Red. The Rampal Project has been categorized as a Red project. The process to obtain the full environmental clearance had two steps.

The first was to prepare and submit an Initial Environmental Examination (IEE) to the DoE to obtain Site Clearance and the second was to prepare and submit a more detailed environmental document known as the EIA to obtain a Certificate of Environmental Clearance (CEC). This two-step process for the Rampal project was completed in August 2013.

3 Background of Rampal Project EIA Processing

To initiate the coal-based thermal power plant project; BPDB appointed a Bangladeshi government agency known as Center for Environmental and Geographic Information Service (CEGIS) under the Ministry of Water Resources to prepare an IEE per the guidance of ECR, 97 (ECR 1997). The CEGIS prepared an IEE and submitted it to DoE for review and issuing of the Site Clearance. A Site Clearance was issued to BPDB on May 23, 2011. However, DoE found the IEE to be deficient of a complete environmental impact assessment and directed BPDB to prepare a more detailed and complex environmental document, namely, an EIA.

The IEE and an EIA both are environmental documents that investigate, analyze and quantify environmental impacts of a proposed project to propose mitigation measures to protect the environment. EIA is a more complex and elaborate version of the IEE. Both documents follow the guidance of the ECR, 97 to comply with environmental laws and rules of Bangladesh.

4 Key Elements of an EIA

Let us look at some of the key elements of an EIA. The ECR, 97 does not itemize the elements below in the exact sense. However, it does imply the following as the foundation of an EIA.

1. *An EIA is a public disclosure document* that allows the general public and stakeholders to engage, review and express their opinion in the planning process of a project (Section VII 3.1.2, 3.3.4 of ECR 97). A *Draft* environmental document is to be disclosed to the public before it is finalized. It is a very powerful tool to engage the public and be transparent to them about any publicly funded project that is of public interest ECR (1997).
2. *An EIA discusses the Purpose and Need of a project* in the document to justify the initiation of a public project. The questions to consider are does the EIA sufficiently show the justification of why public funds be invested in a coal based power plant and is this truly a need to enhance public life?
3. *An EIA describes a comprehensive Project Description* that includes all project features pertaining to pre, post during construction of the project to analyze the full range of environmental impacts due to a project.
4. *An EIA discusses a range of Alternatives or Alternative Sites , (per Section VII) ECR 97* for a proposed project. The EIA also discusses and compares between alternatives to identify the "least damaging alternative" to the environment. Per National Environmental Policy Act (NEPA) of the United States the alternative analysis process always includes an alternative called, a ***no-build alternative***. This means that not building the proposed project is also an option if the project is not found to be viable. Through the public participation process sometimes a no-build alternative is selected and in that case a proposed project can be stopped. Unfortunately, the ECR, 97 does not offer that option.
5. *An EIA study Area or boundary* is defined for a project that includes the actual project, its storage, staging and transportation related to the project (Section VII ECR 97). The Study Area is then studied, analyzed for environmental impacts and mitigations.
6. *Impact Analysis and development of Environmental Management and Monitoring Plans (EMPs)* are the most important elements of an EIA. Impact analysis is based on the study area established and the impacts are quantified in order to propose appropriate mitigation measures to protect the environment. An EMP formulated following the analysis is documented in an EIA with the purpose of implementing and enforcing the EMP.

In order to understand the 600-page long EIA for the Rampal project, an appreciation of the above-mentioned elements of an EIA is critically important. Thus, these elements have been used throughout the present article as a basis of comparison and reference to evaluate the merits and deficiencies of the Rampal EIA.

5 Rampal Project and EIA Preparation

The Rampal project is a joint venture project between Bangladesh and India; the project proponents are BPDB and India's National Thermal Power Corporation (NTPC) Limited. The location of the power plant has been decided to be in Sapmari Katakhali, Rampal, in Bagerhat upazila in the district of Khulna. This location is within 14 km of the national and international conservation area, the Sundarban jungle (Figure 1), which is a highly sensitive mangrove area that supports a valuable ecosystem enriched with birds, mammals and marine resources.

Although a joint venture project, BPDB has taken the burden of responsibility of site selection and its environmental impact assessment for the project within the boundary of Bangladesh.

The IEE that was prepared in 2011 for the proposed power plant discussed only two possible locations (Alternatives) for the proposed project; both locations in the

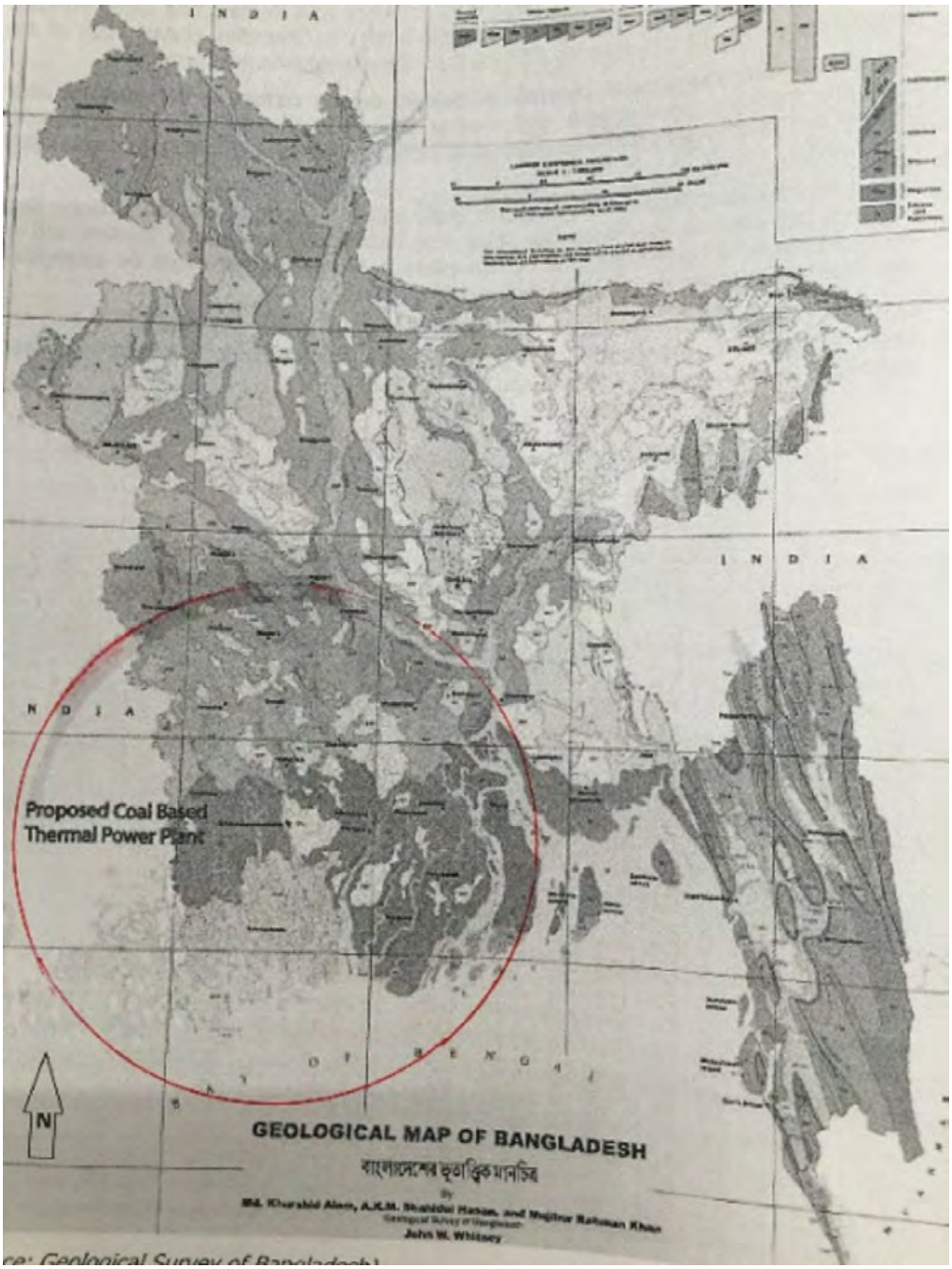


Figure 1: Location of the Sundarbans

Southwest corner of Bangladesh near the environmentally sensitive area, the Sundarbans.

The argument presented in the EIA about the site selection includes the proximity of the navigational waterway through the Passur River for coal transportation for the power plant being connected to the Bay of Bengal (Figure 2). It is unclear where the coal will be transported from. However it was mentioned that India, Africa, Indonesia, Malaysia, etc., are possible sources of the coal for the power plant.

The two locations that were noted are:

1. Labanchara near the City of Khulna and
2. Sapmari Katakhali Rampal in Bagerhat, Khulna

There are no actual impact analyses for a power plant that are discussed at these two locations. Also, there are no maps in the EIA showing both locations.

The DoE issued a Site Clearance Certificate in May 23, 2011. As mentioned earlier, the DoE designated the proposed power plant under the category of Red for industries per the ECR, 1997 due to anticipated severe adverse impact to the environment. An EIA was prepared by the same group, CEGIS, in 2013 and an Environmental Clearance Certificate (ECC) was obtained by BPDB on Aug 5, 2013.

Now, let's consider the actual document and examine some of the aspects of an EIA and the ECR 97 guidance.

Public Participation or public opinion did not appear to have a role in this EIA: The IEE proposed only two locations as mentioned above and the people or other interest groups had very little opportunity for input on the two locations. A very complex and environmentally challenging power plant is being constructed next to a most environmentally sensitive area, the Sundarbans (designated as a UNESCO World heritage Site (EIA Summary) but people found out about the project after the Site Clearance Certificate was already issued by the DoE.

The guidance from ECR, 97 actually does not offer an opportunity for public to participate in the draft environmental process. The guidance is more focused on disclosure and public opinion but there is very little guidance on how the public opinion should be incorporated in the document. The EIA for Rampal Power Plant did not incorporate any public feedback.

There is no evidence of any public participation in the project site selection process prior to finalization of the location of the project site, as the DoE issued the Site clearance in 2011. The EIA lists many members of the public who attended the public meeting in April 2013 but they did not really participate in the decision-making process as the site Alternative was already selected in 2011.

In the executive summary of the EIA, Table A presents a comparison between the two proposed locations. The issues that were analyzed were impacts on society, water resources, agriculture and fisheries, ecosystem, construction advantage, coal transportation advantage through Passur River, etc. In conclusion, the IEE selects the Rampal location for the merit of proximity of coal transportation through the navigable waterway to the project location.

Ordinarily, this process may not have been so controversial if the DoE did not approve a location that is only 14 km from one of the most ecologically sensitive areas in the world. The ECR, 1997 requires industries to be a minimum of 10 km from the edge of an ecologically critical area (Figure 3). Interestingly, the summary Table 8A clearly shows that Labanchara is farther away from the ecologically sensitive Rampal area (33 km vs. 14 km) and from the world heritage site (103 km vs. 70km) and yet Rampal area was selected as the preferred site.

Why the IEE does not propose any other alternative Site in India or other parts of Bangladesh for the power plant remains unclear and unexplained in the EIA. The Site selection process and the issuance of the Site Clearance show severe weaknesses in the areas of public participation, disclosure and transparency of a government action.

The Rampal EIA document does not mention when a draft EIA was prepared for public circulation. However, the document does mention public disclosure meetings (Chapter 15 of the EIA) that took place on April 12, 2013 to describe and disclose the project. This was not a public meeting to engage the public for their participation in the planning process, rather it appears to be an announcement of the project and an attempt to convince the public how the project will bring jobs to the area. It is not clear whether the environmental impacts were disclosed at these public meetings. The land acquisition process started right after the Site selection process was complete. The actual EIA was still pending.

The purpose and need for the Rampal power plant is to generate 1320 MW electricity using coal as the fuel. This is to be the first thermal coal plant proposed by BPDB in Bangladesh but NTPC has multiple coal power plants in multiple locations of India. The Environmental guidance in India follows a safe buffer distance between a coal-based power plant and an environmentally sensitive area which is 25 km, not 10 km. Per the Rampal EIA, the demand for growing need of electricity will be 13,000 MW in 2017 and 34,000 MW in the year 2030. Bangladesh aspires to use coal as an alternative energy source as the country is quickly running out of its domestic natural gas supply that will significantly decline by 2017, the time horizon in the EIA noted above.

BPDB has undertaken an aggressive plan to generate 50% of its electricity to meet the rising demand by using coal as an energy source. The coal transportation system

Figure 2: Access for coal through the Sundarbans to the project location

has created more of a controversy than the plant itself as the navigational route from the Bay of Bengal to the Sapmari Katakhali is through the Sundarban area. The EIA does not disclose clearly how the coal will be transported avoiding impacts to the marine mammals and other biodiversity resources in the waterway. In fact, in Chapter 9 of the EIA it is disclosed that the transportation of coal will cause severe damage to the ecosystem.

If the first proposed power plant, that is expected to generate only 1320 MW out of total need of 17,000 MW (50% of the 34,000 MW) and they are all coal-based, and if all of them follow similar navigational routes as this project proposes in order to transport coal through the Sundarbans, one has to wonder how that may affect country's ecosystem by the year 2030. There are examples of coal-based power plants in other countries that have successfully avoided many of the environmental impacts on nearby ecosystem. However, the Rampal EIA does not discuss those. The entire responsibility for studying impacts to marine resources have been left to be resolved by the International Maritime Organization (IMO) but their input has not been included in this EIA.

Project Alternatives or Alternative Sites were not presented in the EIA at all. The EIA repeated throughout the document that BPDB has already availed the site clearance in 2011 and therefore the location of the power plant is not open for a discussion. There is no other alternatives are available in the EIA; not even a No-Build one that an EIA generally contians. Given the sensitivity of the location of the proposed plant, assessment of multiple build alternatives that serves the purpose and need of the project was a must.

The EIA proposed only one build alternative, the coal-based thermal power plant at Rampal. It is also not clear when the EIA was available to the public. The EIA presents a plan but this offers no options or choices to the public to choose a better viable alternative that causes less

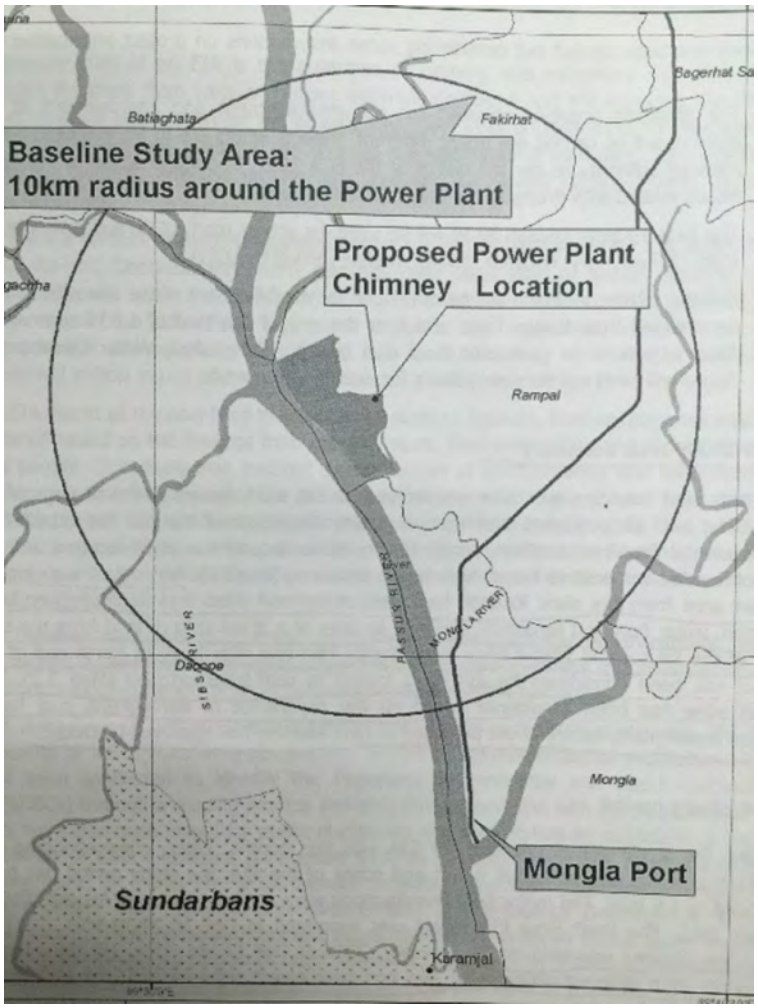


Figure 3: 10-km radius Baseline Study Area around Rampal Plant

environmental harm.

A No-Build Alternative should have been proposed in the EIA to show the analysis between proposed build and no-build alternatives. If the EIA carried out a No-Build alternative assessment, the project could have been stopped completely through the EIA process. In that scenario, the project proponent would have to start the process again with more reasonable locational alternatives for the proposed project.

The study area or boundary for the environmental impact analysis of the Rampal power plant is probably the least discussed topic in the EIA. The EIA describes the different elements of the power plant but discusses very little about the transport of the coal to the power plant. The project proposes to acquire 1,834 acres of land for the plant and lists 35 items as power plant project elements in the EIA (Chapter 5, section 5.7). These include the power plant structure, residential and fuel structures, etc., and a possible future expansion to another 1320 MW power plant in the area. The study area in the EIA is a 10-km radius circle around the power plant comprising 1,834 acres of land. In the same Chapter in section 5.17, the EIA lists a set of elaborate items for the growth and development of the coal plant that include, residential areas, school, mosque, medical center, sports complex, access roads, etc. It is not clear if all of these are also included in the study area.

Transport of coal would be an everyday activity when the plant is in operation. The EIA also states that dredging will be required to improve the transportation of coal through the Passur River through Akram Point to Mongla Port to the Rampal plant jetty. This navigation pathway has not been considered in the impact assessment for the project.

Although this may be the most environmentally damaging aspect of the project, the EIA discloses that BPDB

is leaving the responsibility to assess all coal transportation related movement of vessels to the IMO. They will determine how frequently the vessels will go through the rivers of the Sundarbans. In other words, the EIA was approved without the necessary knowledge of the coal transportation system for the proposed project. BPDB is also leaving the protection of fisheries and other coal transportation related harm to be managed and monitored by IMO. It is not clear in the EIA whether a government project can delegate such actions to an international organization for the purpose of managing and monitoring the marine resources.

The EIA discloses that a jetty will need to be constructed, rivers will need dredging, trees will be cut along Paussar river (Chapter 8, section 8.2.14), and vessels that will create noise and vessels with bright lights will be transporting the coal every day, and yet the navigable way was not included in the project study area for impact analysis.

Overall, the Impact Analysis in the EIA is quite incomplete, inconsistent and inaccurate. This is further discussed next.

Significant impacts to Sundarban's Ecosystem: Per the EIA, Chapter 2, 2.2.2 the Sundarbans has been declared as protected area under ECR, 95 and under the Forest Act 1927 and thereby has been restricted from certain activities in and around it. Commercial activities that could cause damage to the forest and its wildlife resources are disallowed.

As we know, the proposed project will locate the coal plant 14 km away from the edge of the Sundarbans but the transport of coal is proposed through Passur River, thus through the heart of the Sundarbans. The EIA mentions (Chapter 2, 2.5) that the transport, shipment, types of vessels to be used and the frequency of coal transport will be determined by IMO. These items were not known during the preparation of the EIA, and have not been studied, and therefore impacts due to coal transport are undetermined.

However, the same EIA (Chapter 8, 8.2.14) discloses the fact the coal transport through the Passur River would cause significant harm to the ecosystem of the Sundarbans. It mentions that the frequency of the vessels will cause harm by noise, speed, lighting, waste disposal to the Royal Bengal Tiger, deer, crocodile, dolphins, and mangrove if not managed properly. Figures 4a and 4b display the areas that would be affected. In Chapter 16, in conclusion, the EIA states that the impact on the ecosystem of Sundarbans would be "minimum" as the IMO will enforce the environmental management plans throughout the life of the coal plant. It is not clear how this conclusion is reconciled with the observation cited above from Chapter 8. Again, the EIA needs to clarify how the IMO will be brought into take over the responsibility of coal transportation or of resolving associated issues.

The figure on the left shows the impact area in yellow outside the baseline 10km circular area that are going to be affected by the coal transport but these impacts were not studied or quantified.

But the IMO did not even complete the impact assessment for the coal transport. Thus, how is it possible to mitigate, manage or monitor the impacts? The impact assessment for the coal transport is therefore incomplete. Some vague ideas have been included in the name of the EMPs to show all impacts will be mitigated. Also, coal transport would dependent on the coal policy. According to the EIA, the Bangladesh Coal Policy was still in its draft phase and had not been finalized at the time the EIA was prepared (Chapter 2, 2.1).

The emission of CO_2, SO_2 and NO_2 that would arise would also affect the ecosystem over the years but the EIA is claiming the eco-friendly coal power plant will take care of all chemical hazards for the environment.

There is no discussion on temperature increase in the atmosphere due to the factory.

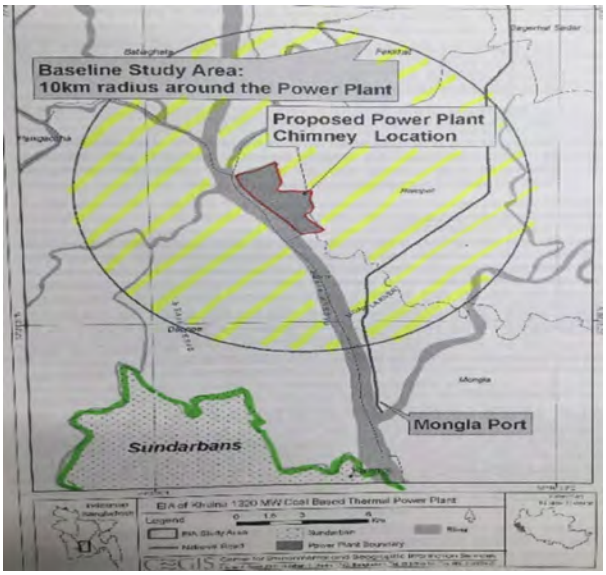
Given below is a discussion on areas where the impact analysis is incomplete and inadequate.

No Cumulative Impact Discussion: In the impact analysis section, there is inadequate discussion of cumulative impacts due to the project. In the EIA there is only one paragraph on the cumulative impact of such a controversial project (Chapter 8, 8.5). This is simply not adequate for the proposed project. The EIA concludes in this section that if the ECR, 97 are followed all cumulative impacts will be within limits of the environmental guidance. In this chapter, all existing industries around the project vicinity and their environmental impacts needed to be discussed to assess if this project would make things worse.

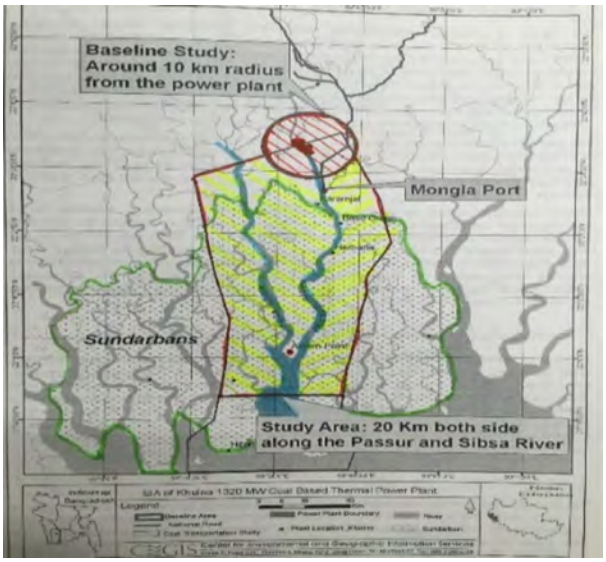
Segmentation in Impact Analysis: The EIA has handled the significant impacts in an unclear manner. The EIA discloses that the coal transportation will be carried through the navigational route of Mongla Port from the Bay through the Passur River that is between two nationally important forest protected areas, classified as Wildlife Sanctuary with the highest level of protection under the Bangladesh Wildlife Act 2010. However, the coal transport and management is left to the IMO and the process for that is yet to be determined (Chapter 6, 6.24.5).

The EIA also mentions that dredging will need to be done to the Passur River for coal transport but a separate impact assessment for the dredging will be completed by the Mongla Port Authority.

Dredging would have a significant impact to the fisheries resources of Sundarbans but since that EIA is not complete, we do not know what other significant impacts would be caused by the project.



(a) 10-km circular baseline study area



(b) Area outside the baseline

Figure 4: Area inside and outside the baseline that would be affected by coal transport: (a) 10-km circular baseline study area, (b) Area outside the baseline. The impact was not studied for the area outside the baseline.

Clearly, segmentation of the project and delegation or postponement of assessment of impacts caused by the various components of the project to other authorities, have made the Rampal EIA incomplete and not viable. A comprehensive EIA would have all the impact information quantified and then propose the Impact Management Plans and Impact Monitoring Plans (EMPs).

Growth Inducement: Growth is definitely expected in the Sundarban area if a large power plant is established in the area. The EIA mentions that to meet the current demand for power in Bangladesh, another 10 to 15 power-plants will need to be built in the near future. With each power plant comes, utilities, roads, housing, schools, other commercial developments, etc. The environmental degradation is already in a sad situation and there is no point to take it to the next level. The protected area designated will not be able to retain its ecosystem and habitats that this area houses for hundreds of threatened and endangered species. There is no discussion in the EIA that addresses the risk and danger of the growth that will likely be induced in this environmentally sensitive area.

6 Environmental Management Plan and Environmental Monitoring Plans

Chapter 12 and Chapter 14 covers environmental management plans and monitoring plans and these two chapters are quite hefty yet very little of it are project specific environmental commitments. Implementation of these environmental commitments is delegated to consultants and other agencies that do not have a stake in the protection of the environment. Does DoE have the capacity to enforce all the EMPs? We have pages after pages of generic environmental commitment compliance language that are not enforceable. DoE mentions 59 items in the Certificate of Clearance that are also very generic.

7 Conclusion

There are quite a few items that lack a comprehensive analysis and assessment in the Rampal EIA discussed in this article.

1. Alternative Site locations for the proposed coal plant other than Rampal are not discussed or analyzed in the EIA. The EIA is prepared after the fact of Site selection. The ECR, 97 allows alternative site selection as mitigation option if the proposed site is proven to have severe adverse impacts. The EIA proposes EMPs and states that all adverse impacts will be mitigated and therefore no alternate site selection is necessary. The analysis to reach such a conclusion is inadequate or incomplete. Rampal power plant will have adverse impacts on the Sundarbans preserved area and that would have been analytically established if cumulative impact, growth discussion, appropriate study boundary and coal transportation plan and impacts were qualified and analyzed.

2. As mentioned earlier, coal transportation details including route, frequency, and type of vessels and its impacts are not complete in the EIA. The EIA discloses it will be completed by IMO, but no timelines are set in the EIA for that.
3. Quantification of noise and light that will be generated by the frequent navigation of barges and boats on a daily basis through the navigable channel in the Passur River due to coal transportation to the plant is a must. There is no quantification of these impacts disclosed in the EIA. EMPs proposed for these impacts are very vague and general.
4. Quantification of thermal change in the environment due to the coal plant is also not discussed.
5. A detailed environmental impact analysis due to proposed dredging of the Passur and other river routes for the coal transport is not included. The EIA mentions the Mongla Port Authority will be preparing two separate EIA's for dredging, etc. The dredging work is required for the Rampal project and the impact should be quantified as a part of the EIA of the project.
6. More studies on fly ash and air quality maintenance specification to be developed are needed but are not included in the EIA.
7. Details on the river bank development and tree removal plans due to installation of jetty etc., for the plant have not been studied or disclosed in the EIA.
8. Public opinion must be taken into consideration about the location and the project at the DRAFT phase of the EIA.

The Rampal EIA is incomplete and inadequate, and a lot more work needs to be done to complete the environmental assessment process. However, the DoE has prematurely issued the CEC already. If the Rampal location is still considered a viable option, supplemental analysis will have to be added to the EIA to document further impacts and make the missing information available before the project proceeds.

The DoE must play a larger role than what has been committed to in this document to preserve the Sundarbans. A project as sensitive as this one requires a much more vigilant role by the DoE.

Disclaimer

A report prepared for Bangladesh Environment Network (BEN) at the invitation of BEN Energy Panel Chairperson. Opinions expressed are not intended to reflect those of organizations the author or BEN Energy Panel Chair are associated with.

Abbreviations

BPDB: Bangladesh Power Development Board

CEGIS: Center for Environmental and Geographic Information Service

CEC: Certificate of Environmental Clearance

DoE: Department of Environment (of Bangladesh)

ECA: Environmental Conservation Act

ECR: Environmental Conservation Rules

EIA: Environmental Impact Assessment

EMP: Environmental Management and Monitoring Plan

IEE: Initial Environmental Examination

IMO: International Maritime Organization

NEPA: National Environmental Policy Act (of Bangladesh)

NTPC: (India's) National Thermal Power Corporation

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Underlying Causes of Early Floods in the Haor Region

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Abstract

Four haor (vast wetlands) districts (Sunamganj, Sylhet, Netrokona, and Kishoreganj) in NE Bangladesh suffered an unprecedented flood in late March-early April of 2017. Though not as extensive, parts of the haor region was affected by hail storm and early flood in April of 2019.

This study analyzed underlying causes of these untimely floods using the rainfall data available in public domain for Cherapunji, West Garo Hills, West and East Khasi Hills, and Jaintia Hills in Meghalaya State of India, and Sunamganj in Bangladesh for the period of 1901–1917. Geomorphic analyses of stream cross sections in the haor region indicate that water carrying capacity of these streams are critically insufficient to effectively discharge the generated surface water run-off that results from major rainfall without causing flooding.

The results of data analysis reveal that the rainfall patterns during the months of April and May have changed during 1959–2017 period when compared to the rainfall patterns during 1901–1958 period. Analysis of monthly rainfall data indicates that flooding in early April is likely to become more common in the future, which is compatible with the concerns expressed in the IPCC reports. The study also concludes that the carrying capacity of rivers in the haor region has substantially declined over the last few decades due to siltation in riverbeds and landuse changes in the watershed area, which is likely to be responsible for an increase in flood inundation and duration in recent years. This study recommends to increase water carrying capacity of haor rivers through widening and deepening of river channels, especially at Bhairab Bridge outlet point, to accommodate expected surface run-off. Adopting an integrated water-sediment-landuse management plan at watershed scale involving all stakeholders and co-riparian nations is essential for successful solution of flooding problems in the haor region.

1 Introduction

The haors are saucer-shaped large freshwater wetlands in northeastern region of Bangladesh. The haor region in Bangladesh occupies 21,000,00 hectares of land in seven districts (Sylhet, Maulavibazar, Sunamganj, Habignj, Netrokona, Kishoreganj, and Brahmanbaria), out of which 950,000 hectares are cultivated for *boro* rice crop (MoWR 2012). The haor region in Bangladesh experiences flooding on a yearly basis (Figure 1). During most years, the flooding starts in late April to early May and lasts for several months.

Flooding is a natural process and it plays a vital role in maintaining continuous sedimentation process on floodplains, recharging groundwater in aquifer, supporting riverine and wetland ecosystems, fisheries, and is an integral part of haor culture and heritage. Bangladesh currently has two sites designated as Wetlands of International Importance (Ramsar Sites), one of which is Tanguar Haor located on the floodplain of the Surma River. Tanguar Haor is considered as Bangladesh's most important freshwater wetland (https://www.ramsar.org/wetland/bangladesh). Wetlands are considered the "kidney of landscapes" as they perform many ecological functions, including reducing flooding propensity, removing pollutants, improving water quality, and providing habitat to numerous plants and animals (Johnston 1991).

In late March and early April of 2017, four districts in the haor region (Sylhet, Sunamganj, Netrokona, and Kishoreganj) experienced an unprecedented and untimely flooding that caused severe damage to crop, livestock, property, human health, and fisheries (The Daily Star 2017, April 5, 16, 17, 18). Historically, annual flooding caused by monsoonal precipitation occurs during late April-early May of each year; however, excessive rainfall in upper reaches of the watersheds in Meghalaya, India, that replenish the haor region resulted in an untimely flood in 2017 that extended over approximately 7,000 km^2, ruined rice crops and damaged infrastructures, fisheries, and residential property.

As per newspaper reports, 80–90% of the *boro* rice crop was completely destroyed by this early flood. The

target for *boro* rice crop was set at 1,300,000 tons amounting to a market price of TK. 13,000 crores. The haor region produces 18% of the rice crop for the nation (The Daily Kaler Kantha (Bangla) 2017, 8 July). Although not as extensive as was the case in 2017, about 195 km^2 of *boro* crop was affected by hail storm and early flood in 2019 (The Daily Kaler Kantha 2019, 5 April).

Since the damage was caused by an early flood, the two key questions that begs answer are: (i) why did the flood occur so early, and (ii) will similar floods recur in the future? This study attempts to analyze the underlying causes of the early flood and offered recommendations to mitigate future damage stemming out of such disasters.

The causes of floods in a watershed—the area that drains part of rainfall that produces surface run-off to a common river or stream—can be broadly grouped into three categories: (1) the amount and timing of rainfall; (2) the reduction in water carrying capacity of river network, streams, and wetlands; and (3) the reduction of relative elevations of floodplain with respect to riverbed and the mean sea level (Khalequzzaman 1994). The haor flood of 2017 has been explained in light of these three underlying causes.

The major objective of this study was to decipher the trends in rainfall patterns in watersheds that encompass the haor region in Sunamganj, Sylhet, Netrokona, and Kishoreganj districts. The daily rainfall data for a weather station located at Cherapunji (https://www.cherrapunjee.com/daily-weather-data/) revealed that a total of 1262 mm of rain fell during March 28-April 4, 2017, which was 5.5 times greater than the amount of rainfall for the same period in 2016. Based on correlation between rainfall data at Cherapunji and all other weather stations mentioned above, this study concludes that an average of 542 mm of rain fell over an 8-day period, which must have resulted in 3.8 billion m^3 of rainfall. Since the ground was already saturated from previous rainfall event, most of this rainfall must have ended up in low lying areas and rivers in the haor region. The calculated amount of rainfall must have generated an average of 5,497 cumec (cubic meters per second) or 194,000 cusec (cubic feet per second) of surface water flow that must have rolled through the low-lying areas and rivers in the haor region.

2 Analysis Methodology, Results and Discussion

The amount and timing of rainfall: most of the major rivers and streams (Rakti, Wah Umngi, Jadukata, Piyan Gang, Gowain-Dawki, Sari-Goyain, Surma, Lubachara, and Kushiyara Rivers) that drain the flood-affected region in the haor originate in different parts of Meghalaya and Assam states of India. To calculate the amount, timing, and duration of rainfall within the haor watersheds during the flood event is very important for an accurate calculation of run-off. The hourly and daily rainfall data are scarce in the haor watersheds. The monthly rainfall data for five locations (West Garo Hills, West and East Khasi Hills, Cherapunji, and Jaintia Hills) were downloaded from the Indian Meteorological Department (http://www.indiawaterportal.org/met_data/) for the period between 1901–2017. The daily rainfall data for the period of the flood (March 28-April 4, 2017) were downloaded from a private rain gauge station in Cherapunji, Meghalaya (https://www.cherrapunjee.com/daily-weather-data/). The monthly average rainfall data for Sunamganj was downloaded from University of Columbia's public domain for the period of 1951–2007 (https://iridl.ldeo.columbia.edu/maproom/Agriculture/Historical_Monitoring/Bangladesh_Precip.html). Monthly rainfall data were used to establish a correlation between the rainfall in Cherapunji and other five locations mentioned above.

Based on the relationships between monthly rainfall at Cherapunjee and all other five locations established through regression equations, the amount of daily rainfall for those five locations were calculated for the duration of the flood (Figure 2). From Figure 2 we note that the daily rainfall data at Cherapunji revealed that a total of 461.2 mm of rain fell during the last week of March in 2017, which was 5.5 times more for the same time period in 2016. In addition, the rainfall during the period of the flood in 2017 fell continuously, most of which resulted in direct run-off and overwhelmed the carrying capacity of rivers and wetlands in the haor region. The timing and distribution patterns of rainfall are also important. The total amount of rainfall during the month of April in 2016 was greater than that in 2017; yet there was no major floods in 2016 that damaged the crop, because the rainfall pattern in 2016 was different when compared to the rainfall in 2017. In 2016, most of the rain fell during the later part of the month and was not continuous for an extended period as was the case in 2017.

The analysis of rainfall data showed that a total of 3.84 billion m^3 of rain fell over the haor region (approximately 7,000 km^2) in 8 days, which would have resulted in a flow of about 5,497 cumec (194,000 cusec) that must have discharged through the downstream outlet point in the Upper Meghna River at Bhairab Bazar. For comparison, the average maximum discharge of the Kushiyara River at Sheola was recorded at 3,000 cumec in 1983 (Sarkar, Nair, Akter and Hossain 2014). The maximum extent of the flood was confined within the Sylhet Basin that has an aerial extent of 8700 km^2 (Sincavage 2017). The flooded area is comparable in size of the haor region (8238 km^2) that gets flooded on a yearly basis (Sarkar

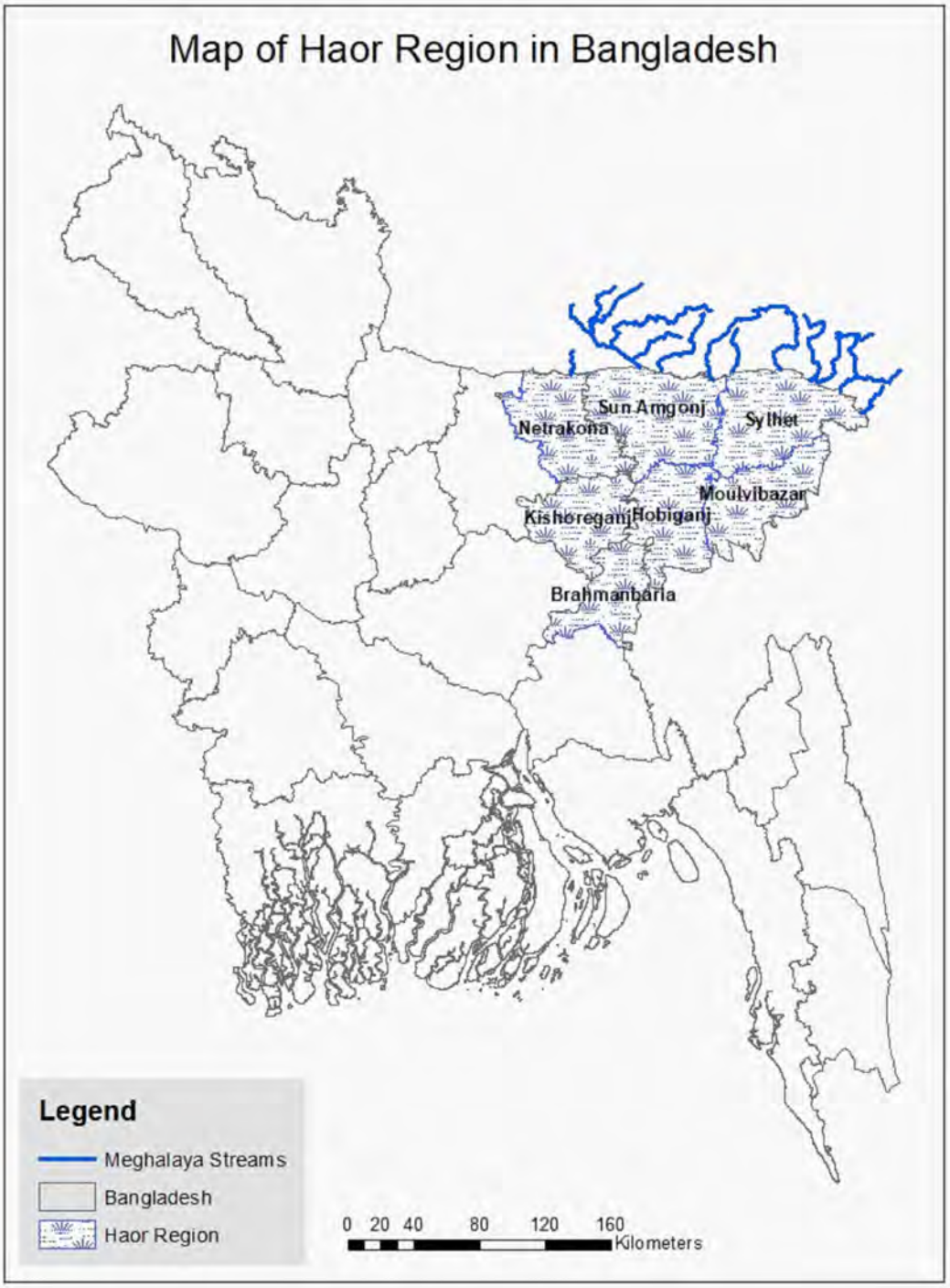


Figure 1: Map showing the haor region and the rivers originating form Meghalaya that drain in the haor region Watersheds of the rivers originating from Meghalaya (India) predominantly experienced flood in 2017.

Inferring Amount of Rainfall for Various Locations during March 28-April 4, 2017 Using the Known Rainfall Data at Cherapunji

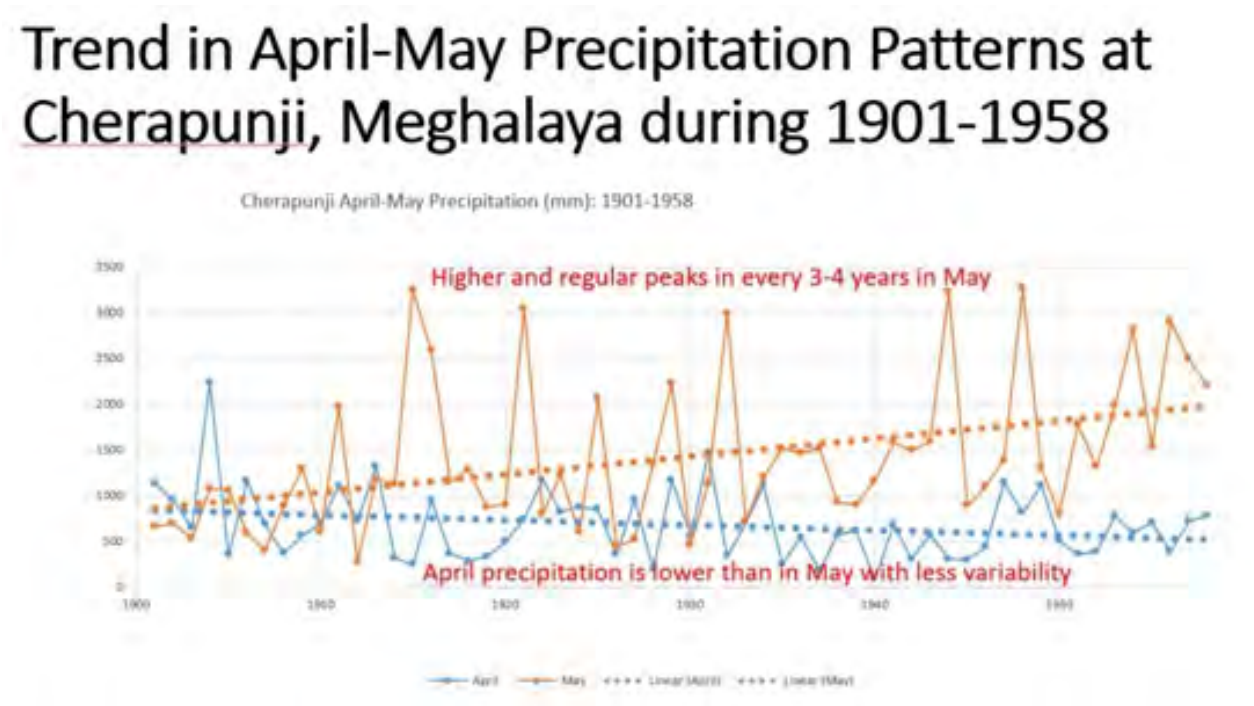
Location	Rainfall (mm)	Relationship to Cherapunji	R^2	Rainfall (inch)
Cherapunji	1262.4	1	1	49.7
West Garo	210.0	Y=0.0908X+95.34	0.28	8.3
West Khasi	341.4	Y=0.2222X+60.85	0.79	13.4
East Khasi	448.1	Y=0.3104X+56.27	0.85	17.6
Jaintia	452.1	Y=0.2937X+81.30	0.72	17.8
Sunamganj	370.7	Y=0.1756X+149.54	0.46	14.6
Average	542.8			21.4
Avg. per day	67.85			2.67
Avg. per hour	2.83			0.33

Figure 2: Relationship between the amount of rainfall at Cherapunji and other five locations within the haor watersheds during the period of flood in 2017. Note that, while Cherapunji received 1262.4 mm of rainfall during the flood period, West Garo, West Khasi, East Khasi, Jaintia, and Sunamganj received 210, 341.4, 448.1, 452.1, and 370.7 mm, respectively.

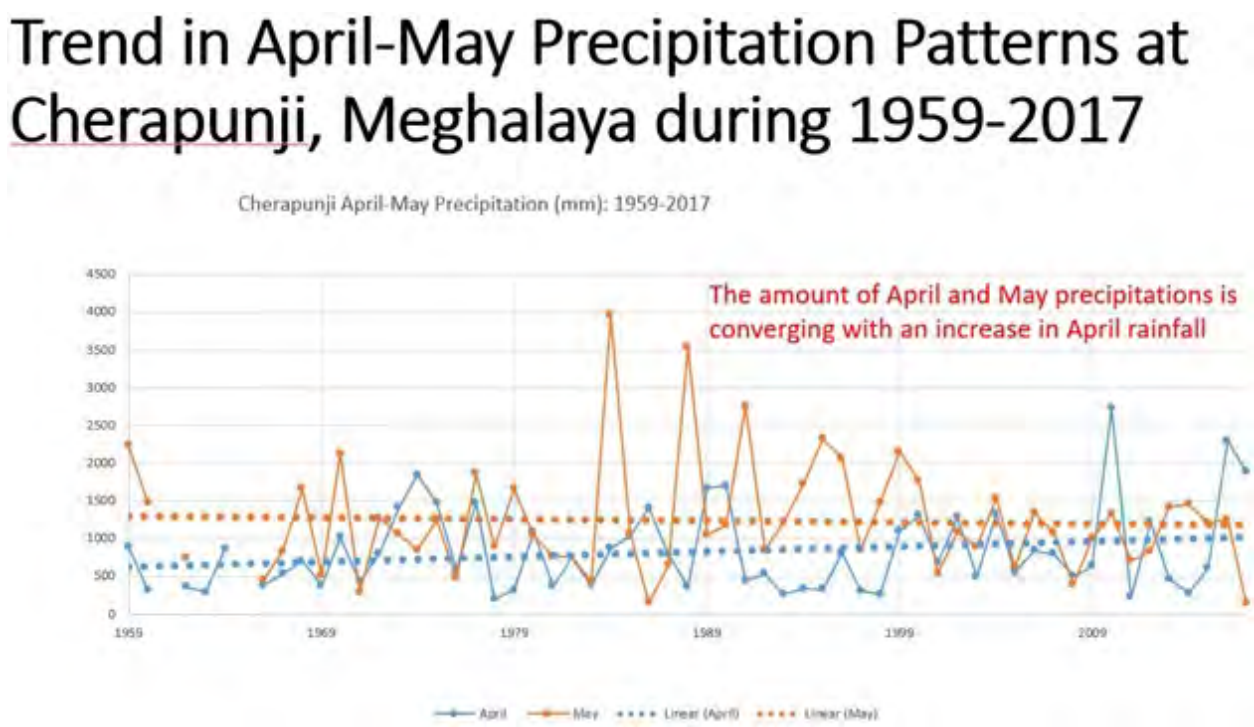
et al. 2014). However, the flood in 2017 occurred earlier than usual. The flood water most likely did not stagnate over the entire haor region with equal depth; part of the flood water must have accumulated over low-lying areas and rivers (10–20% of the flood affected areas), and the other part was discharged through the Meghna River at Bhairab Bazar.

In calculating the amount of surface run-off and river discharge from rainfall, it is important to have hourly data from different parts of a watershed. Rainfall within particular sub-watersheds can influence the run-off and river discharge in the relevant sub-watersheds and in areas downstream of the sub-watersheds. For example, the rainfall at Cherapunji can affect areas near Sunamganj, but will not affect the areas near Chatak or Dowarbazar, or Companyganj, which are located upstream of Sunamganj on the Surma River. On the other hand, the flood water in Sunamganj can affect areas located downstream, such as Bajitpur and Bhairab Bazar. In modeling and predicting occurrences of flood from rainfall at various parts of the haor watersheds, it is important to have detailed rainfall information, as well as soil type, landuse, and slope of each sub-watershed.

Analysis of long-term (1901–2007) monthly averages of rainfall data for the haor watersheds indicated that the rainfall pattern has changed during the last several decades (1950–2017) at East Garo Hills, West and East Khasi, and Cherapunji (which is located within East Khasi Hills watershed). For example, during the earlier decades (1901–1958), the month of May used to receive greater amount of rainfall than the rainfall in April. Also, higher amount of rainfall during the month of May used to have a periodicity of 3–4 years. The total amount of rainfall during May and April was showing an opposite trend with the total amount increasing during May and was decreasing during April during this time period. This trend in rainfall amount and pattern for the months of May and April have reversed during the last several decades (1959–2017) at Cherapunji (Figure 3). A similar trend can also be observed at other locations, except at Jaintia Hills, where the amount of rainfall is on a rise for both April and May over the last 50 years (1952–2002). This means that the amount of rainfall in April is on the rise during recent decades, which indicates that early floods in April may increase in the future. Another study by Mahtab and Convenor (1991) identified an increase in the average annual rainfall in Sylhet region during the period of 1948–1988.



(a)



(b)

Figure 3: The average monthly rainfall data and trend for the month of April and May at Cherapunji during (a) 1901–1958 period and (b) 1959–2017 period. Note that the amount of rainfall is higher for May compared to April for both the periods. During the period 1901–1958, the amount of rainfall in May shows an increase while the amount in April shows a decrease over time. Whereas during the period 1959–2017, the amount of rainfall in May shows a decline while the amount of rainfall for April shows an increase over time.

3 Decline in Water Carrying Capacity and Increase in Flood

Flood is a natural phenomenon by which excess run-off resulting from rainfall is spread on floodplain. As a part of natural variations in the amount of rainfall, most all rivers in the world reach the bankful stage every 2–3 years. As the rainfall data shows, (Figure 3) and has been discussed above, the amount of rainfall used to increase every 3–4 years in the month of April-May in a cyclic manner. Such an increase in rainfall results in higher run-off and river flow in haor region, which causes floods. The rivers in haor region experience normal flood every year, because the amount of rainfall is more than what the rivers in haor watersheds can carry.

However, high velocity in a river during flood can increase its carrying capacity by deepening riverbed or widening its banks through sediment erosion. There exist a natural equilibrium between the amount of flow in a river and its carrying capacity, which is manifested by cross-sectional area of a river. Sauer, Thomas Jr., Stricker and Wilson (1983) formulated the following relationship between the cross-sectional area of a river and its watershed area for North American rivers in mid-Atlantic region where annual rainfall is about 1,000 mm:

Cross-sectional area of a river (ft^2) = 24.8*Area of watershed $(mi^2)^{0.657}$.

Since the haor region receives between 2,500 and 5,500 mm of rainfall annually, it is likely that the average cross-sectional area of a river in the haor region for an equivalent watershed in North America will be 2.5 to 5 times greater. As per this relationship, cross-sectional area, depth, and velocity of a river will increase as it flows downstream to accommodate additional flow resulting from larger watershed area (Figure 4).

Cross-sectional width of all major rivers in the haor region was assessed using Google images for this study. Analysis of satellite images showed that width of the Rakti, Wah Umngi, Jadukata, Piyain Gang, Goyain-Dawki, Sari-Goyain, Surma, Lubachara, and Surma-Kushiyara Rivers narrow as they flow downstream, which is not conducive to carrying flood water as they flow downstream. As a consequence, most all rivers spread on floodplain in haor region during flood season. Flood water carries sediments, which is deposited on floodplain. It is through this sedimentation process that floodplains gain elevations over time and the soil on floodplain is rejuvenated by organic-rich sediments during such flood. In this sense, annual flood cycle is an integral part of haor ecosystem. However, an untimely flood that persists for an extended period of time can cause damage to crop, property, and human well-being.

As a general rule of thumb, the carrying capacity of streams and rivers increases as they flow downstream to accommodate additional surface run-off from tributaries and baseflow fed by groundwater. However, the carrying capacity of the Upper Meghna River—the major conduit of surface water flow in the haor region—is characterized by a decrease in cross-sectional area at the most downstream location at Bhairab Bridge, which is likely to cause drainage congestion in upper reaches of the haor region, resulting in a prolonged waterlogging conditions that prevailed long after the rainfall ended on April 4, 2017.

Analysis of river morphology using Google satellite images indicate that most of the rivers in the haor region have become narrower and shallower over the last few decades. For example, the width of the Jadukata River has decreased by 77% between 2004 and 2017 (Figure 5).

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The reduction in river width and depth results in reduced carrying capacity of rivers, which in turn, increases flooding propensity in a watershed. The reduction in cross-sectional area of rivers can be attributed to siltation of riverbeds caused by increase in soil erosion in the watershed due to changes in landuse practices. Human interference has changed the natural flow patterns in the haor region by constructing embankments along the riverbanks and by building roads across the haor region, which create impediment to natural surface water flow across the haor region. Embankments also constrict flood flow within the rivers and streams, which cause flooding to intensify at downstream region. As a part of implementation of the Master Plan of Haor Area, new roads are being constructed in the haor region from Itna to Austagram in Kishoreganj district, which is likely to interfere with natural flow in the haor region during flood (MoWR 2012). This study recommends to carry out flow simulation model before such roads and embankments are built to assess potential impact of such infrastructures on the natural flow of rivers.

Additionally, unregulated mining in upper reaches of the watersheds, increase in urbanization and agricultural practices are likely to have contributed to an increase in run-off and sediment erosion in watershed areas. Part of the eroded sediments from watershed areas are deposited in riverbeds, resulting in reduction of water carrying ca-

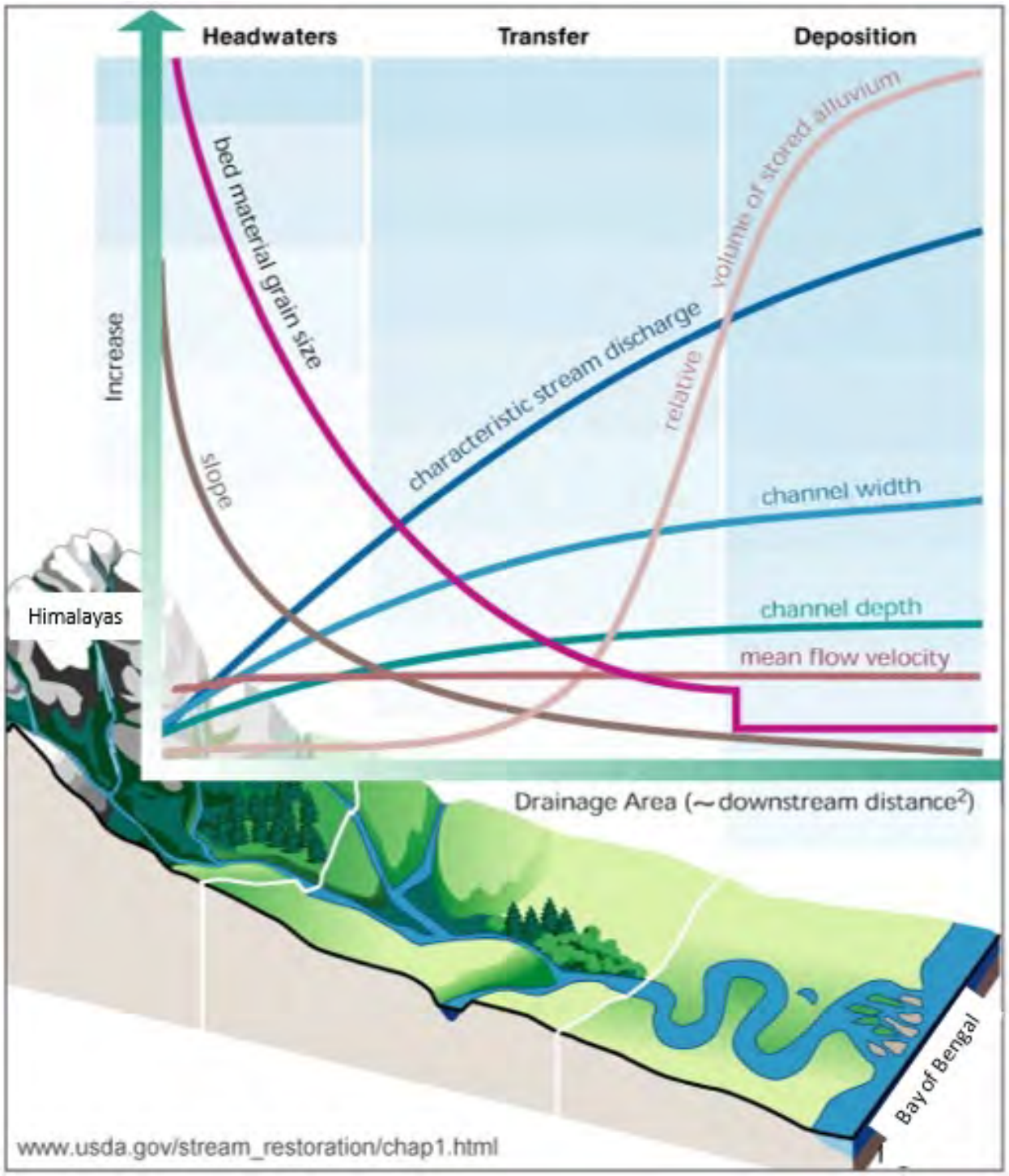

Figure 4: A schematic diagram (modified version) showing increasing channel width of a river flowing downstream as discharge increases. The increase in width from Headwaters through Deposition area is likely to correspond to an increase in depth and thereby increase cross-sectional area (width*depth) of river flowing downstream. Source: https://link.springer.com/chapter/10.1007/978-3-319-73250-3_3

Figure 5: Aerial image showing the changes in width of the Jadukata River between 2004 and 2017. Both of these Goggle images were taken in December. The changes in river morphology and landuse are visible in the images. The sandbars in the river (left panel) are converted to agricultural land (right panel), reducing the carrying capacity of the river.

pacity of rivers and streams. Recent changes in landuse practices can be visually assessed using Goggle images taken in different years.

The rivers in small watersheds in the haor region eventually drain into the Ghorautra-Meghna River system. The width and depth of the Ghorautra-Meghna River was calculated using Google images at various locations along its flow. The results of the calculations are shown in Figure 6. The Google image from 2017 shows that the width of the Meghna River at Kalipur, which is located one kilometer upstream of Bhairab Bridge, is 1,656 meters, but it decreases to 671 meters at the outlet point under the Bhairab Bridge. This is a reduction of width by 785 meters within a short distance.

However, the actual width of the Meghna River at Bhairab Bridge outlet point is less than the measured 671 meters when the widths of multiple pillars from three bridges are taken into account (Figure 7). This drastic reduction in width and carrying capacity of the river at its final discharge point is likely to be responsible for slowing down the discharge of the flow from upper reaches in the haor region, which in turn is likely to prolong the flooding due to congestion in the flow. This study recommends that a detailed survey of elevations along the river and surrounding land area at Bhairab Bridge, hydrography of the river along its course, sediment accumulation patterns upstream of the bridge, water flow simulation model along the main stem of Ghorautra-Meghna River be carried out to determine the water flow characteristics in the river and to assess the impact of three bridges on the flow of the river.

4 Reduction in Land Elevations with Respect to Riverbeds and the Mean Sea Level

The ultimate base level of all rivers is the ocean. If the mean sea level rises with respect to land elevations in a watershed then the river discharge slows down due to decrease in gradient in elevations (Mahtab and Convenor 1991). Damming on a river or drainage congestion in a river can also create a local base level, which can result in slowing down of a river flow due to backwater effect. The Bhairab Bridge is likely to have created a local base level for rivers in the haor region. Control of river flow by constructing dam can drastically change geomorphic characteristics of a river (Skalak, Benthem, Schenk, Hupp, Galloway, Nustad and Wiche 2013). Although the bridges on Meghna River at Bhairab are not dams, they are likely to impact the river flow upstream and geomorphic characteristics (Figure 7). This study recommends to analyze the impact of the three bridges at Bhairab Bazar on river flow in the haor region.

On the other hand, the gradient in elevations between land areas and the mean sea level can decrease if the land elevations in a watershed decreases due to sediment loss from land surface or subsidence of the watershed area (Sincavage 2017). The relative sea level in the Bay of Bengal has been increasing over the last several thousand years and it has been rising at accelerated rates during the last few decades. Some estimates predict relative sea level rise of up to 4 meters in Bangladesh by the year 2050 (Pethick and Oxford 2013). A 4 meter rise in relative sea level will inundate about 40% of the land area, including a large part of the haor region (Gardiner 2014). Additionally, land elevations in the haor region are also decreas-

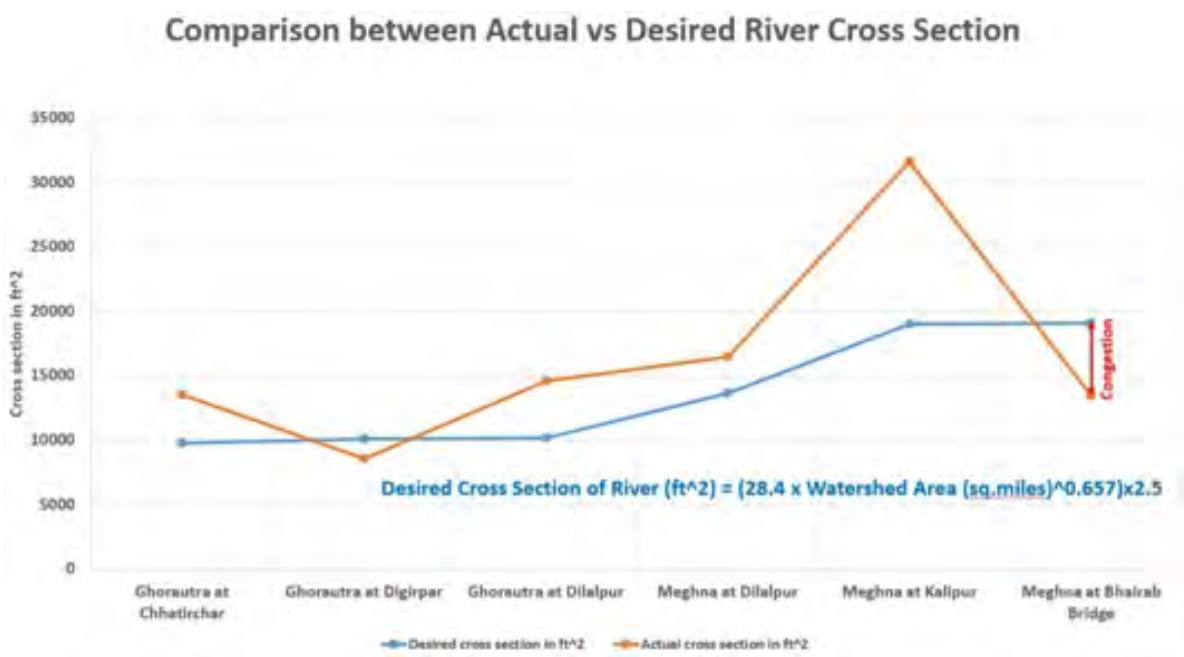

Figure 6: Graph showing changes in the cross-sectional areas of the Ghorautra-Meghna River from upstream (Chatirchar) to downstream (Bhairab Bridge). Note that the reduction in cross-sectional area of the river at the outlet point, which results in congestion in river flow at upstream locations. Such congestion due to narrowing of the river is likely to result in water-logging of flood water in the haor region. The narrowing of the river at Bhairab Bridge is attributed to construction of the railway bridge and two road bridges over the river.

ing due to sediment erosion in watershed areas, as well as subsidence of the greater Sylhet region. Reduction in land elevations and an increase in the mean sea level with respect to land are likely to contribute to an increase in flooding propensity in the haor region.

5 Conclusions and Recommendations

The meteorological data revealed that the timing and intensity of rainfall are changing for the month of April, which is a very crucial month for *boro* rice crop. Moreover, the frequency of early flood will likely increase in the future. It is essential to increase water carrying capacity of rivers in the haor region. A detailed land survey coupled with collection of high resolution digital elevation data can help in planning and managing elevations of land and water bodies in the haor region.

The water carrying capacity of the Meghna River at Bhairab Bridge has substantially reduced due to human interference and infrastructure building on the river. This reduction in cross-sectional area of the river needs to be compensated by increasing the water carrying capacity through capital dredging. A feasibility study to consider the possibility of constructing a bypass or diversion canal at an upstream location on the Meghna River near Kalipur to carry a portion of the discharge to a downstream location in the Meghna River needs to be considered on an urgent basis. It is suggested that a detailed survey of land elevations around Bhairab Bridge, hydrographic survey of water depths along the Meghna River, and a computer simulation of flow patterns along the river be carried out to identify any potential areas along the river that are experiencing flow congestion due to bridge construction and sediment accumulation on the riverbed.

The increase in rainfall in April is in congruence with the IPCC prediction about changes in meteorological processes in the haor region due to climate change (Mirza 2009). It is essential to carry out research to find flood-tolerant rice crop for the haor region. Adjustment in the design, planning, and building of embankments in haor region will be required in the future.

Since 67% of watershed and 56% of flow of the rivers draining the haor region originate outside of the country's territory, it is important that an integrated water, sediment, and landuse management compact be reached with upper riparian countries (MoWR 2012). Bangladesh should ratify the Convention on the Law of the Non-navigational Uses of International Water Courses 1997 (The UN 1997)

Figure 7: Google image showing the Bhairab Bridge on Meghna River and surrounding areas. Note the reduction in width of the river at Bhairab Bridge and widening of the river at upstream location near Kalipur (northeast corner of the image)

and negotiate with other co-riparian nations to adopt the convention.

Scarcity of meteorological data in the haor region is a hindrance to scientific research in water resources planning and management. This study is based on limited monthly rainfall data in the haor watersheds. Therefore, the analyses and conclusions made in this research have limitations. It is recommended that meteorological stations are established in every upazilas in the haor region. The cross-sectional areas of rivers are calculated based on Google Earth images and elevation data. To improve on the quality of the analyses, it is recommended that a land-based survey be carried out to validate the results of this study.

Acknowledgement

This research publication is a partial fulfillment of the sabbatical leave granted by Lock Haven University to the author during the academic year 2019–20.

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Sedimentation Rates Versus Sea-Level Rise at the Bangladesh Coast

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Abstract

After 8,000 years of slow sea-level rise, the onset of rapid climate change during the 20th century has initiated an accelerated rate of sea-level rise. Hence, it is important to know if the current sedimentation rates are enough to counteract the rising sea at the Bangladesh coast. We review a previous work of ours that simulated the effect of sea level rise on the Bangladesh coastline and conclude that we might have underestimated the current sedimentation rates. Based on other recent studies on sedimentation accretion rates at the coast we posit that the current rate of sedimentation in the active and tidally active delta is sufficient to compensate for the sea-level rise for the time being, but will be insufficient in view of future accelerated sea-level rise. Hence, unhindered sedimentation is the most essential component to maintain equilibrium with respect to sea-level rise.

1 Delta Building Process

The creation of the Bengal Delta is due to a natural process that involves erosion, flooding, sedimentation and subsidence after the rise of the Himalayas. In Figure 1, we show the hinge zone that divides the Indian continental craton from the Bengal Foredeep (Reimann 1993). The sedimentation depth increases gradually towards the north and the south of the Rangpur Saddle; the depths are annotated by 5, 10, 15 and 20 kilometer lines. It required more than 20 million years of intense sedimentation, over a deposition area of 100,000 km^2, and up to a depth of 20 km to build the Delta. During this period, the land extended about 500 km south from the Rangpur Saddle that separates the Bengal Foredeep from the Himalayan Foredeep.

The sediment delivery by overbank flooding of rivers is the process through which delta plains maintain their positive elevation above the sea level. Over time the weight of the overlying sediments causes compactification of the underlying sediments through pore collapse that involves mechanical grain reorganization and water expulsion. In addition to this process of compaction further subsidence may occur due to the tectonic shifting of the underlying ocean crust and anthropogenic water withdrawal. The subsidence of the land allows floods to occur and fresh layers of sediment to be laid down; this mechanism keeps the delta plain always very close to the sea-level height even when deltas prograde.

If we consider the wet bulk density of sediment with 50% mud content to be 1.55 gm/cm^3 (Flemming and Delafontaine 2000), then we would need about 3.1 x 10^{15} tons of sediment, without compactification, to fill this area to a depth of 20 km. However, with compactification, the numbers could be three times higher. If we naively assume a 1 billion tons per year sediment flow during this entire time, it would require only 9.2 million years to fill up the basin. However, a vast amount of sediment is transported through the Bay of Bengal to the deep ocean to make the Bengal Fan, the largest submarine fan on Earth. The fan is about 3,000 km in length and 1,430 km wide. If we consider the average thickness of the fan to be 5 km, then with our above approach, it would have taken about 50 million years for the Fan to be formed. This time period is not incompatible with the postulated time of the first deposition of the Fan during the Lower Eocene (~50 million years ago), shortly after the initial collision of the Indian plate with the Eurasian Plate (Curray, Emmel and Moore 2002).

About 18,000 years ago, during the Last Glacial Maximum, the Bengal coastline was situated about a couple of hundred kilometers south of the modern coastline (Bhattacharya and Fraczek 2011). Since then, the land has been submerged to the sea that rose to a height of about 120 meters. After a series of transgression and regression, the modern Bengal Delta started to emerge about 7,000 years ago. This time is not in disagreement with the mean initiation time of the world's deltas which is from about 8,500 to 6,500 years before present (Stanley and Warne

Figure 1: The hinge zone divides the Indian continental craton from the Bengal Foredeep (from Reimann 1993). The sedimentation depth increases gradually towards the north and the south of the Rangpur Saddle. The depths are annotated by 5, 10, 15 and 20 kilometer lines.

1994). On the other hand, the avulsion timescale of the major rivers in the Bengal Delta is about 2,000 years (Reitz, M. D. et al. 2015). It means a river like the Brahmaputra would fill its basin, with an extension of 150 km to 200 km, within a few thousand years before changing its course. Furthermore, within the last 9,000 years, the delta received, on average, about 33 m of vertical sediment deposition, of which only 6 m was deposited over the last 7,000 years (Bhattacharya and Fraczek 2011). The sudden decrease in the sedimentation rates is commensurate with the decrease in the sea-level increase at about 8,000 years ago (Figure 2).

Currently, based on tide-gauge and space altimetry data, the estimated global average sea-level rise rate is about 3.1 mm/yr with an acceleration of 0.1 mm/yr (WCRP—The World Climate Research Program 2018). Another study reaffirms these numbers for the Indo-Pacific region (Dangendorf, S. et al. 2019). The acceleration is expected to rise and some studies estimate the global coastline will experience about 0.8 m or higher of sea-level increase by 2100 (Pfeffer, W. T. et al. 2008). However, (Brammer 2014) noted that it is important to account for the diversity and dynamic nature of the physical geography of Bangladesh's coastal area to mitigate effects of any sea-level rise.

In terms of its sediment budget, investigators more or less agree that the current sediment flow through Bangladesh is about $1x10^9$ tons per year (Wasson 2003). Of this about 40% is deposited in the delta plain, 45% in the sub-aqueous delta and 15% in the deep sea, including the Bengal Fan (Wasson 2003). However, we think this number needs to be reassessed in light of the accelerated sediment accretion in the Meghna estuary (Hassan, Abu Syed and Mamnun 2017).

2 Effect of Sea-level Rise: A Simulation

To correctly estimate the effects of the sea-level rise on the Bengal Delta, one can construct a scenario that includes sedimentology, radioactive isotope dating techniques, sequence stratigraphic analysis, and numerical modeling for water and sediment transport. However, using the deduced past surface and sedimentation rates from the borehole data, one can simulate the margin of the advancing sea and the creation of the modern delta from a simple model (Bhattacharya and Fraczek 2011). For the current baseline elevation, a corrected digital elevation model (DEM) dataset produced by NASA's Shuttle Radar Topography Mission (SRTM) can be employed.

Based on an estimate of 10^9 tons of sediment/yr flowing through the Bangladesh Delta, we derived a spatially differentiated sedimentation rate of 3.1 mm/yr in the coastal area and 1.5 mm/yr elsewhere (Bhattacharya and Fraczek 2011). These numbers match the global sedimentation rates over a 100 to 1000-year accumulation time period (Sadler 1981). A conservative estimate of 1 mm/yr subsidence was used across all areas. Recent estimates, however, indicate the subsidence rates are much higher than what we assumed (Reitz, M. D. et al. 2015). In Figure 3, we show one example of our simulation where, about 9,000 years before present, the sea transgressed all the way to the current position of Dhaka. This transgression has allowed for the new deposition to be made resulting in the modern Bengal Delta. Extending our simulation to a hypothetical case of a 2 to 3 m sea-level rise during the 21st century we find 14.4% of the Bangladesh land area submerged (Figure 4).

However, the high sediment accretion that has currently been seen at the Meghna estuary is not seen in the simulation. This is expected as this model did not take into account sudden incursion of sedimentation due to upstream upheavals. It is postulated that over the last 7,000 years or so, the Bengal Delta has prograded with a mean accretion rate of ~5 km^2/yr (Allison 1998). It is to be assumed that this number does not reflect sudden bursts of intense progradation and erosion that might have occurred throughout this long period. A number of studies, using historical charts and satellite images showed that at the lower eastern delta mouth sediment accreted at an average rate of ~5–10 km^2/yr during the period 1776–1996 (see Sarker and Thorne 2006, and references therein). The average accretion rate was found to have increased to 18.9 km^2/yr during 1973–2000. Sarker and Thorne (2006) have postulated that the increased rate of sediment accretion during the late 20th century at the Meghna estuary could be due to the Assam earthquake of 1950 and intensive land utilization, including farming and restriction of sediment deposition due to embankments.

Mathur (1953) has estimated that, during the 1950 earthquake the landslide earth volume was 45 x 10^9 m^3. Sarker and Thorne (2006) deduced that the crest of the sediment wave, due this earthquake, bearing the coarser grains, passed through the lower Meghna estuary channels during 1980s that resulted in large land accretion. After the passing of the sediment wave the accretion rate fell to ~10 km^2/yr during the period 1996–2008, but this lower rate is still double the historic accretion rate; this is attributed to enhanced agricultural practices and restriction of sediment distribution on the mainland due to embankments.

However, using a slightly different methodology and covering the entire coastal zone, the net rate of erosion/accretion was found to be –75.1 km^2/yr (2000–2008) and +84.1 km^2/yr (2008–2016) (Hassan et al. 2017). These authors also found that the average net accretion rate was

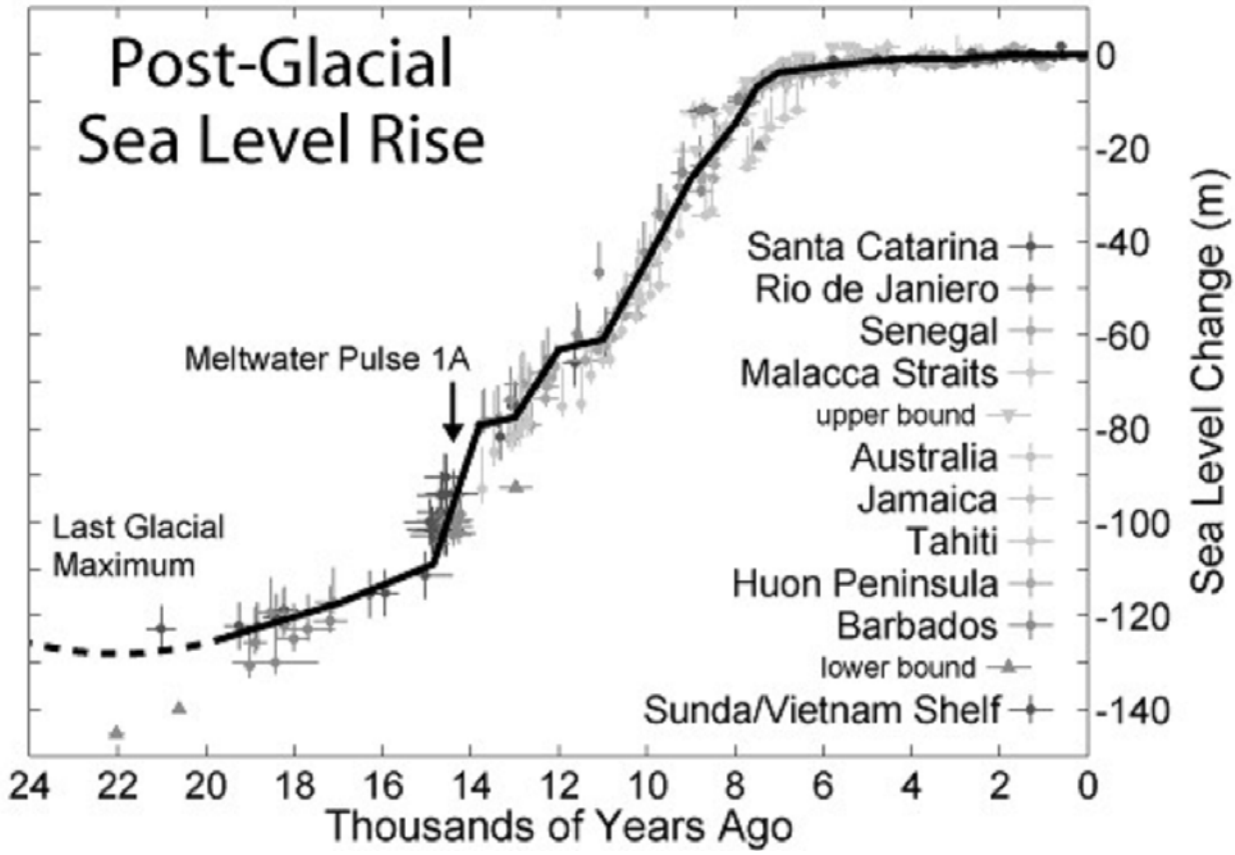

Figure 2: The sea level rose about 120 m over the last 18,000 years. Approximately 8,000 years ago, the rate of rise stabilized to about 1 mm/yr. However, in recent years, the rate is estimated to have increased to 3.5 mm/yr (figure courtesy of Wikimedia Commons)

31.8 km^2/yr during the period 1973–2016. A study on the total area and volume of earthquake-triggered landslide estimates the Assam landslide volume to be 2 x 10^9 m^3 (Marc, O. et al. 2014) instead of 45 x 10^9 m^3 (or 45 km^3). Mathur's (1953) 45 km^3 number seems to be an overestimate as the largest landslide volumes due to earthquakes tend to be about or less than 1 km^3. Indeed, 45 km^3 of material could provide almost 35 years of nominal 10^9 tonnes/yr sediment supply if the bulk sediment density is 1.3 g cm^{-3} (Allison and Kepple 2001).

Still, a 2 km^3 of volume is substantial. It is not clear, however, if the Assam earthquake was the only source of increased sediment accretion during the period 1973–2000. If we are to assume the Assam earthquake's landslide volume was overestimated, but still had substantial effect on the accretion rates, we have reasons to expect that the other earthquakes in the region would have similar effects. The landslide volume of the 2015 Nepal earthquake is 0.88 x 10^9 m^3 (Roback, K. et al. 2018) which also could have effects on the sedimentation rates. Hassan et al. (2017) mention a series of severe earthquakes (1950, 1963, 1999, 2005 and 2015) in Nepal, India and Tibetan Plateau in addition to severe floods in 1974, 1987, 1988, 1998, 2004 and 2007 when a substantial portion of Bangladesh was inundated. It is argued that the combined effects of earthquakes and floods are the primary causes of the enhanced accretion process in the late 20th and early 21st century.

The image in Figure 5 shows the change in coastal geography over a 20-year period. A smoothed coastal bathymetry image made for the same region shows compatibility with the accretion seen in Figure 6.

This map indicates intense sedimentation process in the white and grey areas. Notice almost no sedimentation in the western delta. The original bathymetry data had a resolution of 3 km, resampled and smoothed to 1 km in the figure.

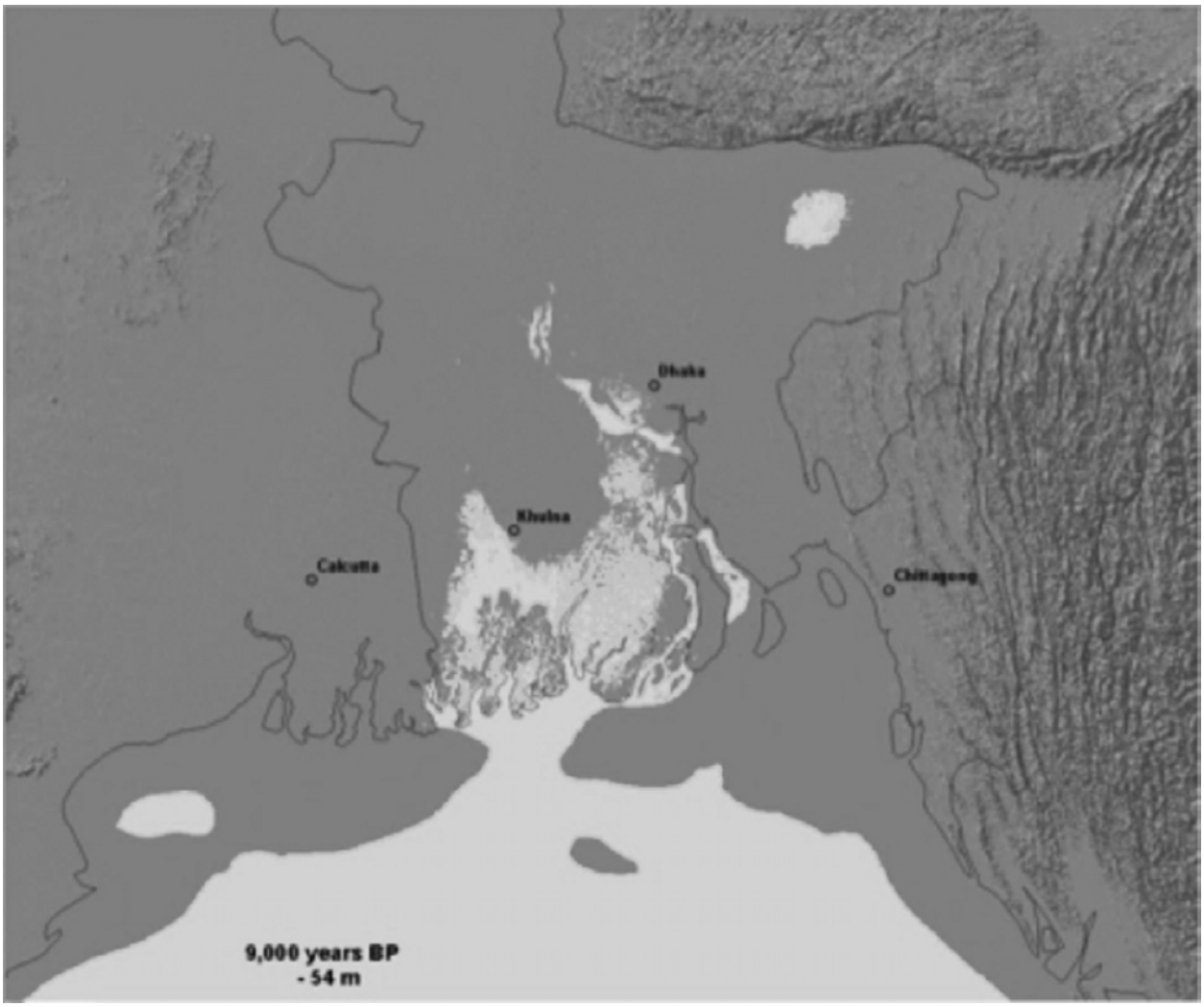

Figure 3: A model showing the sea transgression into the land 9,000 years before present (Bhattacharya and Fraczek 2011). This allowed new deposition to be made, resulting in the modern Bengal Delta. The white areas indicate the sea transgression inland.

3 Need to Reassess Sedimentation Rates

The difference between our model output and observations show that the sedimentation rates need to be reassessed across the delta, especially at the coastal areas. It is possible that the sedimentation rates that we assumed are correct on a millennium scale (1000 years), but not correct on a 100-year scale. We know that the pulsed sediments in the fluvial delta could reach rates of 8 cm/yr or higher (Rogers 2012). The Sadler plot, shown in Figure 7, attests that the delta could receive over 1 cm/yr of sediment over a time interval of 100 years.

A combined analysis of direct sedimentation measurements and short-lived radionuclides from the fluvial delta west of the Meghna estuary show that transport processes and lateral sedimentation are highly variable across the delta (Rogers and Overeem 2017). These authors derived sediment accumulation values from the seasonal flood pulse using Be-7, a short-lived cosmogenic fallout radioisotope (half-life = 53.3 days) and Pb-210 (half-life = 22.3 years). Pb-210 is a naturally occurring end-product of the U-238 decay series and is effective for identifying fluvial sediments deposited in near shore environments within the last 100 years. They found that the overall aggradation rates average 2.3 cm y^{-1} in the flood plains of the lower central delta, west of the Meghna estuary and east of the Sundarbans, which is more than double the estimated average rate of local sea-level rise (~1 cm/yr). Even with a subsidence rates of up to 1.8 cm/yr, they conclude that "mean accumulation is more than sufficient for

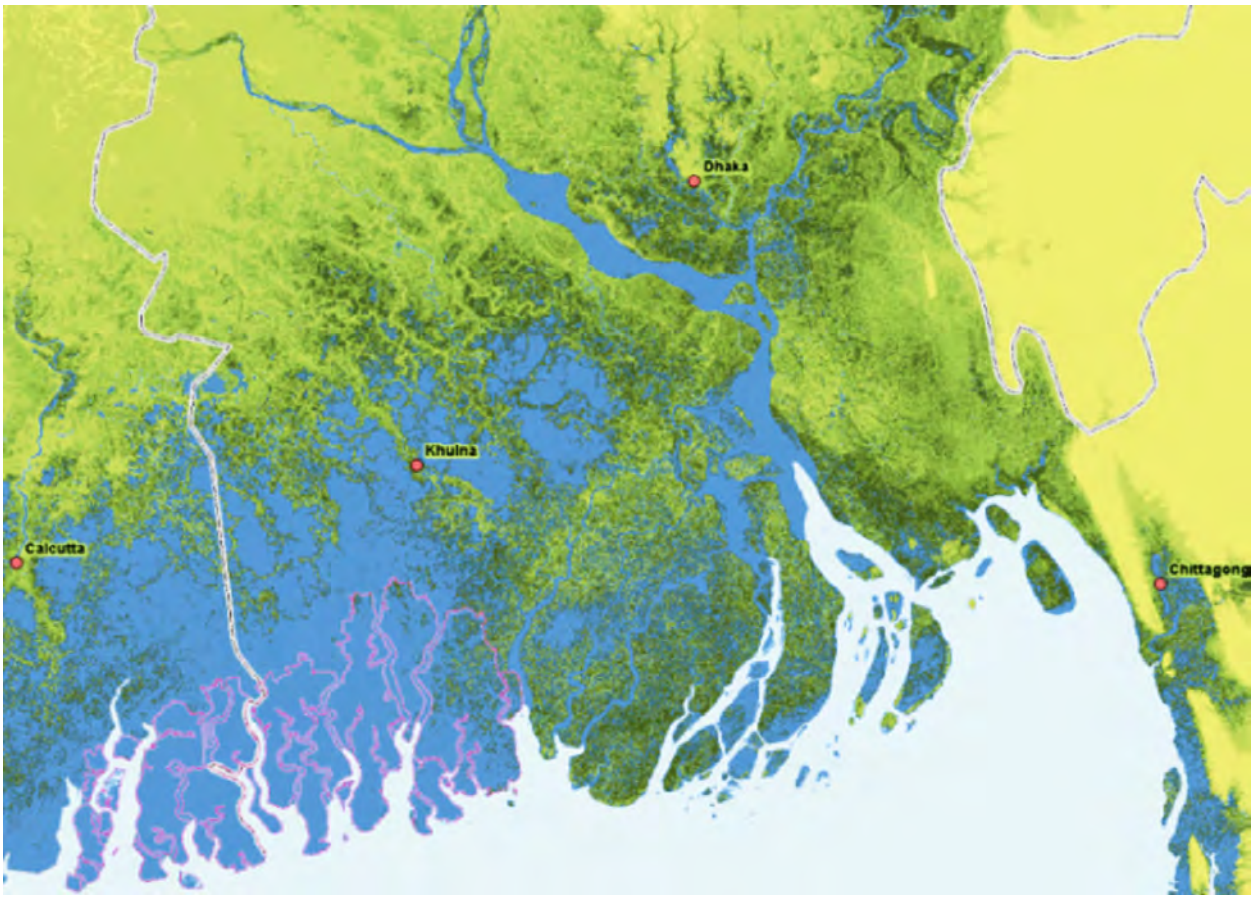

Figure 4: Extending our simulation to a hypothetical scene of a 2 to 3 m sea-level rise, we find 14.4% of the Bangladesh land area submerged (Bhattacharya and Fraczek 2011).

reducing the risk of coastal flooding in the central lower Bengal Delta." The results are not in contradiction with Allison and Kepple (2001), who, based on vibracores and auger samples collected from the lower tidal delta plain, found that the sediment accumulation is taking place on decadal and millennial time scales at rates reaching 1.1 cm/yr. Rogers (2012) asserts that the overall accretion rate in the Sundarbans, west of the lower active delta, is 1.0 ±0.87 cm/yr and suggests that vertical sedimentation is generally in equilibrium with average rates of relative sea-level rise.

A previous analysis by Auerbach, L. W. et al. (2015) showed that islands in southwest Bangladesh, enclosed by embankments in the 1960s, have lost 1.0–1.5m of elevation over a period of 50 years, whereas the neighboring Sundarban mangrove forest has remained comparatively stable. They write, "We attribute this elevation loss to interruption of sedimentation inside the embankments, combined with accelerated compaction, removal of forest biomass, and a regionally increased tidal range." They note that after the embankments of several large islands failed during Cyclone Aila in 2009, the newly reconnected landscape received tens of centimeters of tidally deposited sediment, equivalent to decades' worth of normal sedimentation. Sarker, M. H. et al. (2011), based on the land accretion rates in the Meghna estuary, note that, "For the predicted rate of sea-level rise, for example 60–100 cm in the next 100 years, transgression of the sea in the Meghna estuary is not expected. In this situation, the rate of vertical accretion in the estuary would keep pace with the sea-level rise. However, polder areas within the tidal and estuarine plains will not get any benefit from further sediment input from upstream unless a method of planned and effective sediment injection into the polders is adopted."

Nevertheless, many experts have expressed doubt that the amount of sediment flux that currently reaches coastal areas is not enough to keep pace with rising sea level (Khalequzzaman 2015). They recommend extensive data collection on sedimentation, subsidence, river flow parameters and sea level in order to establish the sedimentation variability pattern to cope with the sea-level rise. Given the variable nature of the sedimentation rates

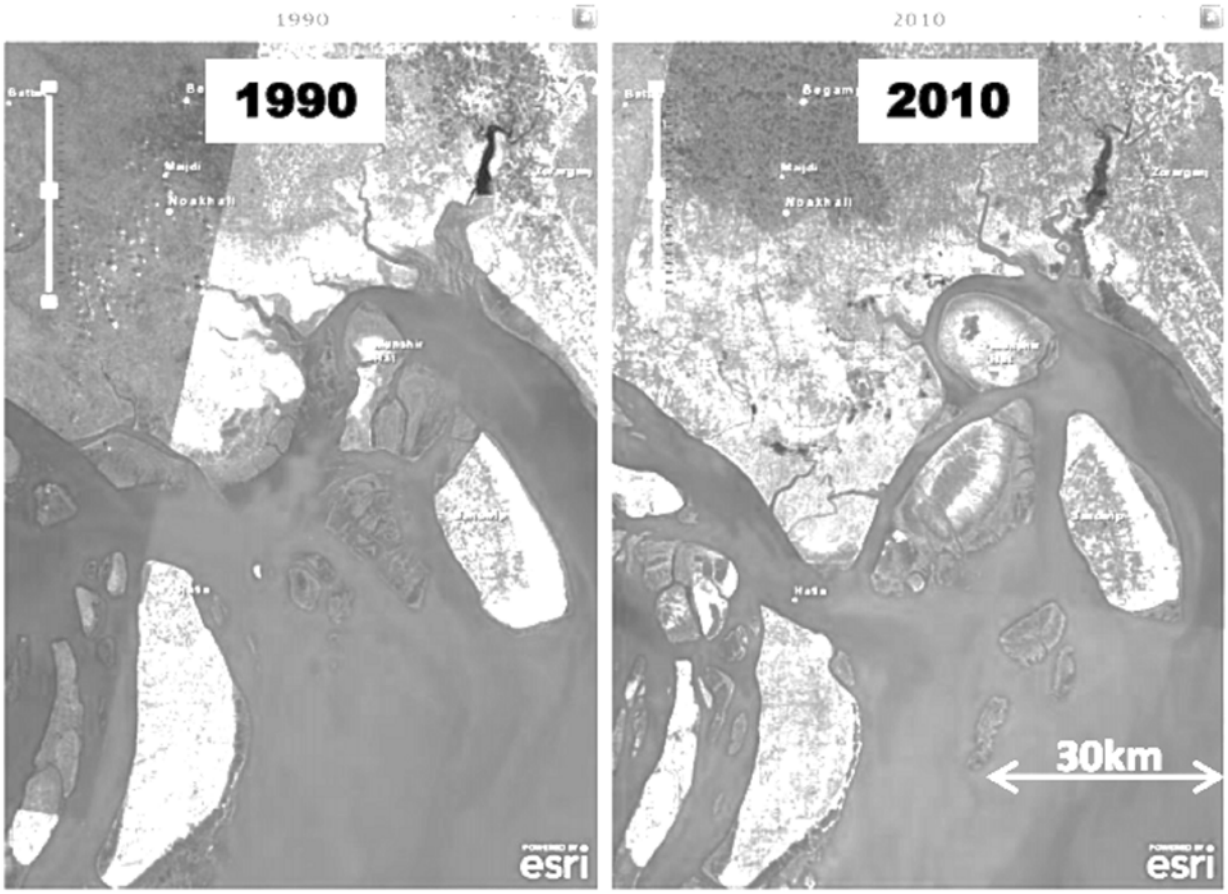

Figure 5: The net land accretion is visible in the Bangladesh coastline (Rana 2012).

(Sadler 1981) and predicted future sea-level rates, the current sedimentation rates may not be sufficient to counteract the effects of the sea-level rise in the near future. In light of this, it is essential that man-made structures upstream do not impede the sediment flow to the active delta that is still being formed in Bangladesh.

4 Bangladesh Delta Plan 2100

The Bangladesh Delta Plan 2100 (BDP) (General Economics Division (GED), Bangladesh Planning Commission 2019), with input from the Dutch government and specialists, introduces an Adaptive Delta Management (ADM) plan that aims to implement a holistic approach to support water governance, planning and implementation. Among other issues, the plan details (i) the socio-economic characteristics and poverty profile of sensitive ecological hotspots, (ii) sustainable land use and the managing of water resources in changing climate scenarios; and (iii) the creation of a knowledge base for monitoring and evaluating the current situation, as well as for designing and implementing future plans. Although lacking in specifics, the plan, nonetheless, entails some ambitious technological designs, for example, (i) a network of large barrages on the two main rivers of the country in order to facilitate an even water distribution system, (ii) regulated inland and coastal polder systems that would use renewable energy to maintain water levels and regular sedimentation; and (iii) the development of flood-free polders located inside stable chars/sandbanks or alongside the rivers, connected with long bridges.

The idea of a futuristic plan that extends to the year 2050—and even beyond, to 2100—that aims to implement an adaptive approach is a laudable effort. However, the philosophy of building large scale structures in the raw, dynamic delta of Bangladesh, in many ways unlike the deltaic conditions in the Netherlands, needs a closer look. Large barrages across mighty rivers like the Padma and Jamuna would become sediment traps and thus likely to increase the risk of flood in the upstream locations. The sediment-starved land within the coastal and inland polders suffers significantly from subsidence, and simply try-

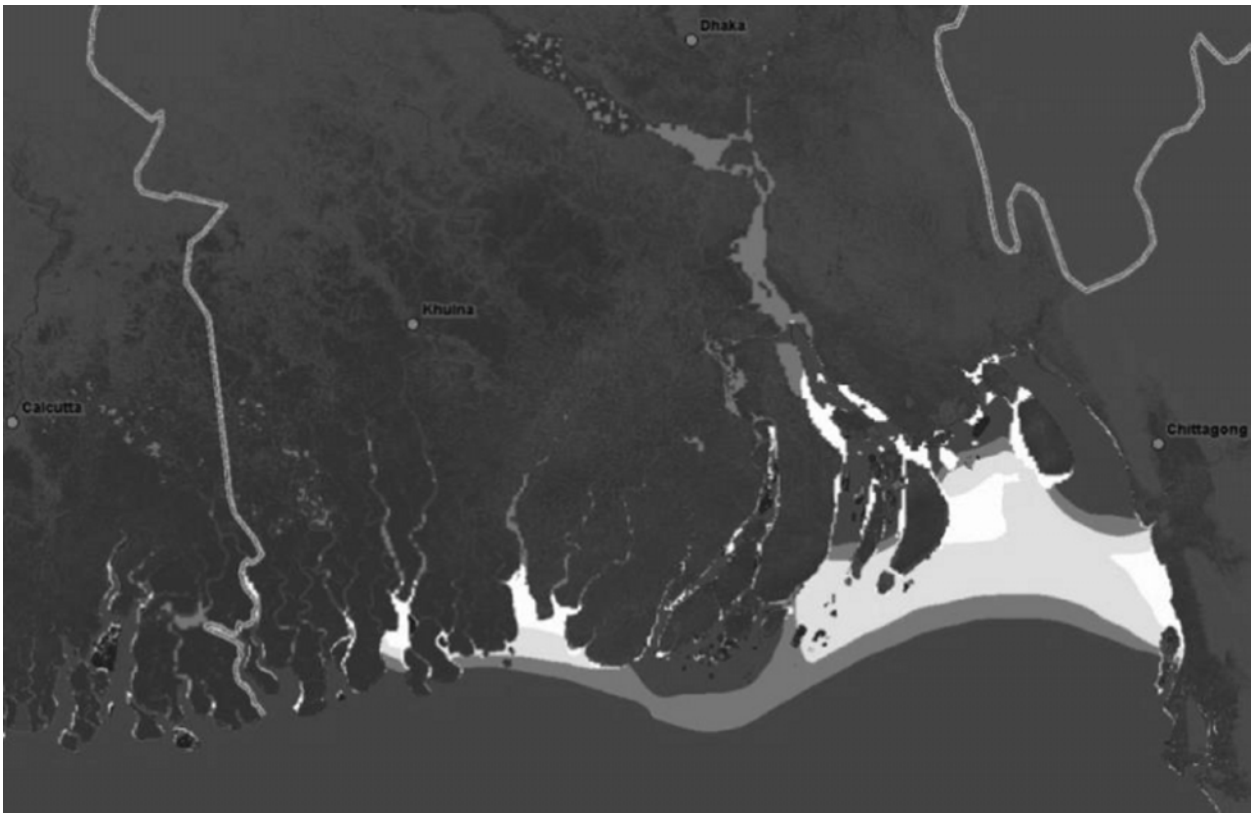

Figure 6: Coastal Bathymetry (Fraczek 2011): white (-1 m), grey (-2 m), and darker grey (-3 m). The darkest color indicates waters deeper than 3 meters.

ing to transform the existing polders—in face of sea-lever rise—may not solve the issue. If we have learned anything from the experience of 60 years of riverbank protection, river training has yielded mixed results and poldering of the chars is not a viable option.

5 Conclusion

The sedimentation rates on a 100-year timescale are possibly higher than the rates seen for a 100- to 1000-year timescale. Instead of 3.5 mm/yr sedimentation for the coastal area, as used in our model, recent works indicate that the rates could be as high as 2 cm/yr. Several investigations have already proven that, given unhindered sedimentation rates, the Bangladesh coastline could keep up with the current sea-level rise; however, man-made structures upstream are bound to decrease the sedimentation rate. It is our opinion that large-scale structures are not the solution for the long-term sustainability of the Bengal Delta in the era of climate change. With the dynamic fluvial conditions that are present in the Delta, with intense subsidence, such structures would result in further inundation, in addition to impending the sediment flow needed to compensate for the sea-level rise. In order to counter the rising sea level and retain the stability of the Delta, we need to assure that the sediment supply remains unhindered across the Delta. To help with this goal it is imperative that a proper sedimentation model is built for the entire Delta.

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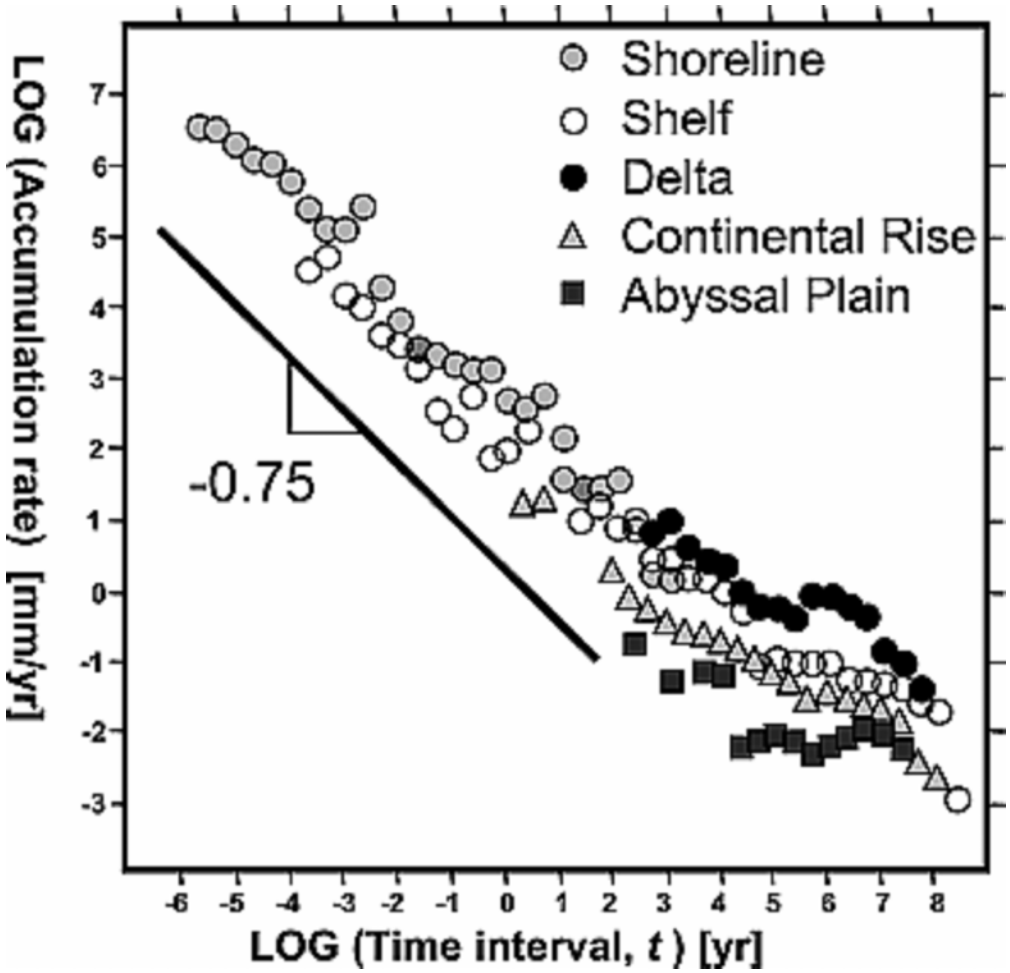

Figure 7: Representative "Sadler plot" shows sediment accumulation rates as a function of measurement interval for siliciclastic shelf deposits (Schumer and Jerolmack 2009).

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Bangladesh Energy/Climate Nexus Part I Quest for Energy Fix and a Trailblazing Rural/Household Energy Sector

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Abstract

Bangladesh, at cross-hairs of the world's twin mega challenges, growing energy demand and fossil fuel-driven climate change, faces a conundrum as she seeks access to modern energy systems to augment her extraordinary economic growth of the past decade. Advances in the rural/household sector, encompassing the majority of the population and typically reliant on traditional fuels, are based on a unique combination of off-grid solar home systems for lighting and improved cook stoves for cleaner cooking, and heating, with significant domestic technology, innovation, and entrepreneurial contents. For the urban/industrial/commercial sector, currently based primarily on the country's dwindling gas reserve, energy planners have adopted the classical centralized generation and distribution system common in the West, with two seemingly contradictory approaches, reliance on imported coal and liquefied natural gas proffered for a rapid economic expansion, and utility-scale, 'clean' electricity generation with a smattering of nuclear plants and solar farms in order to meet the country's commitment to the Paris climate treaty. Both approaches rely on external technology, expertise, and concepts.

The paper gives a historic perspective on the country's often painful and environmentally damaging efforts to augment her meagre access to modern energy resources mainly for the urban/industrial/commercial energy sector, provides an overview of energy growth plans for this sector, and describes the remarkable progress in the hitherto neglected rural/household sector. The paper then notes, how the lessons from the historical perspective and the experience in the rural/household energy sector taken together, can inform development of a unique homegrown approach for the urban/industrial/commercial energy sector to fit the country's economic aspirations, terrain and, societal needs, instead of the current approach being pursued.

1 Introduction

Humanity faces two extraordinary challenges, the ability to provide sufficient energy resources for worldwide economic growth and mitigate the adverse impact of global climate change that is primarily blamed on use of fossil fuels as energy sources. These fuels have been instrumental in the rise of the 'developed' world and are now driving the growth in rapidly emerging economies. Bangladesh is at the nexus of this conundrum. The country needs massive amounts of energy to lift her millions out of poverty but does not have an unencumbered access to modern energy systems. On the other hand, despite her low carbon footprint, the country is facing the brunt of global climate change with more devastating floods and a potentially rising sea-level that could submerge a significant part of the country's coastal regions, possibly creating millions of climate refugees. This poses two major questions: 1) What are Bangladesh's energy options for the future and 2) how can the country cope with the impact of climate change? In this paper we primarily examine the first question and comment briefly on the second.

Despite the challenges noted, Bangladesh has made significant strides in achieving her Millennium Development Goals that ran through 2015. For the last two decades, the gross domestic product (GDP) has grown between 5% and 7% per year and a greater growth rate is envisioned. However, often the actual growth rate did fall behind somewhat compared to that projected by the Country's Five-year Plans due to a variety of reasons. Among others, lack of availability of sufficient and reliable power appears to be one.

There has been much discussion on Bangladesh's energy needs ever since the country won her war of independence in 1971. One study by the Energy Panel of Bangladesh Environmental Network (BEN) had assessed

the country's energy landscape and made a broad set of recommendations encompassing suitable energy source options, organizational needs, funding, and domestic expertise growth (BEN 2007)[1]. Some of the recommendations of the BEN study are summarized in **Appendix A**. One major common perspective between the BEN study and other studies such as the by Japan International Cooperation Agency (JICA) developed Power Supply Master Plans (PSMP 2016) is the need for a comprehensive, integrated energy policy in Bangladesh; current efforts appear fragmented.

In order to better understand the energy path for Bangladesh, it should be recognized that the country has two major energy sectors, rural/household and urban/industrial/commercial, with an evolving mix (Badruzzaman 2015). In the rural/household sector, the country was heavily reliant on biomass-based cook stoves for cooking and boiling water, while for lighting, kerosene lamps and oil-based lanterns have been the mainstay. Electricity, needed for its rudimentary industrial/commercial sector and small urban population, was generated using a few thermal power stations.

However, since the 1960's, much has happened in Bangladesh's energy production. These include construction of the country's only hydroelectric power station in 1962, introduction of improved cook stoves designed in the laboratories of Bangladesh Council of Scientific and Industrial Research (BCSIR) in the 1980's, a major expansion in gas production through the late 1990's, an ongoing installation of solar home systems and solar irrigation systems in rural areas mostly by non-governmental organizations (NGO's) starting in 2000–2010 time frame (IDCOL 2018), and the current government's Power Supply Master Plans (PSMP) to generate large amounts of electricity (PSMP 2010–2011; 2016).

The PSMP's propose construction of several coal-fired plants, at least two nuclear plants, importation of liquefied natural gas (LNG) for gas-fired plants, and at a least a couple of solar parks or farms. In addition, nearly 300 MWe off-grid solar electricity capacity has been added (SREDA 2019). After an inexplicable slowdown of several years, the current government is considering renewal of gas exploration (GSMP 2018). Rural electrification has been a major endeavor of successive governments (Chowdhury 2009) and the government recently announced achievement of a 90% electrification country-wide (Prothom Alo 2018).

Thus, much progress has been made, and on paper, the country has a number promising options for energy generation for the next several years. However, some of the choices being exercised have raised concerns. In the current and companion papers, we examine the various choices being considered or developed and their potential impact. As with many developing countries, energy resource access and utilization have been challenging for Bangladesh, compounded by the complexities of evolving energy source choices over time, attendant economics, and associated policy decisions. The policy decisions have often been at the behest of external 'experts' who are not always conversant with the country's economic, technological, and societal perspectives. Foreign interests, from time to time, have compounded the energy and resource challenges in the developing world (War on Want 2016), and as we will see, Bangladesh has not been an exception to this.

Furthermore, climate change concerns have raised serious doubts about the wisdom of continued growth in use of green-house gas (GHG)-generating fossil fuels, which however, currently appear to offer the least expensive and quickest way to meet power needs for economic growth in the developing world, especially in Bangladesh. This presents the country with a dilemma. GHG-free energy sources, such as solar and wind, are either at their infancy or those such as conventional nuclear are extremely expensive, or potentially very risky. Here too external entities and interests appear to be present both in the pro- and anti-fossil fuel conversation and the associated 'clean' energy projects currently being developed.

Thus, before we discuss Bangladesh energy state and options, it would be worthwhile to briefly note the country's major and evolving energy sectors and review, from a historical perspective, how we arrived at the current state of energy to put context to the discussion that follows. Each major energy option brought online to date has caused a challenge and often an immitigable price to pay. It will be important to be cognizant of these perspectives as we examine the future.

2 Bangladesh Dual Energy Sectors

As mentioned above, Bangladesh continues to have two broadly distinct energy sectors with an evolving mix. The rural/household sector still encompasses the majority of the people and has been reliant on disease-causing biomass stoves for cooking and heating, and risky kerosene lamps for lighting. The urban/ industrial/commercial sector is mainly reliant on electrical power. Absence of reliable electricity had adversely impacted economic growth and led to frequent load-shedding. Efforts at improving both sectors have been underway, but with distinctly different characteristics. We provide a brief historical perspective on these developments, from the early days to about 2000, when novel energy options became more prevalent.

3 Bangladesh's Energy Journey: A survey

3.1 History of Rural/household Energy Sector

This sector had not received significant attention from policy planners till recently. In 2004, rural energy sources for cooking and heating were firewood (44%), crop residues (25%), dung (17%), and tree leaves (15%); electricity constituted only one percent of the total energy use (Asaduzzaman, Barnes and Khandker 2009). Efforts began after independence under a variety of entities to alleviate the burden of cooking with biomass by replacing traditional biomass stoves for cooking. Improved cook stoves (ICS) with much better combustion efficiency offered the promise of increasing the fuel utilization to approximately 30–50% from 10% in traditional stoves in developing countries for cooking and heating. This would reduce indoor air pollution, fuel requirement, and deforestation. In 2016, worldwide 3.8 million people, mostly women and children, died from indoor air pollution; nearly 50,000 were in Bangladesh (WHO 2016).

ICS programs got underway in Bangladesh in the early 1980's with a BCSIR program to design and disseminate improved stoves, mainly in rural areas. It was a government-subsidized program with multiple governmental entities involved. By 2000, over 300,000 ICS had been disseminated in Bangladesh. However, the program faced serious challenges, one of them being acceptance by the users. The BCSIR-inspired programs were discontinued but had clearly demonstrated the benefits while also identifying a number of challenges, such a need for routine monitoring and evaluation, funding, lack of coordination among various entities, etc. This has been reviewed in a recent paper (Badruzzaman 2015).

A number of biogas and bio-digester plants were introduced in the mid-2000's under microloan financing. New ICS and biogas programs under different models have been launched recently and will be discussed later in the paper.

Rural electrification was an obvious component of the country's post-independence development effort—The First Five Year Plan, 1973 (GoB, Planning Commission 1973). The Plan put forth rural electrification as a cleaner and more reliable source of power than diesel used in irrigation pumps and tube-wells. However, there was no mention of electricity for lighting in rural households. The Plan was skeptical about the economic viability of rural electrification and stated, "Although rural electrification will stimulate the economy through increased production in agriculture and industry, it may not in the short run bring adequate financial return on the investment, even if the tariffs are comparable to those prevailing in the urban high density loading areas. The programme will be economically viable only with the spread of electricity in the rural areas which can be accelerated by the formation of cooperatives of the users of electricity" (The First Five Year Plan, 1973, page 328).

The government introduced a grid-supported rural electrification program in the late 1970's through cooperatives. Starting in the early 2000's, off-grid roof-top solar home systems (SHS) were introduced through NGO's in rural areas (IDCOL, 2018). Over 4 million SHS set up till now, have begun to alleviate the lighting/cooling needs in these areas and positively impact people's lives. Despite its successes, the NGO-based program faces challenges, including encroachment by the government program. Both will be discussed in more detail later in the paper.

3.2 History of the Urban/Industrial/ Commercial Energy Sector

The history we relate next would primarily encompass electricity generation, the lynchpin of this sector.

Hydropower: The 230 MWe Karnafuli hydroelectric power station, reliant on the Kaptai dam constructed in Rangamati district in south-eastern Bangladesh, was first commissioned in 1962 and additional generators were installed through 1988. The earthen dam contemplated since 1906 was built between 1957 and 1962. It was constructed using American financial and engineering support. While the dam and the hydroelectric power station ushered a new source of electricity, it was accomplished at a huge cost because the dam's reservoir was created by inundating homes and cropland of thousands of tribal inhabitants most of whom were never appropriately informed of the likely impact of the project or compensated (Chakma, Chakma, Dewan and Ullah 1995). The ancient city of Rangamati was submerged; the ecological damage was incalculable. Over 100,000 people became either internal refugees or migrated to neighboring Indian states where they were not welcome.

It should be noted that displacement and non-compensation of people due to water projects such as dams is not unique to Bangladesh. International entities such as the World Bank are major funders of such projects and often they have either been unable or unwilling to implement resettlement of affected people (Bosshard 2015).

The displacement due to the Kaptai dam sowed the seeds of the armed conflict that has continued to simmer despite a peace treaty signed with the government in 1997 (Parveen and Faisal 2002). Raising the capacity of the plant is always a consideration and has been proposed recently (BPDB 2003, Kibria 2004). However, this would

raise the reservoir water level further inundating land the people use for cultivation. Ironically, at the end of all this, the dam is unlikely to produce more than a very small fraction of the country's electricity and that too at an extraordinary cost.

Natural gas: Sources of significant amounts of natural gas had been identified in the 1950's or earlier. Natural gas was being supplied to homes in major cities for cooking since the 1960's. In 1974, the government of the newly-independent country invited foreign petroleum companies to explore and expand the indigenous gas reserve. However, it was not till the mid-1990's that major petroleum companies showed an interest in exploration. Meanwhile, BAPEX, the exploration arm of the national petroleum organization, PetroBangla, made significant discoveries and added capacity. Natural gas became the major energy resource for electricity supplied to cities and industries. For example, in 2004 44% of the natural gas was used in electricity generation. However, BAPEX was hampered by a lack of more modern technology and funds.

The 1997 Second Block Bidding drew many foreign petroleum companies, large and small. For reasons unknown, some small companies, often without technical or financial strengths, were generally preferred. Most foreign companies demanded the right to export the gas they extract, mainly to neighboring India. Their argument was that export was necessary in view of their expressed need to recoup the substantial investment they would have to make.

Many inside the country and in the Diaspora, including this author, argued that merely exporting gas without accounting for the country's own needs for the gas would be counterproductive and may cause domestic shortage of gas (Badruzzaman 2000). The government of the day, in its wisdom, did not allow export and the foreign companies which set up shop in the country supplied the gas to the domestic market and were profitable under the payment schedules agreed to, contrary to the fear they had expressed. By 2015, Chevron, the largest of the foreign companies in the country, was supplying over 50% of the country's natural gas. The recent shortage of gas has proved the wisdom in the cautions against export and of the then government's decision. However, from the early 2000's, domestic gas exploration has been sluggish for reasons hard to comprehend and it is only now that renewed exploration is being discussed. The same debate whether to export or not has resurfaced (Byron and Rahman 2019). We will examine this issue in the companion paper on fossil fuel sources.

Meanwhile, the 1997 blowout of an Occidental Oil Company's gas well in Magurchara near Srimangal and the 2005 Tengratila blowout of workover wells of Niko Resources in Chattak, Sylhet caused irrecoverable loss to the country's only source of marketed energy.[2] The incidents destroyed much more, ranging from vegetation, ecological habitats, and in the case of Magurchara a tea estate. The loss from the Magurchara incident alone was estimated to be in hundreds of millions of dollars (Dhaka Tribune 2019). Both incidents happened under the watch of small or marginally qualified foreign companies with limited technological capabilities. No direct compensation for the loss of resources has yet been received although some help to communities has been provided by the companies involved. These blowouts demonstrate the need for care in transparently choosing qualified partners, use of modern drilling practices for gas exploration, and strict compliance practices (Khan and Nasir 2014). These are often lacking in Bangladesh.

Domestic Coal: Bangladesh has about 1400 million short tons of mineable domestic coal reserves, much of it high quality, bituminous coal (GoB, Energy and Mineral Resources Division 2005, Draft Bangladesh Coal Policy). There is a producing underground coal mine at Barapukuria, Dinajpur in northern part of the country and an associated 200 MWe power plant. The mine is operated by Barapukuria Coal Mining Company, a subsidiary of PetroBangla a state-owned company (also known as Bangladesh Oil, Gas and Mineral Corporation). It was developed by a Chinese company, China National Machinery Import and Export Corporation (CMC). After the expiry of the initial development agreement in 2011, they entered into a development agreement with a consortium of Chinese companies comprising of CMC and Xuzhou Coal Mining Group. The estimated nearly one million metric tons extracted is slated for the power plant.

The performance of Barapukuria mine has not been stellar due to poor planning, operation, and possibly inappropriate technology (Wikipedia 2020). There have been fatalities or near fatalities from the operation of the mine, including the death of a British mining expert and a worker, injuries, a roof cave-in, and shutdown of a section of the mine. The 2500-acre underground mine includes 650 acres of agricultural land. According to a 2011 International Accounting Project report, nearly half of the agricultural land has been lost due to subsidence, several villages lost access to ground water, and water extracted for the mine resulted in a rapid drop of the local water level (Hoshour 2011).

Bangladesh also has shallow coal reserves in Phulbari. Open-pit mining was proposed to extract coal from these reserves. The process would damage water tables, destroy valuable cropland and displace over 100,000 people. Asia Energy Corporation, a wholly-owned subsidiary of London-based GCM Resources pushed for open-pit mining at Phulbari leading to opposition by domestic activists, experts from Bangladesh diaspora, and local community.

The (BEN 2007) study noted previously in the paper included technical arguments against such mining practices with examples of harm from Vietnam, India and Pennsylvania, USA.

On August 26, 2006, police firing on a large protest against open-pit mining in Phulbari, led to deaths of three teenagers and injuries to 100 others, provoking a countrywide agitation. In order to diffuse the situation, the government made a number of commitments including ban of open-pit mining in the district. Many overseas activist organizations pressured organizations invested in the project to drop out and several did.

However, Asia Energy never gave up its goal, maintained a local presence and its lobbying of government entities, and kept seeking investor funding. Activist efforts joined by international partners continued as did a low-level conflict with law enforcers. In February 2014, the Bangladesh Prime Minister announced that the issue of coal extraction was to be left to "future technology as food security and protecting the land of the farmers is the first priority" (EJ 2017). The announcement brought a sense of relief after a six-year struggle but it apparently did not fully dissuade GCM, the parent company of Asia Energy, from selling shares in London Stock Exchange citing the project. This resulted in recent protests in London (LMN 2019).

The above conflicts appeared to temper the push for open-pit mining, and point to government's abandonment of this approach to extract shallow deposits of domestic coal and consideration of use of imported coal, instead. However, despite the government's commitment against open-pit mining, the 2016 Power Supply Master Plan prepared by the JICA contains the following recommendations on open-pit mining: (PSMP 2016, Page 1–36): "a) Carrying out pilot operation of open cut mining technology in the Barapukuria coal mine and b) Approval of small scale open cut mining at Phulbari after the pilot operation at Barapukuria coal mine."

4 Current State of Bangladesh Energy-Generation Options

4.1 Urban/Industrial/Commercial Sector: An Overview

The government undertook an ambitious plan to increase electricity production through the 2010 Power Sector Master Plan (PSMP 2010–2011). It was updated in 2016 (PSMP 2016). The 2010 Master Plan has set the target of generating 24,000 MWe in 2021, 40,000 MW in 2031 and 60,000 MW in 2041 (Ahmad 2017). Domestic natural gas has been the major fuel for generating electricity in Bangladesh but its reserves has been decreasing and domestic gas exploration has been slow since the early 2000's. Thus, the PSMP anticipates the use of imported fossil fuels (coal and LNG) as the two major sources for expanding electricity production in Bangladesh. The 2010 version of the PSMP envisioned an evolution of installed capacity from 7300 MW in 2010 with 9% oil, 5% coal, 82% natural gas to 37,750 MW in 2030 with10% oil, 50% coal, 25% natural gas, 15% "other" including renewable and nuclear. The Payra power plant in Patuakhali, country's first large-scale coal plant began test production in mid-January (Byron 2020), ahead of the controversial Rampal plant under construction in very close proximity to the Sundarbans. The Rampal plant poses a significant risk for the World Heritage Site (Ahmed 2013, Harvey 2016). In general, the use of fossil fuels, especially coal, would increase the country's carbon footprint considerably. Implications of this outcome are discussed in a companion paper.

The government also plans addition of electricity capacity using nuclear plants and utility-scale solar farms. Two nuclear plants are planned. The first is being built at Rooppur in Ishwardi, Pabna. It has also generated much controversy (Rahman 2015). The government had approved the installation of a 200 Mwe, 1000 acre solar farm in Teknaf for grid-connected electricity (Mahapatra 2015, Rab 2017). Recently, arguments have been made for a larger share of grid-based solar power, possibly using some cropland (Kammen 2019). The nuclear plants and utility-scale solar farms would help to meet the country's commitments to mitigate climate change by using CO_2-free electricity generation, under the 2015 Paris Climate Treaty. However, both pose significant challenges. The issues are discussed in a companion paper.

4.2 Rural/Household Sector

4.2.1 Clean Cooking Program

According to the 2017 REN21 data, over 142 million (89%) people in Bangladesh rely on firewood, dung cakes, charcoal or crop residue to meet their household cooking needs (REN21 2017). Studies have shown that the associated percentage of wood-fuel harvest appears unsustainable (Bailis, et al. 2015). Kerosene lamps have been the major source of lighting. We first discuss the activities underway in cooking and heating in this energy sector. As noted previously, improved cook stoves designed by the BCSIR were first distributed in Bangladesh in the 1980's but did not see a significant acceptance (Badruzzaman 2015). The referenced paper also noted that the ICS program was reinitiated by several NGO's with government's encouragement and support from international development agencies (Barua 2007, GTZ 2010). The paper also noted the so-called market-based ICS program pro-

moted by the USAID that included import of Indian ICS, which often were not at par with BCSIR-designed stoves.

In conjunction with ICS, biogas plants have been implemented in some areas for cooking. By 2015 over 45,000 biogas plants had been installed in the country (REN21 2017). The slurry from bio-digesters acts an organic fertilizer. It is important to note that these programs are in congruence with the Sustainable Development Goals (SDG's) identified by UN member States in 2015 (UN 2015, UNDP 2015). In fact, the programs encompass seven of the seventeen SDG's: SDG-3 (Health and well-being,) SDG-5 (Empowering women and girls, SDG-7 (Access to reliable, efficient modern energy,) SDG-13 (Combat climate change) and SDG-15 (Sustainably manage forests and halt land degradation) (Rosenthal, et al. 2018).

In addition to the local players, the UN Foundation entered the ICS space in Bangladesh through its multi-country Clean Cooking Alliance. The other countries are China, Ghana, India, Kenya, Nigeria, and Uganda. The foundation's objective is to strengthen the market for clean cookstoves and fuels (UN Foundation: 2010). Since user non-acceptance of ICS in the early days appeared to be based less on technical flaws and more on perception and unfamiliarity with a technology that was so intimately related to a family's life (namely, meal preparation), the Alliance launched a behavior modification campaign to increase awareness and promote the use of ICS. The Alliance awarded grants to companies working in the sector to allow investment in production, distribution, human resources, and marketing, to receive capacity-building support and training on marketing and financial management. They worked with the Ministry of Power to create a Household Energy Platform. The Alliance is utilizing the government's 10% reduction of import duty on ICS to make imported cooking technologies more affordable to consumers. Over 700,000 ICS have been installed in Bangladesh by 2015 (REN21 2017).

However, the import of ICS would drive out local ICS entrepreneurs. ICS technology is not a high-level technology and local scientists and engineers at BCSIR had designed good quality stoves. It is not clear why locally made ICS are not used or why resources are not being used to develop higher quality ICS technology in the country, if current local ICS did not suffice. Similarly, it should be possible to manufacture, install and repair biogas plants using in-country resources and expertise.

Recently, the State-owned development financial institution, Infrastructure Development Company Limited (IDCOL) that has been instrumental in the success of the off-grid solar-based rural electrification program (discussed later) has begun dissemination of ICS and biogas plants in rural areas. It is not clear if IDCOL will build its own full-fledged ICS program, including manufacturing, or will be simply a vehicle for distributing imported cook stoves (IDCOL 2018).

4.2.2 Rural Electrification

In development paradigms, rural electrification has been widely identified as a key driver for alleviating poverty and boosting economic growth, especially in countries where large fractions of the population are in rural areas. It has been very successful in Bangladesh (Sharif 2013). As we will see in the following discussion, rural electrification has been a two-step process first as a government-run and funded effort using conventional fossil-fuel based systems with significant challenges, and then as a donor-funded off-grid solar home system managed and funded by a semi-autonomous company in areas where grid connections were not available. Recently, the two appear to be competing and overlapping in the service they provide. We first discuss the direct government effort.

Rural Cooperatives: Rural electrification in Bangladesh began in 1977 under the Rural Electrification Board (REB) Ordinance, 1977. Its mandate was electrification of rural areas by building electric lines and substations. Its counterpart Bangladesh Power Development Board (BPDB) manages electric distribution in urban areas.

In view of the previously noted perspective of the country's planners on rural electrification, the effort in Bangladesh was modeled broadly after the US Rural Electricity Cooperatives created during the New Deal to bring electricity and telephones to rural America, in view of lack of incentive for nearest utilities. In that model, customers were the members of the cooperative. The financial model was based on earning of dividends or reinvestment of profits. The 2013 Rural Electrification Board Act, replaced the 1977 Ordinance and the Board was renamed Bangladesh Rural Electrical Board (BREB).

As of 2018, BREB or its predecessor, Rural Electric Board (REB), have developed over 78 operating rural electric cooperatives called Palli Bidyuit Samity (PBS), which have extended over 17 million new connections and constructed more than 330 thousand kilometers of electric lines (BREB 2018). BREB purchase power from national power development board, mainly. Tariff rates are below cost for domestic and agriculture consumers and above cost for industrial and commercial consumers. BREB set up a streamlined collection system to ensure financial stability. The program has been hailed as a major success and was showcased at an Africa Electricity Initiative Workshop (Chowdhury 2009).

Despite success in terms of system design and revenue collection, BREB-based rural electrification in Bangladesh had faced some systemic challenges. It is instructive to review these. One challenge was the low level

of actual connections, despite building of electrical lines, for example, 53% official vs. 28% actual in 2009 (Palit and Chaurey 2011). However, this was similar to the situation in many other developing countries, except China. Figure 1 illustrates this for Bangladesh and India.

Although the trend of official vs. actual, is similar in both countries the reasons for the difference were different. According to the authors of the cited reference, these were as follows.

India: The low-level of rural electrification was attributed to:

1. Definition utilized for 'electrification.' Historically, level of electrification was measured as % of villages connected with the national grid extension to any point of the village vs. actual households getting connected. This was however, similar in several other South Asian countries.
2. Multiple national programs.
3. State government utilities were less interested in pushing national government targets; national government programs were often underfunded.
4. The government changed the definition of 'electrification' to the more realistic to actual connection. This led to many villages being de-electrified. The government created electricity supply (input) franchises and declared the political goal of "power for all." Unfortunately, only 20% connections were achieved vs. 61% target by 2012. The targets appeared highly unfeasible and overly optimistic.

Bangladesh: The reasons for significantly lower actuation connections relative to claims of electrification were:

1. A poor rural population could not afford the upfront cost of connection,
2. Impedance due to focus on enforced performance targets (revenue/km of line), collection efficiency (strong-arm tactics),
3. Inadequate electricity generation for the grid supply distribution set up, and
4. Inadequate financial resource

Despite the above challenges, the BREB claims to be on track for 100% electrical coverage by 2020 (Bangladesh Post 2019).

Off-grid Solar-based Rural Electrification: Until recently, the grid-based rural electrification discussed above did not reach most rural people, especially the poor. As we noted previously, inadequate generation of grid power was also a major problem. So starting in the late 1990's, NGO's began to deploy off-grid solar home systems (SHS). The nighttime electricity is supplied by batteries that store the solar electricity generated during the day. The funding and project implementation have been primarily through the state-owned development financial institution, Infrastructure Development Company Limited (IDCOL)(http://idcol.org/home/solar).

IDCOL initially received funding from the World Bank and Global Environmental Facility (GEF). Later, many other international agencies[3] came forward to provide financial support for expanding the SHS program. Donors provide grants and soft-term loans and IDCOL then invests these funds in Partner Organizations (PO's) and NGO's. PO's/NGO's with project plans apply for support to IDCOL which evaluates the project against both technical and financial viability metrics. As of January 2019, IDCOL has invested about USD 696 million (BDT 52,240 million). Of this amount, USD 600 million was in the form of loans and USD 96 million was in the form of grants. IDCOL provides technical and operations support through its technical and operations committees. Despite being a state-owned entity, IDCOL considers itself 'a for-profit social enterprise (IDCOL 2018).

The IDCOL SHS program began in January 2003 and as of January 2013, about 4.13 million SHSs have been installed; initial plans were to install 6 million SHS by 2016 (Haque 2013). It should be noted that SHS are limited in terms of the number of electrical outlets and gadgets they can support. At the upper end of the system deployed by IDCOL, at 85Wp,[4] it can support nine lamps, one black-and-white television, and a mobile phone charger. Despite the slower installation rate and the limited scope of SHS, the program has installed 185 MWp of power bringing electricity to remote areas not covered by the grid-based rural electrification program run by the BREB. IDCOL claims to have brought solar electricity to over 18 million or 12% of the country's population.

In terms of lighting, IDCOL estimates that its SHS program has reduced 1.14 million tons of kerosene use worth USD 411 million (at 30 cents per liter). They anticipate that the 4.13 million SHS already installed would avoid consumption of another 3.6 million tons of kerosene worth USD 1.3 billion over the next 15 years (IDCOL 2018).

Solar home systems have provided significant social benefits in rural Bangladesh. They have allowed longer study time for children in the evening and permitted women more freedom to pursue business opportunities such as weaving, making clothes for sale, or utilizing more time in leisure activities such watching TV or visiting friends after a long day, thereby measurably improving the economic well-being and quality of life for women and families. As discussed later rural electrification either through the grid system or the SHS has provided significantly greater benefits to the more vulnerable segments of a household, women and girls.

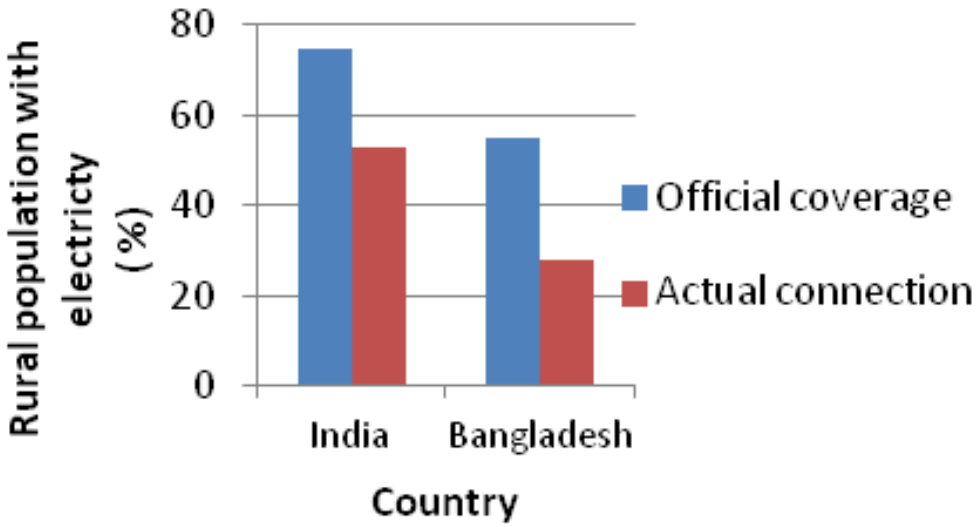

Figure 1: Rural Electrification. Official vs. Actual Electrification in two South Asian Countries (Palit and Chaurey, 2011

BREB Vs. IDCOL programs- competing versions of rural electrification? A recent news story titled, 'Solar energy dims as grid power expands,' (The Daily Star 2016) has brought to fore an inherent but undiscussed tension between separately pursued grid-based vs. SHS rural electrification. The story states, "Solar home system providers find their market squeezed due to the rapid expansion of electricity connections in off-grid areas, particularly by Bangladesh Rural Electrification Board (BREB)." IDCOL would be particularly affected since it is a profit-based enterprise. Figure 2 illustrates the situation. The figure depicts a continuing growth of REB connections while IDCOL SHS installation peaked around 2013 and then declined steadily. In 2018 only 4,160 SHS were installed vs. 853,026 at its peak in 2013.

This challenge has been compounded by the BREB renewing its own effort in the SHS space; BREB had installed the first SHS's in the country in 1993. By June 2019, BREB has installed 53,762 SHS and solar roof-top systems through its cooperatives, under a "No Profit, No Loss" model for a total capacity of 6.762 MWp (BREB 2019). BREB has also introduced a net-metering system to optimize between its grid-based and its SHS/roof-top systems, and sell the excess SHS electricity to the grid. As of June 2019, BREB had generated 751, 613 kWh of electricity from SHS and exported 184,951 kWh (24.6%) of it to the grid.

While the total number and capacity of SHS by BREB is still small compared to those of IDCOL-installed SHS, BREB's "No profit, No Loss" model and ability to export its excess solar production to the grid using net-metering has put a significant pressure on IDCOL's standalone SHS systems, set up with a for-profit model.

IDCOL recognized this in its 2018 report by stating, "….. the market of the SHS is currently nonexistent due to government's free distribution of SHSs under its safety net program (KABIKHA/TR program)." This has forced IDCOL to reduce its SHS effort and diversify into other sectors, both in non-energy and energy sectors. In the latter, IDCOL are now focusing on SHS-based mini grids, biogas plants and ICS.

The implication of the competing SHS implementation by two entities, BREB and IDCOL, both related to the state, is troubling. Grid electricity is more seamless to access with no on-site generation and storage system to worry about, and thus users would generally prefer it. In addition, if they install the BREB SHS, they would possibly sell excess solar electricity back to the grid. IDCOL SHS users with a standalone solar system would not be able to do so and may be left with stranded excess electricity. If grid electricity reaches their area, users may opt to switch but will be stuck with paying for the off-grid system they may not use. For the country as a whole this would imply waste of hundreds of millions of dollars of investment.

The predicament faced by off-grid or mini-grid systems should the main grid arrive is not unique to Bangladesh or to solar-based systems. A recent World Bank report examined this in three Asian countries, Cambodia, Indonesia and Sri Lanka (Tenenbaum, Greacen and Vaghela 2018). In Cambodia, the mini grids used diesel plants. In Sri Lanka and Indonesia these were based on

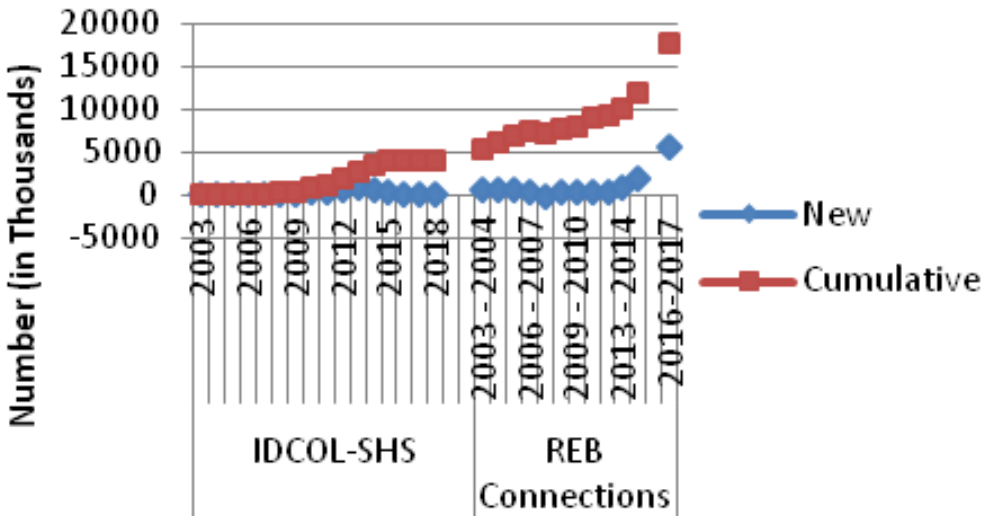

Figure 2: IDCOL SHS installations vs. Rural Electrical Board Connections in Bangladesh

micro-hydro. Using the three case studies, the report concluded that the prevailing view that mini grid (or off-grid) and main grid systems are separate and mutually exclusive paths to rural electrification is overly simplistic, and together the two seemingly competing systems "can lead to more reliable and less expensive electricity for consumers." Each country utilized unique approaches, from the regulatory 'stick' to financial incentives to leverage the benefits of the two systems. Since solar power is often intermittent and Bangladesh national grid has not always been reliable, an interconnected system is likely to offer greater system reliability, and with net-metering introduced by BREB, the cost to consumers could be much smaller. BREB and IDCOL should explore the lessons in the World Bank report in conjunction with the two unique advantages their own systems offer.

5 Generic Challenges of Rural Electrification

While the above data provide a window into the challenges to rural electrification in Bangladesh, this was not unique to the country. In fact, several researchers have observed that impact of grid-based rural electrification has been mixed when viewed across several countries, despite it being a key component of the development paradigm. For example, rural electrification may have had a modest impact on labor participation and no effect on asset ownership, etc., in India (Burlig and Peronas 2016). In Kenya, it "may reduce social welfare as the costs of grid expansion significantly outweigh its benefits" (Lee, Miguel and Wolfam 2016). A systematic study by the World Bank unearthed similar insights into the actual impact of rural electrification in Bangladesh and explained some of the observations above (Samad and Zhang 2017). The authors surveyed over 7000 households for 2005 and 2010 and correlated the results to a number of parameters. They found the following:

1. The length of daily power outages had a strong negative impact on almost all developmental outcomes. An hour of power outage increase per day was associated with about 5.9% increase in kerosene use and 0.3% reduction in annual income.
2. There was no difference between no electrification and grid outage of 21 hours or more.
3. Benefits of electrification increased with years of exposure to grid electricity.
4. Labor market benefits appeared to take the longest time to materialize.
5. Rural electrification led to longer study and evening work hours with girls and women benefiting from it disproportionately. It is not clear why the authors imply this to be a detriment.

The benefits of grid-based rural electrification were predicated on a steady power supply, and grid failure can be a major problem, as Samad and Zhang (2017) illustrate. Off-grid SHS with battery support would address this. Affordability of connecting to the grid has been another challenge. Off-grid SHS would face similar challenges. Micro-finance was introduced to address the financing challenge. As the example cited next illustrates, SHS can be expensive and often requires funding support.

6 Rural/household Sector: Room for Integrated Small Energy Systems?

In the above discussion of the rural energy sector, we noted two tracks in off-grid energy generation and utilization, one for clean cooking and the other for electricity generation, often with separate funding mechanisms. Also, since most are donor-funded or government subsidized, off-the-shelf costs of the systems are difficult to discern. Thus, in order to examine the potential for an integrated small energy system consisting of both cooking/heating and lighting components, and their system costs, the author helped organize and then mentor a pilot project in Bangladesh during 2010–2012 (ALO 2011). The system consisted of ICS, biogas plants, SHS, and solar school systems. The project was funded primarily under the Corporate Social Responsibility (CSR) program of a major international oil company operating in the country and in partnership with two California-based Bangladeshi diaspora non-profits. The project was implemented with the help of a local NGO familiar with the community.[5] Details of the project are described elsewhere. Here we note its key elements and major lessons learned.

Alternative Livelihood Options (ALO) Project: The objective of this pilot project was to explore improving the quality of life through Small Distributed Clean Energy Systems in remote, rural, and poor communities. The targeted population was the poorest in the community, namely, day-laborers, share-croppers, small entrepreneurs with no access to electricity or other modern energy sources, and often no political connections to get access even if gridlines existed nearby. The project included 1000 families in two villages. The average household income of a family of five was Taka (Tk.) 4,000 (USD 50) per month; Taka is the name of the Bangladesh currency. The energy systems distributed were 500 ICS in each village, two biogas plants, one in each village, 150 SHS in 150 households, and solar schools systems in six primary schools with 2000 students. Since SHS and solar school systems would include batteries, the collection and safe disposal of these were built into the program.

The financial model was initial reliance on funding by the sponsors (the oil company and the two diaspora non-profits) and growth from the savings achieved by the project. The ICS cost Tk. 800 (USD 10) per unit and the biogas plant cost Tk. 48,000 (USD 600)/unit. An SHS, running three lights and one fan, cost Tk. 27,500 (USD 344)/unit. The solar school system cost Tk. 126,000 (USD 1,575) /unit. It ran eight lights, one cell charger and 6 fans. A family with the average household income (of Tk. 4000/month or USD 50/month) can afford an ICS. However, the ICS efficiency was no more than 25% relative to the 30–50% indicated previously based on laboratory testing.

The fuel cost saving obtained from the ICS component of the project was substantial but considerably lower in the field than that would be if fuel-use efficiencies claimed by designers from laboratory data were met.

The biogas plant and the SHS were out of the reach of a family's financial means. The pilot CSR project paid for the costs in this instance. Of course, savings from not needing kerosene lessened the burden, but were not sufficient to meet the SHS cost. In general, a funding mechanism, in the form of subsidies, micro-loans, grants, or something similar would be needed to implement these systems. Savings in wood fuel cost from the ICS accommodated some of the SHS cost, for example, demonstrating the advantage of an integrated system.

The project sought to measure a number of quality of life indicator. A key indicator of interest was reduction in air pollution. However, the planned direct monitoring of air pollution exposure in the field by having women wear small personal monitors on their outfit did not materialize due to a number of reasons, including the cost of the these monitors. The potential pollution reduction was indirectly ascertained by monitoring respiratory health outcome of the users of ICS; 90% fewer clinic visits for respiratory illnesses were noted. The risk of kerosene-based fires and associated injuries and deaths were eliminated. Longer evening study hours by the students and a higher attendance rates by them were reported. Women were able visit friends or engage in other recreational activities at night.

Several productive economic activities were generated from the project. A number of the users set up ICS-repair businesses. The project, from its savings, was able provide some micro-loans for new business start-ups, mostly run by women, for vegetable production, duck farming, tailoring, etc. Thus, the systems led to benefits similar to those noted from IDCOL and BREB solar systems. However, the pilot project also illustrated long-term financial viability challenges such (CSR-funded) projects would face in general that need careful evaluation that is beyond the scope of the current paper.

While the above gains achieved in the early years of the CSR pilot project were significant, as time went on system breakdowns began to impact performance of solar panels and ICS. Only one of the two biogas plants remained functional for the duration of the project. Also, uncertainty in the fuel supply due to the sale of the cows the biogas plant relied on was another challenge. In the early years of the project, the SHS, though somewhat expensive, were welcomed by the villagers; they had no access to grid electricity. However, as grid-based electricity became more available in the project area a few years

later, the villagers did not want the SHS systems, especially, if these could not be readily repaired or replaced.

Thus, a part of the investment appeared largely wasted as would be the case for IDCOL SHS systems should the BREB system usurp their use. One exception in the CSR pilot project was the continued use of the SHS by some users who were prone to power outages which were frequent for many grid connected users. This illustrates the benefits of a coupled system.

However, the CSR project was more than on electricity. It demonstrated that integrated small energy systems can bring clean energy for cooking *and* lighting to thousands of rural households in Bangladesh, often very poor, and outside the radar of the country's development activities.

Common Lessons from IDCOL SHS and Rural Small Energy Systems Projects: We have noted the benefits (and challenges) of the IDCOL projects and the CSR pilot project individually. Here we note the benefits common to both. Stand-alone, individual SHS allow electrification in remote areas outside the grid. However, when such systems are introduced, provisions should be made for potential future connections to the grid using net-metering, if and when grid electricity reaches the community. Having the SHS would increase the community's access to clean electricity. Also, a coupled (grid-and roof-top solar) system could improve grid reliability. Finally, the community is likely to develop an appreciation of solar electricity as the country transitions out of fossil fuel-based electricity. Perhaps, going forward IDCOL can partner with the BREB to implement net-metering in the area covered by its SHS.

Another key lesson from both programs is the challenges of keeping the systems in good repair. It is more difficult with distributed systems without a clear supply chain and availability of qualified repair establishments, and ultimately a dedicated monitoring and evaluation program.

Finally, both initiatives demonstrate the value of distributed energy generation and supply systems in rural communities, especially in this riverine country, without the need to set up expensive transmission lines or fuel transport systems; local resources would provide a significant part of their energy solution. Of course, the attendant challenges, some of which are noted in the paper, would have to be accounted for starting in the planning phase.

7 Climate Mitigation and Adaptation in Rural Bangladesh

While the paper does not focus on adaptation to climate change, we note a couple of innovative, locally conceived climate mitigation and adaptation approaches that have been developed in the flood-prone country. One such concept in northern Bangladesh is a mitigation-cum-adaptation approach with floating schools in barges/boats with solar panels on rooftop providing electricity for lighting, fans and computers in the classroom inside the barge. It was pioneered by a Bangladeshi architect, Mohammed Rezwan, in 2002, though his NGO, Shidulai Swanirvar Sangstha, with funding from outside development organizations (Shidulai Swanirvar Sangstha 2002). The boat is also used to gather children for the class from homes that have been cut-off by flood waters. The NGO now has 23 such solar boat schools. The project won the 2007 Ashden Award.[6] The boats are also used to provide adult education and training in sustainable agriculture that the next example illustrates.

The author, accompanied by his spouse, visited the Shidulai project on the Gumani river in early 2019. The Figures 3 and 4 depict one such solar boat school and the activities inside the boat. The photos were taken by the author with the permission of Shidulai personnel that conducted the visit. The photos is included in the paper with thanks to Shidulai

The children were from economically disadvantaged rural families and normally they would often spend their day swimming in the river. Here they were attending school.

The students' joy of learning was evident as they excitedly told the visitors what they were learning on the computer powered by the solar panel on top of the boat. They intimated that they learned better when the computer was used for live demonstration instead of just using books. One child beamed as he showed the US-based visitors that he could write his name in both Bangla and English.

The boat schools were used for adult education on various topics, in late afternoons. An example is depicted in Figure 5.

The concept of floating gardens depicted in Figure 5 evolved from the recent work with farmers by Practical Action, an NGO. The technology uses locally available materials to grow vegetables even during the floods (https://www.youtube.com/watch?v=_JatsIs73RA) These gardens are made up of layers of water hyacinth, bamboo, cow dung and compost, placed on rafts. The crops are then grown on the top layer of soil. The garden floats to the top of the water during the rainy season and returns to

Figure 3: A Shidulai floating solar boat school (Shidulai Swanirvar Sangstha 2002)

ground level when the floods subside.

8 Lessons for the Future?

Distributed energy systems, both in electricity generation and transmission appear to fit Bangladesh's rural/household sector. This raises an obvious question. Would it fit the urban/industrial/commercial sector as well? A complete answer to this question is beyond the scope of the present paper and will be discussed in a future paper. Obviously, there will have to be a sizeable centralized segment in Bangladesh's energy system but clearly the country's entire energy system does not have to be centralized, as is currently planned. Local solar mini-grids can often be appropriate in urban areas as well and can be valuable in the age of climate change. Let's illustrate it with a recent event in California, USA.

Potential advantages of localized grids were recognized during the recent power outages suffered by the centralized grid due to wild-fires in California. These fires, often caused naturally, are also started by electrical sparks at the electrical line connections. Fires in 2017 disrupted the lives of millions and caused burning down of entire towns with tens of deaths. In 2019, California's largest utility, Pacific Gas and Electric, used planned power shutdowns during the fire season to prevent such fires, leaving millions of homes, often entire communities, many businesses, schools, and universities without power for days. Many of these entities were well beyond fire zones but the centralized nature of the electric grid necessitated the shutdown of large parts of the grid (Glanz and Plumer 2019). The experience has led to rethinking of the nature of electrical transmission in the State away from centralized grid to micro- and mini-grids utilizing solar (Our Daily Planet 2019).[7]

Recognition of the above example in Bangladesh could help save billions of dollars that would be needed to build centralized systems. Building and maintaining transmission lines, especially over long distances, in a country cross-crossed by rivers, streams, ponds, and other water bodies, and prone to cyclones, tornadoes and floods, would be extraordinarily challenging and expensive. This can be prevented or minimized as the distributed solar system built by IDCOL indicates.

Figure 4: Inside a Shidulai boat school classroom. Note the fans, lights and the laptop computer the teacher is using for the instruction. (Shidulai Swanirvar Sangstha 2002)

9 Summary

Bangladesh, a developing country with two distinct but related energy sectors and limited access to modern energy systems, has made a complicated journey in the quest for energy access. An overview of this journey indicates that energy solutions encouraged by external experts with limited understanding of the country's energy sectors, their evolving mix of energy use, societal aspirations, and history have often resulted in difficult and untenable situations. The long-term damage inflicted by the Kaptai Dam hydroelectric project that did not appropriately plan for and address its aftermath and the gas blowouts at the hands of unprepared foreign partners should inform the pursuit of three key grid-scale electricity projects underway or under planning. These are the Rampal coal plant that could irreparably damage the Sundarbans, the Rooppur nuclear plant under construction that could be catastrophic in a very high population density country, or large utility-scale solar farms some have been suggested on croplands, potentially endangering the country's food security. The history of Bangladesh's energy journey reviewed in the paper points to the need for caution as the country pursues these (coal, nuclear and solar farm) options. Companion papers will examine these in more detail.

The rural/household sector assessed in this paper has shown a remarkable forward march from about 1% electrification in 2004 to over 90% claimed fifteen years later. This has been possible due to the introduction of off-grid solar systems by various entities supported by IDCOL a government-supported financing organization and government's own grid-based rural electrification program through rural cooperatives. However, there appear to be a turf-war brewing between IDCOL and BREB as the latter moves into the off-grid solar electricity space. The paper suggests an approach to avoid that and draw on the strengths of both.

An integrated, clean small energy systems pilot project noted in the paper illustrated the advantages of a system that supplies both clean cooking/heating and clean electricity solutions, especially to the very poor in rural communities. In addition to health and social benefits, it can often give rise to entrepreneurship growth. As was illustrated in the CSR project, ICS manufacture, installation, and repair can become a business, as would supplying the fuel for the ICS and biogas plants. Programs that involve imported ICS will adversely affect the local

Figure 5: A copy of a slide on the floating garden technique being taught to a group of women farmers (not shown) in the Shidulai solar floating school in the afternoon. (Shidulai Swanirvar Sangstha 2002)

ICS business, however. Of course, since ICS rely on fuel wood, a sustainable management of vegetation is a must to prevent deforestation. While solar plant systems are manufactured in Bangladesh, in-country manufacture of the actual panels should be considered, instead of their import. In general, self-sufficiency and local entrepreneurs in small energy systems components will drive local economic activity and should be actively promoted instead of importing the various components.

Integrated small energy systems could also benefit the urban poor, especially those in the slums, often living under grid lines but with no electricity connection, and inhaling the dangerous smoke that their traditional cook stoves belch out.

Rural electrification programs offer valuable lessons. IDCOL's roof-top distributed solar home systems allowed for a more rapid penetration of electricity in rural homes; the government's grid-based rural electrification was slower. The recent attempts by the government to enter the SHS market combining it with its grid-based system to sell excess solar electricity back to the grid while raising the prospect of two competing entities also demonstrates the potential for a partnership between the two to increase grid reliability and resilience. This benefit clearly can inform decisions that are being considered for electricity generation and distribution in the urban/industrial/commercial energy sector.

Finally, the paper shows that despite their limitations, rural energy programs discussed in the paper illustrate the strengths of locally grown solutions developed by people (either in government or NGO's) familiar with the country's terrain, history, and societal needs. The IDCOL program and the solar boat school program by Shidulai noted in the paper are clear examples of this. Such examples should clearly inform the country's decision makers to incorporate Bangladeshi talent, resident and non-resident, and not just external entities and experts, as has often been the case especially in the urban/industrial/commercial sector (to be discussed in companion papers) while they plan the country's energy future.

Abbreviations

BAPA: Bangaldesh Poribesh Andolon

BAPEX: Bangladesh Petroleum Exploration and Production Company

BCSIR: Bangladesh Council of Scientific and Industrial Research

BEN: Bangaldesh Environmental Network

BPDB: Bangaldesh Power Development Board

BREB: Bangladesh Rural Electrification Board

CSR: Corporate Social Responsibility

GDP: Gross Domestic Product

GEF: Global Environmental Facility

GHG: Green-house Gas

GSMP: Gas Sector Master Plan

GTZ: German Technical Cooperation Program of the German government

ICS: Improved Cook-stove

IDCOL: Infrastructre Development Company Limited

JICA: Japan International Cooperation Agency

MWe: Megawatt-electric

NGO: Non-Governmental Organization

PO: Partner organiztion

PBS: Palli Biddut Samity (Village electricty cooperative)

PSMP: Power System Master Plan

SHS: Solar home system

USAID: US Agency for International Development

Appendix A: A Summary of BEN Energy Panel Recommendations

The BEN Energy Panel made number of detailed recommendations. The key ones are briefly listed next.

- Developmentof a comprehensive strategy with multiple components: These would include a clear identification of options for energy sources, short and long term, a choice of utilization options for preferred energy sources, based on sound economic analysis and optimized to the country's best interests, assessment of environmental, land-use, social and resource impacts of each source option, and incorporation of safeguards against adverse impacts. The report cautioned that no energy source, not even so-called clean energy sources, is totally harmless.

  The other elements of the proposed strategy were steps to increase the local technical expertise base in the energy sector, strengthening or development of relevant institutions, the associated legal, regulatory and enforcement frameworks to support the strategy, and approaches to manage the upsides and downsides of the strategy.
- Judicious consideration of multiple energy source options: This would include increased exploration of the domestic natural gas resource, postponement of domestic coal exploitation, especially by open-pit mining, until the economic environmental and economic challenges are better understood, avoidance of the conventional nuclear power option and exploration of safer, novel nuclear technologies that were being developed at the time the report was being prepared, and a greater consideration of renewable options.
- Greater attention to the rural/household energy sector.
- Setting up of a non-partisan Center of Energy Excellence consisting of appropriate expertise to provide a central and permanent location for unbiased discussion, dialog and input to decision makers on energy technology, economics and policy issues, to allow the development of a comprehensive energy strategy the panel recommended as noted above. Such a center was particularly needed in view of the fragmented discussion that was underway in the country's energy options, often modulated by external interests.

Endnotes

1. The BEN study report was also conveyed to the then Energy Secretary in September, 2007.
2. Marketed energy is from fossil fuels, hydro, nuclear and modern renewable sources such as solar and wind.
3. These included GIZ, KfW, ADB, IDB, GPOBA, JICA, USAID and DFID.
4. Wp stands for watt-peak. Solar modules are rated in Wp. This value specifies the output power achieved by a solar module under full solar radiation. The actual electricity generation would generally be lower.
5. The oil company was Chevron, the two diaspora organizations were SpaandanB (https://www.facebook.com/ spaandanbbangladesh) and Agami (www.agami.org) both based in the San Francisco Bay Area of California, and the NGO was Bangladesh-based Center for Natural Resource Studies (CNRS) (cnrs.org.bd). The author was a research scientist at Chevron when the pilot project was developed and implemented.
6. Ashden is a London-based charity that promotes sustainable energy and regional development. It offers annual awards to highlight accomplishments in these goals: https://en.wikipedia.org/wiki/Ashden
7. Many California homes even in urban areas and connected to the grid, also have roof-top solar and

are a part of the net-metering system that sells the excess solar generation back to the grid. Forming local grids with these may be an option.

8. Dr. Ahmad is the Secretary, Power Division, Ministry of Power, Energy and Mineral Resources, Government of Bangladesh.

Acknowledgment

The paper draws from the material the author uses in the course, Energy and Civilization, he co-teaches at University of California at Berkeley, with Professors Jaime Rector and Chris Rosen. He thanks his colleagues and students for many useful conversations on contrasting the energy/climate conundrum faced by the developing world vs. the developed world.

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