CLIMATE CHANGE
IN THE **BAY OF BENGAL** REGION
EXPLORING SECTORAL COOPERATION FOR SUSTAINABLE DEVELOPMENT




COAST

Climate Change in the Bay of Bengal Region
Exploring Sectoral Cooperation for Sustaiable Development

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Editors' Note

The editors would like to register their deep appreciation of the efforts of all the authors who have enriched this volume by contributing papers on a range of important aspects concerning the climate change impact and its negative scenario which is a critically important driver of socio-economic and sustainable development in the Bay of Bengal region. The authors, all of them Fulbright scholars, deserve sincere thanks for their scholarly inputs which blend their knowledge, expertise and rich experience in the both adaptation and mitigation sector in combating climate change impact in their respective climatic context. This volume and the exercise that preceded it would not have been possible without the full support of The American Center in Dhaka. In this connection, we are extremely grateful to Mr. George Mesthos, Cultural Affairs Officer, The American Center, US Embassy Dhaka for his excellent support to COAST Trust and his interest in this volume. On behalf of the authors and the editorial board, a special word of profound gratitude to all editors who have put in enormous efforts in getting this manuscripts ready for publication.

Forwarding

The American Center Dhaka and the Coastal Association for Social Transformation (COAST) Trust signed a cooperative agreement in September 2015 to implement a project entitled "The Bay of Bengal Working Group." The main objective of this project is to establish a people-to-people constituency among U.S. Exchange Program Alumni who are members of civil society (academia, non-governmental organizations, and the media) from the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) member states through video conference conduct and joint publication. The American Center and US Embassies in other Bay of Bengal region and selected 23 exchange alumni in three thematic areas; education, climate change and blue economy.

The Climate Change is one of the thematic issues, on which the alumni's have submitted their paper from different BIMSTEC member countries. The papers have comprehensively addressed the climate change impact which being happened in BIMSTEC countries, described and tried to evaluate on both adaptation and mitigation approaches taken of their respective context of climate scenario. Papers also have tried to find out the opportunities of sector cooperation in necessary areas to enhance the regional cooperation and facilities in combating climate change impact towards sustainable development in this region.

"These papers are the beginning of a conversation about climate change in the Bay of Bengal meant to spur more in-depth research with the appropriate methodology on climatic issues. We express our heartiest congratulations to the authors for their write ups and giving their intellectual and empirical inputs. The American Center also deserves gratitude for their immense patience to continue supporting this project with COAST after huge disruptions in 2015 and 2016 that underscore the need for greater people-to-people cooperation in the emerging Bay of Bengal region."

Rezaul Karim Chowdhury
Executive Director
COAST Trust

Acronyms

AATW	-	Artificial Aquifer Tube-Well
ACYPL	-	American Council of Young Political Leaders
ADB	-	Asian Development Bank
AR5	-	Fifth Assessment Report
ASEAN	-	Association of South East Asian Nations
BCAS	-	Bangladesh Centre for Advanced Studies
BCCRF	-	Bangladesh Climate Change Resilience Fund
BCCSAP	-	Strategy and Action Plan
BCCTF	-	Bangladesh Climate Change Trust Fund
BIMSTEC	-	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
BNAP	-	Bangladesh National Action Programme
BOBLME	-	Bay of Bengal Large Marine Ecosystems
C	-	Carbon
CBA	-	Community-based Adaptation
CBA-ECA-		Community Based Adaptation in the Ecologically Critical Areas
CBD	-	Convention on Biological Diversity
CDM	-	Clean Development Mechanism
CIDA	-	Canadian International Development Agency
CO_2	-	Carbon Dioxide
CPEIR	-	The Climate Public Expenditure and Institutional Review
CREL	-	Climate-Resilient Ecosystems and Livelihoods
CSISA-MI	-	Cereal Systems Initiative for South Asia Mechanization and Irrigation
CVI	-	Coastal vulnerability index
CWBMP	-	Coastal and Wetland Biodiversity Management Project
DTWs	-	Deep Tube Wells
EBA	-	Ecosystem-Based Adaptation
EEZ	-	Exclusive Economic Zone
ENSO	-	El Niño–Southern Oscillation
EPA	-	Environmental Protection Act
EPR	-	Environmental Protection Rules

EQUINOO - Equatorial Indian Ocean Oscillation
EWRP - Everglades Wetland Research Park
FGCU - Florida Gulf Coast University
GHG - Greenhouse Gas
GLOF - Glacier Lake Outburst Flood
GSDP - Gross State Domestic Product
ICIMOD - International Center for Integrated Mountain Development
IETC - International Environmental Technology Centre
IIED - International Institute for Environment and Development
INCOIS - Indian National Centre for Ocean Information Services
IPAC - Integrated Protected Area Co-management
IPCC - Intergovernmental Panel on Climate Change
IRR - Internal Rate of Return
ISME - International Society for Mangrove Ecosystems
IUCN - International Union for Conservation of Nature
IWMI - International Water Management Institute
LAPA - Local Adaptation Plan of Action
LCA - Life-Cycle Assessment
LDC - Least Developed Country
LLDC's - Landlocked Developing Countries
LWE - Land, Water and Ecosystems
MCCICC - Multi-stakeholder Climate Change Initiatives Coordination Committee
MCT - Ministerio de Ciencia e Tecnologia
MEAs - Multilateral Environmental Agreements
MFF - Mangroves for the Future
MKAL - MK Aromatics Limited
MKWS - MeinmahlaKyun Wildlife Sanctuary
MLE - Monitoring, Learning and Evaluation
MoEF - Ministry of Environment and Forests
MoSTE - Ministry of Science, Technology and Environment
MSW - Municipal Solid Waste

MSY	-	Maximum Sustainable Yield
NAP	-	National Adaptation Plan
NAPA	-	National Adaptation Programme of Action
NCP	-	North-Central Province
NESDB	-	The National Economic and Social Development Board
NGOs	-	Non-Governmental organizations
NSDP	-	Net State Domestic Product
OCCAP	-	Odisha Climate Change Action Plan
ONEP	-	Office of Natural Resources and Environmental Policy and Planning
OSDMA	-	Odisha State Disaster Management Authority
PES	-	Payment for Ecosystem Services
PKSF	-	Palli Karma-Sahayak Foundation
PO	-	Polymer Oil
PPP	-	Polluter-Pay Principle
PVC	-	Polyvinyl Chloride
RE	-	Renewable Energy
REDD	-	Reducing Emissions from Deforestation and Forest Degradation
SAARC	-	Asian Association for Regional Cooperation
SLR	-	Sea Level Rise
TEC	-	Technical Committee
TOC	-	Total Organic Carbon
UNCCD	-	United Nations Convention on Combating Desertification
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environment Program
UNFCCC	-	The United Nations Framework Convention on Climate Change
USAID	-	US Agency for International Development
VGF	-	Viable Gap Funding

Preface

Regional cooperation and integration has vast potential for accelerating economic growth, reducing poverty and economic disparity within and across the countries involved, and addressing some of the challenges of managing regional issues among the member countries. BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral, Technical, and Economic Cooperation) is like one of the region that formed in 2004. The region is accounts for US$ 2.7 trillion GDP, 22 percent of global population (1.6 billion population) and 7 percent of intra-regional trade.

Yet, the region remains among the least integrated in the world. In recent years, the member countries have demonstrated greater commitment to moving forward the regional cooperation agenda. One of the most recent examples is the Bangladesh India MoU (Memorandum of Understanding) of 2010, which not only envisages greater cooperation between these two countries, but also provides a framework for the landlocked Bhutan and Nepal to benefit from mutual understanding between Bhutan-Bangladesh and Nepal-Bangladesh to strengthen cooperation in different sectors like transport and power are primary example. This has boosted the prospects for accelerating regional cooperation among these countries to address the region's massive development challenges.

Apart the climate change will affect every one of our member countries in Bay of Bengal and will be hit hardest, soonest and have the least capacity to respond. The countries of BIMSTEC region are particularly vulnerable to the impacts of climate change due to its extensive coastal areas, heavily populated coastlines and large sections of the population those have been living under poverty also.

The region is also heavy reliance on agriculture for livelihoods. The agriculture sector is accounted for creating a major portion of employment along with contributing the GDP (Gross Domestic Product) of member

countries. But the sector makes vulnerable to droughts, floods, and tropical cyclones associated with warming, sea level rising and salinity etc. Its high economic dependence on natural resources and forestry is one of the world's biggest providers of forest products those are also put at risk due to climate change. So the region is needed to proper address adequately in both adaptation and mitigation pathways. Otherwise it could seriously hinder the region's sustainable development and poverty eradication efforts.

Although the member countries of BIMSTEC region have made significant progress on their own strategies in addressing climate-related issues, nevertheless there is need for closer cooperation and increasing use of existing mechanisms and policy options for both regional and global level, especially for funding, technology transfer and capacity building to address future threats. Respective governments need to do more to fully integrate climate change concerns into their sustainable development policies, taking knowledge, through experiences sharing each-other and further steps could be taken to encourage for all sector and stakeholders in both mitigation and adaptation efforts.

The papers are the outcome on the above concerned issues written by some full bright US (United State) alumni of BIMSTEC member countries. The papers have maunly focused on the issue of combating climate change and demonstrated a wide range of adaptation and mitigation measures those are already being applied in the different member countries in respect of their own climate context. The implementing measures drawn examples from the communities of different country context and explained these approaches followed, opportunities created by them, and their impacts on people and nature. It further discussed the challenges faced by innovation in both adaptation & mitigation and how those could be transformed into opportunities. The paper advocates for evaluation of these innovations, before and after scaling up, to avoid mal-adaptation in respect of country context. It emphasizes knowledge generation and management as a key component of climate related projects for informed decision-making.

Despite the above, the papers advocates for much more needs to be done. Adaptation along with appropriate mitigation strategies is required to building capacity and taking technical and non-technical measures in climate-sensitive sectors. Cross-border learning and experience sharing

would be more effective and useful in this arena. Following this urge, the papers have tried to put their learning and empirical experiences on combating climate change issues. The experiential learning and the propose recommendations could be a regional solution to climate change by introducing in the respective government development policies that in fact need to incorporate in both adaptation and mitigation activities. The strategic recommendations will also be supportive to tap the wide range of regional, global and even bilateral funding sources and initiatives that exist to help developing countries respond to climate challenges.

Bangladesh

Dr. Haseeb Md. Irfanullah

Over the past 16 years, Haseeb Md. Irfanullah has evolved from being a botanist to an aquatic ecologist, from a conservationist to a development practitioner. He has developed interest in and understanding of climate change adaptation, disaster risk management, natural resource governance and biodiversity conservation – all focusing on human well-being. At the current stage of his evolution, Haseeb finds his niche in nature-people-knowledge nexus. In 2004, he received a Ph.D. in aquatic ecology from the University of Liverpool, U.K. Before that he studied Botany at the University of Dhaka for his B.Sc. and M.Sc. degrees. Haseeb is currently working for IUCN (International Union for Conservation of Nature) as the Programme Coordinator of Bangladesh Country Office in Dhaka. He and his co-workers have so far published 35 research papers; authored, edited and contributed to 37 books and other publications; and written 42 articles and thought pieces on diverse topics - ranging from microscopic plants to freshwater ecosystems to climate change adaptation to poverty-technology link to research communications. In 2014, Haseeb was a member of the Bangladesh delegation on 'Climate Change and Adaptation' under the International Visitor Leadership Program (I.V.L.P.) of the U.S. Department of State.

What Does Bangladesh Tell Us About Innovation In Climate Change Adaptation

Haseeb Md. Irfanullah, ***Bangladesh***

Abstract

Bangladesh is often called the 'adaptation capital of the world' because of its exciting progress as one of the most climate vulnerable countries of the world. Given the continuously changing social, economic, political, and climatic regimes at the national, regional and global levels, it is important to keep the pace of adaptation going by taking innovative steps and actions in all relevant arenas – from policy to finance to institutions to technology. Bangladesh prepared the National Adaptation Programme of Action (NAPA) in 2005 – the first ever strategic document to make adaptation an organized effort. The present paper considers three related areas of adaptation: 1) adaptation planning and implementation, 2) nature-based adaptation technology development and diffusion and 3) evolution in programmatic approach, and looks into major developments between 2006 and mid-2016 through an innovation lens. The paper draws examples from the communities on Bangladesh's coast to explain the adaptation approaches followed, opportunities created by them, and their impacts on people and nature. It further discusses the challenges faced by innovation in adaptation and how those could be transformed into opportunities. The paper advocates for evaluation of adaptation innovation, before and after scaling up, to avoid maladaptation. It emphasizes knowledge generation and management as a key component of adaptation projects for informed decision-making. It argues that such initiatives should have a monitoring, learning and evaluation system built within them. Such an arrangement can help to create a dynamic environment for projects to harness innovation at all levels –individual, institutional and policy – and at the same time be effective.

Introduction

The situations we are in, and more importantly, how we respond, often define our persona before others. As in a human society, a country also finds itself associated with a particular identity as a member of the global society. Climate change discussions widely talk about Bangladesh's vulnerability to climate change and natural disasters. Opposite to this rather gloomy reputation, Bangladesh is sometimes called the 'adaptation capital of the world' (Irfanullah, 2013). This deltaic South Asian country of 160 million people has gained such a positive persona because of her significant progress in climate change adaptation despite being one of the most climate vulnerable countries of the world.

Climate change is a combination of long-term, irreversible changes in earth's climatic parameters leading to some global phenomena, like sea level rise. Our mitigation endeavors, the reduction of global carbon emission to a significant effective level, have been like a roller coaster ride over the last couple of decades. Even if efficient mitigation measures are taken now by all countries, the climate will continue changing and impacting nature over the decades to come. Adaptation, a term widely used in biology explaining an organism adjusting, modifying and surviving within its changing environment, has found a new dimension in the climate change discourse. Adaptation to climate change is the adjustments made by humans to the impacts posed by changing climate and variability.

For a human society vulnerable to climate change, adaptation is essentially a collection of measures taken in a given situation, at a specific time. But it is far from stopping there or remaining static. In addition to continuously changing and variable climate, the societal, economic and political regimes also change at local, national, regional and global levels. It is therefore important to keep adaptation momentum going at all levels by taking innovative steps and actions to cope with newer situations. Such innovations are not only to play a role in technology development and promotion, but also in policy formulation and implementation, financial mechanisms and institutional arrangements.

Bangladesh's first practical attempt to make adaptation an organized national endeavor took shape in 2005 through the

National Adaptation Programme of Action (NAPA). In the pre-2005 era, pioneering programs like 'Reducing Vulnerability to Climate Change' upheld the needs and the importance of adaptation actions on the ground, with the people. Over the last decade, such understanding continued to grow; adaptation in Bangladesh has basically become collections of people-oriented actions on the ground highly depending on cost-effective, affordable technologies. In recent years, Bangladesh has become a part of regional and global resilience-building efforts. The 'Mangroves for the Future' (MFF) (www.mangrovesforthefuture.org), for example, is a regional initiative in the wake of tsunami 2004 now expanding from Pakistan to Vietnam. As in other 10 countries, the MFF in Bangladesh has connected the coastal people with the nature to improve their adaptive capacity, mostly through ecosystem-based solutions. Such participatory, community-led actions are, however, not sustainable unless they are supported by public policies, strategies and plans, and implemented. This context allows us to identify three related areas of adaptation: 1) adaptation planning and implementation, 2) nature-based adaptation technology development and diffusion, and 3) evolution in programmatic approach.

In this article, I first take a look into the major progress, achievements and trends between 2006 and mid-2016 in the areas of adaptation planning, technology and programmatic approach, through the lens of innovation. I give examples of vulnerable communities from all over Bangladesh, particularly from the coast, to explain the adaptation approaches taken, opportunities created by them, and their impacts on the people and the nature. I further discuss the major challenges faced by innovation in adaptation and how those could be transformed into opportunities to build community resilience.

Adaptation in Bangladesh: Through an Innovation Lens

Adaptation planning and implementation

Bangladesh first prepared the NAPA in 2005.The document proposed 15 programs to improve the country's adaptive capacity. In 2009, the 'Community Based Adaptation to Climate Change through Coastal Afforestation' project started as one of

the first projects outlined in the NAPA with support from the Least Developed Countries Fund (LDCF). During 2008-2010, the Government of Bangladesh took some unprecedentedly prompt actions in climate change policy and strategy formulation. In 2008, it formulated the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), and revised it in the following year (MoEF, 2009). The BCCSAP has 44 programs clustered into six themes. These thematic areas include food security, social protection and health; comprehensive disaster management; infrastructure; research and knowledge management; mitigation and low carbon development; and capacity building and institutional strengthening. One important aspect of the BCCSAP is, unlike its predecessor the NAPA, it was not developed to meet a national commitment to the United Nations Framework Convention on Climate Change (UNFCCC). Rather, it was a nation-driven initiative, prepared as a part of the country's overall development strategy. In 2009, the NAPA was also revised; but the BCCSAP has remained the core national document to guide nationally-coordinated climate change adaptation efforts since 2009.

The enthusiasm and political commitment from the government around the BCCSAP did not stop with its formulation. It was followed by putting in place legal instruments (Bangladesh Climate Change Trust Act 2010) and institutional setup (Bangladesh Climate Change Trust). These allowed resource allocation in the form of the Bangladesh Climate Change Trust Fund (BCCTF) to ensure effective implementation of the BCCSAP. Such an arrangement has never been seen before in Bangladesh. Before the BCCSAP, a number of environment-related planning documents were prepared by the government under different multilateral environmental agreements (MEAs), as they are called. In addition to the NAPA (2005) under the UNFCCC, other examples include, the Bangladesh National Action Programme (BNAP) for Combating Desertification (2005) under the United Nations Convention on Combating Desertification (UNCCD), the National Biodiversity Strategy and Action Plan (2006) for the Convention on Biological Diversity (CBD), and the National Capacity Self-Assessment (2007) encompassing the above three conventions. None of those was supported by a dedicated institution and financing mechanism like the BCCSAP.

Over the eight fiscal years (2009-10 to 2016-17), every year, the Government of Bangladesh has been allocating $13 million to $91 million of its own money to the BCCTF (www.bcct.gov.bd). Up to the current fiscal year (2016-17), approximately $403 million has been allocated to undertake country-wide climate change adaptation and mitigation actions in light of the BCCSAP. As of June 2016, 440 projects have been funded by the BCCTF. Of those, 377 are being implemented by government or semi-government agencies and the rest by non-governmental organizations (NGOs). Till date, $3.25 million has been allocated to the NGOs. The Palli Karma-Sahayak Foundation (PKSF) – a 25-year old not-for-profit company having partnership with about 300 NGOs – is responsible for managing the fund for NGOs. So far, 153 BCCTF projects have been completed, of which 110 were implemented by government institutions. An analysis of the BCCTF funding (January 2010-February 2014) showed that more that 70 percent has been under the infrastructure thematic area of the BCCSAP, followed by mitigation and low carbon development (13%) and food security, social protection and health (10%) thematic areas (Pervin and Moin, 2014).

The implementation of the BCCSAP is further supported by a multi–donor fund–Bangladesh Climate Change Resilience Fund (BCCRF)– managed by the World Bank. The governments of Australia, Denmark, the European Union, Sweden, Switzerland, the United Kingdom and the United States channeled more than $ 188 million to the BCCRF at its inception in 2010 (www.bccrf-bd.org). So far, 10 projects have been funded ranging from disaster risk management to renewable energy promotion to coastal afforestation. There is a $ 12.5 million component called 'Community Climate Change Project.' As in the BCCTF, the PKSF is implementing this BCCRF project to channel funds to NGOs through an open selection process. The BCCRF has also been a novel initiative. The idea of this multi-donor trust fund came about after the UK-Bangladesh Climate Change Conference was held in London in September 2008, where the BCCSAP was launched. Putting multiple donors' money in one pot to be used by one country to tackle its climate change vulnerability was indeed a unique initiative.

Besides the BCCSAP, a number of long-term, holistic, unique development plans are under preparation where climate change adaptation is being considered as a very important aspect of sustainable growth. The Bangladesh Delta Plan 2100, for example, is being developed by the Bangladesh Planning Commission with financial support from the Government of the Netherlands (www.bangladeshdeltaplan2100.org). This plan envisages this deltaic country's planning process to be long-term, holistic, integrated, adaptive and dynamic. It has identified strategic integration of climate change adaptation in the development planning as one of the key elements.

In addition to national plans and their implementation, sectoral planning could also be seen in recent years to improve climate resilience of the respective sectors. Currently, the Food and Agriculture Organization of the United Nations is helping the Government of Bangladesh formulate the Bangladesh Environment, Forestry and Climate Change Country Investment Plan with support from the US Agency for International Development (USAID). This plan is essentially a five-year framework that identifies priority areas for investment in the above three sectors, and estimates the funding needs to be channeled by the government and the development partners. Very recently, the Plan of Action on Disaster and Climate Risk Management in Agriculture for Department of Agricultural Extension has been prepared for the agriculture sector. Similarly, cross-cutting issues, like gender, have also been addressed in planning processes to make resilience-building gender-sensitive and effective (Bangladesh Climate Change and Gender Action Plan, 2013). But implementation of many of them is yet to attain due momentum.

Nature-Based Adaptation Technology Development and Diffusion

Over the years, many attempts have been made, particularly in the vulnerable, saline-prone coastal region of Bangladesh, to explore nature-based adaptation solutions. Ranging from drinking water options to crop agriculture models to floating gardening, these technological innovations and their promotion have significant positive impacts on improving resilience of the vulnerable people.

Scarcity of freshwater is one of the major impacts of climate change on Bangladesh coast due to salinity ingress as well as trapping of storm surge waters. Any remedy to the situation has direct positive impacts on health, nutrition security and women – the manager of household water supply in rural Bangladesh. To make drinking water available to the people, three main approaches have usually been taken under different initiatives: capturing rainwater, filtering polluted surface water and managing utilization of available safe freshwater. Rainwater harvesting systems have been introduced widely on the southwest coast of Bangladesh, especially after tropical cyclones Sidr (2007) and Aila (2009). Although different types of water storage systems are available, above-ground large plastic tanks are the most popular one.

A number of filtering technologies have been introduced in this region, like pond-sand filter and arsenic-iron removal plant, to clean polluted waters. Practical Action, a UK-based NGO, designed and piloted a novel option, Artificial Aquifer Tube-Well (AATW), in Shyamnagar, a coastal sub-district of Bangladesh. In this system, a 30-foot deep concealed vertical column of sand-gravel layers is installed mimicking the natural aquifer. Polluted water from adjacent pond is allowed to percolate through this column, to accumulate at the bottom, only to be extracted with a handpump tube-well. The hand pump tube-well used in the AATW is an interesting innovation. Instead of the regular tube-well, made fully of cast iron and steel and used all over the country, this one has a concrete body, iron head, handle and piston, and inner glass cylinder to reduce friction with the piston. This concrete-glass-iron structure came from Rangpur of northern Bangladesh, a place 460 km away from Shyamnagar. The young engineer involved in establishing the AATW first saw this innovative concrete-glass-iron tube-well in his grandfather's place where it was popular as thieves do not steal it. Concrete-glass-iron tube-wells are theft-proof since, unlike the iron tube-wells, these do not have any resale value. In saline-prone areas, the salty atmosphere is corrosive to iron. Thus, an innovation as a remedy to theft finds a new purpose as a remedy to salt corrosion.

Although limited in number, the rain-fed ponds of Shyamnagar and other places are brought under a community-based

management system for their optimum utilization. Similar water management systems have also been introduced to uncontaminated underground points from where piped-water is supplied to distant households. Such supply is managed by a local committee to ensure water supply timing, service charges and necessary maintenance. In some saline-prone areas, freshwater sources are also used by water vendors, who collect, carry and sell drinking water to households – a business unimaginable in other parts of Bangladesh. In 2015, the southeastern saline-prone region of Bangladesh has seen introduction of solar desalinization plants. Under a community-based adaptation project, the Department of Environment has established two plants, functioning through reverse osmosis technology, to ease the drinking water scarcity of 5,000 people (DoE, 2015).

Making sufficient water available for crop agriculture is a big challenge in the saline-prone coast. To optimize the water use, drip irrigation using polyvinyl chloride (PVC) pipes and earthen pots, has been tried on a small scale in some areas with limited success. On a larger scale, as seen in last winter in coastal Satkhira district, a canal re-excavated under the Mangroves for the Future (MFF) initiative by Caritas (NGO) changed the whole landscape. The canal held rainwater in monsoon and allowed 400 farmers, under a pre-decided water-sharing system, to cultivate rice and vegetables once again on the land left empty since the cyclone of 2009.To maximize the use of low saline water, Practical Action tried an innovative model in Shyamnagar with support from the Asian Development Bank (ADB). In this model, monsoon rainwater is caught in small ponds to irrigate adjacent rice fields in the winter. The pond owners get payments from the rice farmers for this service. Moreover, pond owners also get benefitted from these tanks by cultivating low-salinity-tolerant fish, almost round-the-year. The Department of Environment has recently built two solar irrigation plants – one in the northeastern Hakaluki Haor (a large wetland) and the other in southeastern Cox's Bazar (DoE, 2015). The haor area faces water scarcity in dry season. This plant makes irrigation water available to the winter crops. On the coast, on the other hand, similar solar irrigation plant helped farmers to grow rice and vegetables in areas where it was impossible in the recent past due to high salinity and shortage of rainfall.

In recent years, agricultural research institutes of Bangladesh have made very good progress in developing new rice and other crop varieties tolerant to salinity, flooding and drought. These inventions have been taken out of the laboratory and field stations by government's extension department as well as NGOs as part of technology diffusion and are being practiced widely. Each salt-tolerant crop variety, however, has a salt-tolerance limit, above which its growth, flowering, or seed setting gets affected. Performance of these varieties also depends on rainfall, which varies widely nowadays, making the adoption and sustenance of these varieties by the farmers a challenge. Development of new varieties, improvement of salinity management, and strengthening of agricultural extension, thus remain a continuous process.

Floating gardening has been a home-grown celebrity adaptation technology of Bangladesh (UNEP, 2014). It has been a traditional agro-practice of south-central Bangladesh where rafts made of rotten water hyacinth are used to raise seedlings and cultivate crops on stagnant waters. In the late 1990s to early 2000s, floating farming was promoted as a means of natural resource management of wetlands supporting local livelihoods. Later on, under CARE's Canadian International Development Agency (CIDA)-funded 'Reducing Vulnerability to Climate Change' project, it was first promoted as a means of overcoming adverse effect of waterlogging – a phenomenon expected to sustain widely under climate change. Until 2012, floating gardening was promoted in different parts of Bangladesh by CARE, IUCN, Bangladesh Centre for Advanced Studies (BCAS) and Practical Action. In 2012, the BCCTF supported the Department of Agricultural Extension to promote floating gardening among 12,000 farmers in nine districts (UNEP, 2014). Apart from introducing to new areas as an innovation, floating gardening itself has not gone through any major changes; except a few sporadic innovations. In Chalan Beel in Pabna, for example, floating gardens were built with empty drums and bamboos, also having fish enclosures and duck huts. In recent months, Practical Action has started testing a similar model – cage aqua-geoponics system – in coastal Satkhira, under the Dutch Government-funded Blue Gold program.

Evolution in Programmatic Approaches

Climate change adaptation in Bangladesh is essentially based upon natural resource management, directly involving the local vulnerable people. It is therefore not surprising that participatory or community-based natural resource management experiences of Bangladesh have given the basic shape of adaptation initiatives in this country. Most of the adaptation projects here follow a community-based adaptation approach to build community resilience. Community-based adaptation to climate change has gained significant momentum over the past decade. An analysis of some key natural resource management initiatives can show how building community resilience has been mainstreamed over the last decade in Bangladesh.

If we take coastal afforestation, newly accreted land on Bangladesh coast has been brought under forestation since the early 1960s as a means of land improvement. Since the late 2000s, this regular job of Bangladesh Forest Department has been considered as an adaptation option as well. The LDCF-funded 'Community Based Adaptation to Climate Change through Coastal Afforestation' project (2009-2013) and the BCCRF-funded 'Climate Resilient Participatory Afforestation and Reforestation' project (2013-2016) are two important examples where coastal afforestation has been considered as the basic means to improve community resilience, with the communities. Many other projects and organizations have tried coastal afforestation, but on a very limited scale, often focusing on specific communities. The regional MFF program and the USAID-funded 'Climate-Resilient Ecosystems and Livelihoods' (CREL) are two recent examples incorporating coastal afforestation as one of the major project interventions. In all these initiatives, coastal afforestation and reforestation remain a challenging endeavor. Innovations continue in seedling raising and plantation techniques, managing land tenure of the plantation sites, tackling social conflict over land use, convincing and managing the local political leadership, ensuring local participation in protecting the plantation, and overcoming the impacts of natural calamities in these remote areas.

Over the years, shifts in programmatic approach have been seen in development partners' working on the same natural ecosystems. The 'Nishorgo Support Project' (2003-08) and its successor 'Integrated Protected Area Co-management' (IPAC, 2009-12),both funded by the USAID, for example, were essentially Protected Area conservation projects with a co-management approach involving forest-depended people. The follow-up phase of these projects, the CREL (2013-17), has taken a climate-resilience building approach while conserving nature and supporting the well-being of the people depending on it. Similarly, the Department of Environment of Bangladesh implemented 'Coastal and Wetland Biodiversity Management Project' (CWBMP, 2003-11) with support from the United Nations Development Programme (UNDP). This project was the first comprehensive attempt to improve four ecologically critical areas of Bangladesh taking natural resource governance as the core element. During 2011-15, 'Community Based Adaptation in the Ecologically Critical Areas through Biodiversity Conservation and Social Protection' project (CBA-ECA project) of the Department capitalized on the CWBMP. It took strong community-based adaptation approach to conserve these ecologically critical areas (DoE, 2015).The project had many adaptation interventions, like submersible embankment and green belt creation, swamp and coastal afforestation, livelihoods diversification, and solar irrigation and desalinization plants installation, implemented with support from the UNDP, the BCCTF and the Government of the Netherlands. The CBA-ECA project has created a unique example, by combining community-based ecosystem conservation, community development and resilience building of vulnerable people of some ecologically fragile areas of Bangladesh.

Innovation in Adaptation: Challenges and Opportunities

Since climate change and its impacts are long-term, adaptation initiatives to adjust to these impacts need to be long-term as well. As we know, this has hardly been the case. Projects solely focusing on piloting innovations tend to be for shorter period. Needless to

say adoption of nature-based technologies by the people takes time. If we keep the inherent limitations of projects aside, innovation in adaptation may face three main challenges. We need to transform those challenges into opportunities if we want to see innovations making effective contribution to our adaptation ventures.

We face the first challenge when innovations in adaptation do not properly consider the innovation-evaluation-diffusion cycle. Till now, adaptation innovations continued sporadically, mostly on a pilot basis, as part of short-term projects. A basket-full of novel adaptation technologies are available, but their proper evaluation to ensure their acceptance by the people, and effectiveness in changing social and climate context are missing. We therefore rarely see critical analysis of a nature-based technology, rather only its flawless success stories (Irfanullah, 2016). As a result, scaling up of those piloted innovations are hardly spotted. We have, however, seen introduction and scaling up of indigenous floating gardening – from its center of origin in the south to the north and northeast of Bangladesh – as an innovation. I want to call it 'backward innovation'. It is because, while introducing it to new areas, we have removed some of its key elements of sustainability (UNEP, 2014). Instead of its natural, self-sustaining, market-driven mode, we made it an artificial, project-dependent, subsistence-focus model to new areas, a disappointing deviation from technology diffusion philosophy. We also forgot to address the possibility that water hyacinth-based floating farming may not sustain in changing climate. Water hyacinth availability directly depends on wetland hydrology and water salinity, both to be affected by climate change. As a result, over the last decade, our 'mass fascination' of promoting floating gardening without appropriate evaluation and research represents a potential example of maladaptation (Nobel et al., 2014). To avoid such a disaster, it is therefore important to pass an innovation through the evaluation stage before going for scaling up. Evaluation should continue even at the scaling-up stage to ensure that an innovation remains relevant and produces expected impact.

This brings us to our second challenge – an absence of an in-built knowledge generation and management system within the adaptation initiatives. The knowledge and lessons generated on innovation are often not sufficiently documented and shared

among the stakeholders. As a result, similar innovations are being tested by different agencies in similar contexts, thus reinventing the wheel over again. We also need knowledge management to sieve out the best practices, which would otherwise be overlooked. The CBA-ECA project of the Department of Environment is probably one of the rarest examples of government project that has captured the processes and lessons of its four-year life cycle, thus paving the path for similar future initiatives (DoE, 2015). But, such knowledge generation has to be a continuous process throughout the project tenure, with regular outputs. It should not be only an assignment to a team of independent consultants for a couple of months before the end of a project. Generated knowledge and evidence can also help us to make informed, unbiased decisions, as opposed to making choices based upon perceptions, which widely vary from person to person.

The third challenge appears when adaptation projects do not have a monitoring, learning and evaluation (MLE) system integrated into the project design. Monitoring and evaluation is often an integral part of any project, but I am emphasizing the learning component. An MLE mechanism can help adaptation projects to make necessary adjustments throughout the project's lifetime. It gives project participants a space to innovate, to improvise during project implementation. The Bangladesh component of the regional MFF initiative, for example, has such a component in-built in its small and medium grant facilities, which has proven to be very useful. Such an arrangement can help to create a dynamic environment to make projects adaptive to changing situations by harnessing innovation at all levels – individual, institutional and policy – and at the same time be effective.

Conclusion

The BCCSAP of Bangladesh, the funds from the government (BCCTF) and the donors (BCCRF), and facilitating institutions (Bangladesh Climate Change Trust and the World Bank, respectively) exemplify an innovative mechanism to tackle impacts of climate change in years to come. The analysis of recent adaptation projects have shown how the government agencies, the NGOs and the development partners have integrated adaptation concept into livelihoods improvement, biodiversity conservation,

natural resource governance, disaster risk management, or halting ecosystem degradation. To be effective, adaptation initiatives should have mechanisms to evaluate its innovations, should emphasize knowledge generation and management, and should have a built-in monitoring, learning and evaluation system.

The adaptation technological innovations of Bangladesh are mostly nature-based solutions. These offer useful lessons to all societies with similar social, economic, geographic and climatic vulnerabilities. Being the lower riparian country in the Ganges-Brahmaputra-Meghna basin, positioned on the tip of the Bay of Bengal, Bangladesh faces floods from the north and cyclones and saline invasion from the south. Despite that, the country has effectively shown how these vulnerabilities can be transformed into resilience, matching the title given to her – the 'adaptation capital of the world.' Her strength lies with her people. The people of Bangladesh know they will remain vulnerable to climate change for decades to come, but are not overwhelmed by this reality. They continue to innovate, improvise and adapt, and inspire the world with their spirit of resilience.

Acknowledgement

The views expressed in this article are the author's own, and do not reflect those of the IUCN, the US Embassy Dhaka or the COAST Trust.

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Bhutan

Karma Wangchuk

Energy Efficiency Design in Traditional Bhutanese Communities

Karma Wangchuk, ***Bhutan***

Abstract

As developing countries graduate from poverty to prosperity, their people want to emulate Western type development and consumerism. In an ecologically fragile area like the Himalayas, energy intensive development would be a disaster to both the environment and the inhabitants. Already the glaciers are receding from the effects of climate change and the occurrence of Glacier Lake Outburst Flood (GLOF), better known as the "Tsunami from the Sky" are frequent realities. While Bhutan is endowed with a rich culture set within wonderful natural landscapes, our emerging lifestyles are already at a discord with traditional living. While our parents and their forefathers were able to live in harmony with nature, our generation is beginning to see issues of rapid urban growth contributing to urban blight, excessive waste, air pollution issues, congestion, and high energy demand. We should take the opportunity to learn from the traditional building practices and space organization of our past as we move forward - staying at the forefront of sustainable design practices by adopting centuries of knowledge bequeathed to us by our ancestors. If we morph modern technology with ancient wisdom, we will have the opportunity to mold our new settlements into energy efficient and aesthetically pleasing communities that are sensitive to the environment and culturally vibrant.

Introduction

Within the BIMSTEC region, Bhutan is one of the most vulnerable countries to climate change and its impact owing to its mountainous terrain prone to frequent landslides. As a tiny land locked country, Bhutan is highly dependent on the climate sensitive sectors of agriculture and hydropower. While 70 percent of the population is dependent on subsistence agriculture, about 40 percent of the country's annual budget comes from exporting electricity from its numerous hydropower plants. Although Bhutan is carbon negative (it absorbs more green house gases than it emits) the effects of climate change are universal without regard to national boundaries. Therefore, it is important for individual countries to adapt quickly and become resilient to climate change, by formulating ways to mitigate the negative consequences of climate change. The nations of BIMSTEC have an opportunity to fight the negative effects of climate change together and learn from each other's experience.

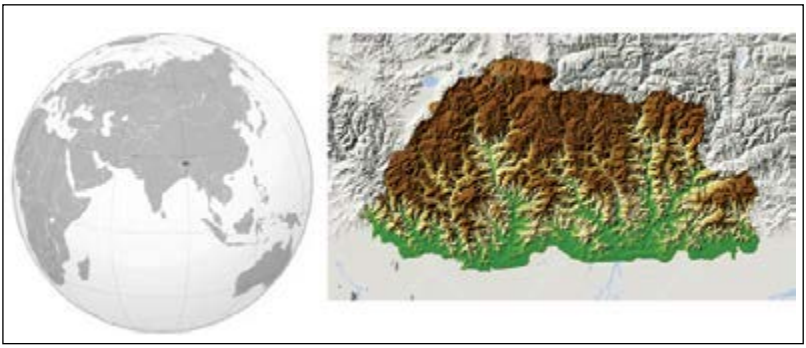

Figure 1: Bhutan is but a speck on the globe. The country is very mountainous with elevation ranging from 300 to 25000 feet.

Wedged between the two most populous countries in the world, Bhutan is the last Buddhist Kingdom in the Himalayas. Measuring a little less than 15,000 square miles in area with a small population of only three quarters of a million people, Bhutan is but a speck on the globe. However, in a world fast homogenizing as a result of rapid globalization, Bhutan has managed to stay relevantly visible, through a concerted effort of; consciously preserving its unique

cultural identity; conserving its pristine natural environment; promoting the concept of Gross National Happiness; and pledging to remain carbon neutral. The country measures only 100 miles as the crow flies from the southern foothills to the northern mountain tops. However within this 100 mile distance the elevation ranges from 300 feet to 25,000 feet. This abrupt variation in elevation over a very short distance has resulted in the formation of three distinct climatic zones namely alpine, temperate, and sub-tropical with corresponding rich species of flora and fauna within our tiny country. Bhutan is considered one of the biodiversity hotspots in the world, with more than 50 percent of the present land area falling under parks and protected areas.

Another benefit of the rapid elevation change is the ample opportunity to harness the latent potential energy of fast flowing rivers by constructing hydro power plants to generate clean and renewable hydro-electric energy. Presently only about five percent of the estimated 30,000 MW of hydroelectricity potential is tapped. Seventy-five percent of the current installed capacity of approximately 1600 MW is exported to fuel the factories in India, which would have otherwise used electricity generated from coal fired power stations. In this way, Bhutan's clean electricity helps reduce green house gas emissions in the region.

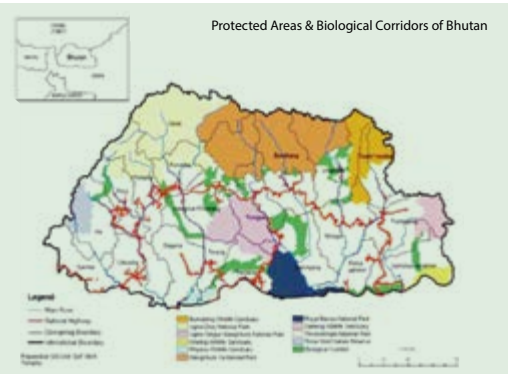

Figure 2: Bhutan is constitutionally mandated to maintain 60 percent forest cover for all time to come. Currently Bhutan has more than 70 percent forest cover.

The majority of the populace lives in the temperate valleys of the inner Himalayas engaged in subsistence farming. The fast flowing springs and rivers not only irrigate our farmlands and provide our drinking water, but they are also a vital stock of water reserve for

our downstream neighbors. It is estimated that the water from the Himalayas sustain one third of the global population. For these reasons, the Himalayas are rightly referred to as the 'third pole' (ICIMOD), as the mountains hold the most glaciers after the poles and play an important role in cooling of the planet. All of Bhutan's rivers drain into the Brahmaputra.

As a progressive society, Bhutan has no gender bias between men and women. Hierarchy in the society is based on meritocracy as there is no caste system in culture. After becoming a constitutional monarchy in 2008, the written constitution mandates that 60 percent of Bhutan shall remain under forest cover for all times to come. Presently, the forest cover is more than 70 percent of our land area. The constitution also guarantees universal health care and free education until high school. As a result, a significant share of our national budget is spent on education and healthcare (NSB Bhutan).

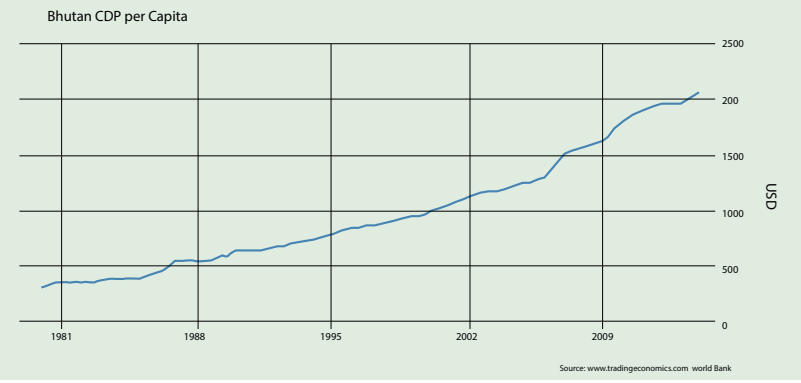

Figure 3: Bhutan 's steady growth in the last two decades. Bhutan is soon slated to leave behind its Least Developed Country (LDC) status.

Socio-Economic Factors

Although planned development activities were started only in the early 1960s with the construction of the first roads, Bhutan has made enormous progress in the socio-economic indicators in a very short time. From being one of the least developed countries in the world with a per capita income of only USD 300 in1980, Bhutan has since steadily advanced to the current per capita income of USD 2100, a seven fold increase. Adjusted for purchasing power

parity, the current per capita income is equivalent to USD 7500. The poverty rate in Bhutan has also declined to 12 percent since 2015. Bhutan is soon slated to graduate into the middle income countries. In terms of governance, Bhutan has one of the cleanest governments in Asia as per the Transparency International Report 2015. Freedom of speech is guaranteed by the constitution and we have uncensored access to the internet and all the major international cable television channels.

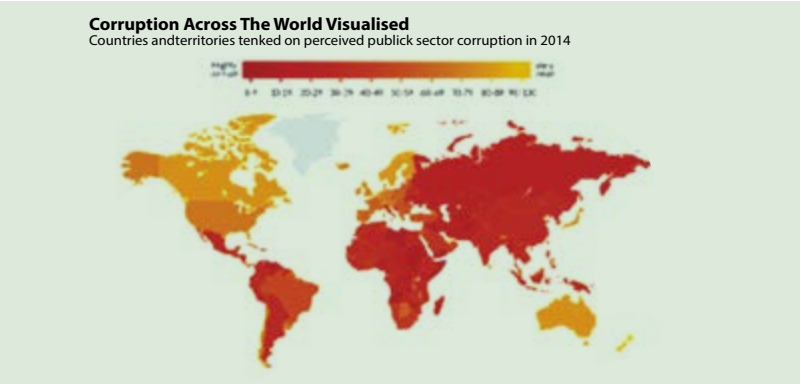

Figure 4: Bhutan is one of the least corrupt countries in Asia.

However, all this progress is coming at an incredible price. As we modernize and do well economically, our desire to do well materially also increases. Already lifestyle diseases like diabetes and obesity are becoming common, and vast areas of farmlands are being lost to the rapid pace of urbanization. Whereas centuries of toil and close understanding of the landscape and nature resulted in our picturesque cultural landscape, overnight some of the most beautiful paddy terraces have been converted into concrete jungles to accommodate the growing urban population.

As urbanization rates escalate (estimated to be 7-10 percent per annum) issues related to congestion, housing problems, pollution, waste, and crime also see a corresponding increase. In Bhutan, the point of inflection where the number of people living in the urban areas is going to become greater than the people living in the rural areas, is projected to happen around 2020. While urbanization is inevitable as we modernize, it is equally important to embrace this change in an intelligent way, without losing our cultural identity.

Basic education is free in Bhutan. As a result, more children are able to attend school; however, our education system does not teach our youth to embrace farming or cultivating the land. Therefore, we have an educated youth population that has a deep disdain for any job that involves manual labor. Youth unemployment is "by choice" and hovers around 9 percent (MoLHR Survey). On the other hand we have more than 50,000 expatriate workers in our burgeoning construction sector.

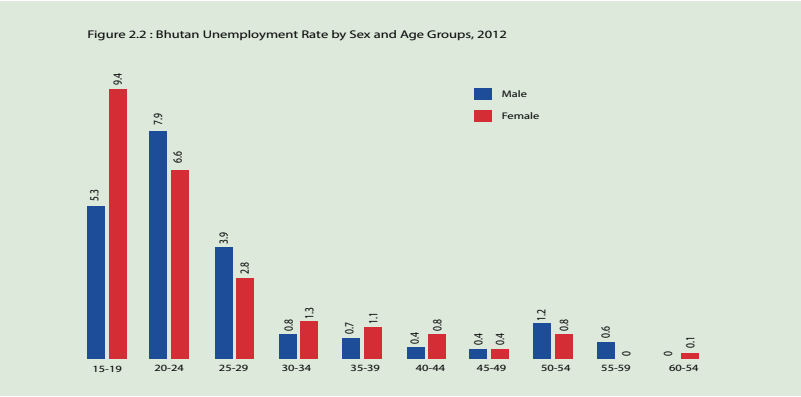

Figure 5: Youth unemployment is high in Bhutan as a result of young people's disdain for manual work.

Culture and Climate Sensitive Construction

The cultural identity of Bhutan lies in its rural hinterlands. Here the landscape has been carved by generations of families who had an innate understanding of their environment. The growing of paddy is very water intensive. Terraces have to be carved out of the hills and valleys so that the fields can be flooded using gravity flow during the growing season. A great degree of cooperation with the community is required because water resources have to be shared. The community has to collectively guard their crop against wildlife predation. A high degree of collaboration and planning is required to get anything done. As far as possible, whatever was available within their immediate environment was used to their advantage in a sustainable way. Homes were made of rammed earth built over stone foundations. Elaborate wooden facades were fashioned by village carpenters, using logs cut from the nearby forest.

Almost all the building materials were readily available within the village. Houses were built in clusters on unproductive land as all the fertile land was allocated to agriculture. Building materials were locally sourced and the close knit communities helped each other by contributing free labor based on the principles of reciprocity. All these efforts culminated in a landscape that was culturally distinctive with terraced paddy fields surrounding a cluster of villages interconnected with meandering footpaths. The carbon footprint was very minimal. The buildings were oriented to get the maximum sunlight into the rooms. The rammed earth houses kept the residents cool in the summer and warm in the winter.

Figure 6: A great degree of cooperation and coordination is required to farm terraced land. Houses are built in clusters of marginal land.

The urban environment of today looks nothing like the idyllic setting that characterizes rural Bhutan. Already vast tracts of urban Bhutan are blighted by the sight of concrete buildings that look out of place and incoherent with our cultural landscape. The building technology adopted is considered modern but foreign to Bhutan. As a result, the traditional craftsmen, whose knowledge crafted much of Bhutan's rich architectural history is rendered obsolete on our urban construction sites. Instead legions of foreign workers are a ubiquitous sight at all construction sites in Bhutan's fast

growing urban areas. Since Bhutan falls in the highest seismic zone (GSI Seismic Map), there is a misperception, often magnified by how financial institutions give loans, that modern buildings made of reinforced concrete are less susceptible to earthquake and fire damage, and therefore superior to traditional rammed earth and timber houses. Moreover, most of the modern building materials have to be imported therefore contributing to green house gas emissions as Bhutan's transportation sector is entirely dependent on fossil fuel imported from India.

Figure 7: Thimphu, the capital of Bhutan. Urbanization is rapid and the resultant form is nothing like the Bhutan of yester years.

While people traditionally walked from one place to another in the past, owning a vehicle has become a high priority on the Bhutanese wish list today. Already there are, on average, one car for every ten Bhutanese. This has resulted in traffic congestion during peak hours and using up almost all of our hydro earnings spent on importing fuel. The inefficient delivery of public transport facilities is one of the main reasons why owning a car is seen as a necessary convenience. It is ironic that Bhutan exports clean energy (electricity from hydro power) and uses that earning to import dirty energy like fossil fuel (according to Bhutan Trade Statistics).

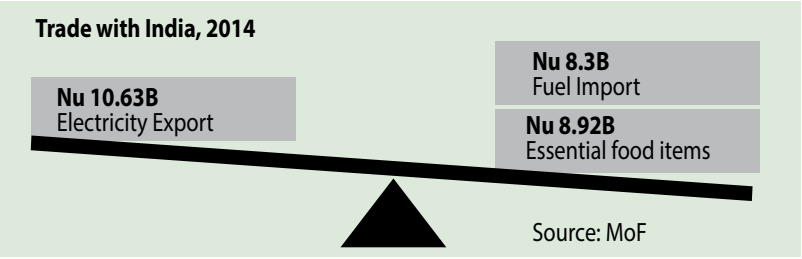

Figure 8: Bhutan exports clean energy, and uses those earnings to import dirty energy.

As more people aspire to climb up the economic ladder, the demand for car ownership is only going to grow with the resultant increase in the import of fossil fuel contributing to global warming and climate change. Since most of the population lives on the valley floor close to their fields fed by the rivers, the potential damage to life and property from glacial lake outburst flood (GLOF) as a result of climate change and accelerated melting of glaciers is a constant threat for our communities. The effects of GLOF which is also known as the 'tsunami from the sky' will also be equally devastating to the communities of our downstream neighbors. Risk reduction measures include artificially lowering the water level in the lake through human intervention.

Figure 9: Risk reduction method to avert GLOF includes artificially lowering the water level of the lake through human intervention

Aside from GLOF, some of the potential impacts of Climate Change on Bhutan are landslides, erratic weather pattern (heavier rains and longer droughts), reduction in irrigation availability affecting crop production, changing growing zones and prevalence of diseases and pests, and water scarcity affecting our hydro-power generation. While the well-being of its population is the ultimate aim of all development plans, it is important to ensure that we balance economic returns with the preservation of our rich environment and cultural heritage. Therefore, it is important to find areas of cooperation where we can address the challenges of climate change both in terms of green house gas emission reduction and resilience building against the impacts.

Perhaps we should learn from our fore fathers and use our immediate environment to cater to our everyday needs. A good understanding of our climatic conditions and working in consideration of the limits imposed by our natural terrain are some of the immediate actions we are undertaking. Some of the most recent town planning concepts adopted in Bhutan call for the preservation of farmland in order to ensure that the cultural landscape is preserved to retain Bhutan's distinct place as an exotic destination for tourists.

Figure 10: Recent town plans call for preservation of farmlands and preservation of Bhutan's cultural identity.

There has been considerable discussion about making certain parts of the city pedestrian only areas, and improving and enhancing the footpath network within the urban areas. This is an important undertaking if we want to wean more people off cars. Bicycle paths extend from the city boundaries into the surrounding forests. The ancient trails used by our forefathers are repurposed as hiking and bicycle trails. As healthcare is free in Bhutan, any proactive and preventive policy to keep the population healthy by keeping them active is going to pay far more dividend than any reactive, remedial solutions.

Figure 11: Automated early warning systems are installed to give downstream population a head start to evacuate the disaster zone.

Adequate buffers have been maintained from the rivers' edge to ensure that no new developments are allowed in the high hazard areas at the risk of getting affected by flooding from GLOF. Where the risk is great, artificial lowering of the water level have been carried out to mitigate the risk. Automatic early warning systems have been installed to ensure that precious life and limb are not lost in the event of a disaster, by giving the population an early head start to flee the disaster areas. Awareness and advocacy programs are constantly carried out in the vulnerable communities. Mass tree planting initiatives are carried out to plant native trees in critical watershed areas. Just last year Bhutan broke the world record in planting the most trees in one hour (about 50,000 trees). The communities are already aware that the protection of their catchment area of the watershed are critical to the overall quality

and quantity of their water source. Rainwater harvesting and landslide management exercises are carried out where required.

Figure 12: Mass tree planting being carried out on steep slopes.

Also alternative renewable sources of clean electricity from solar and wind are being explored. The renewal energy master plan stipulates at least 20 MW of power from alternative renewals to supplement hydropower. As the hydro generation drops drastically as the river volume plummets in the winter months, solar and wind generated power can take over as Bhutan gets clear blue skies and strong winds during the winter months. Bhutan enjoys good irradiance of 5kW/m2and average wind speed of 4-6m/s during the winters. (Department of Renewable Energy, MOEA)

The revised taxation on vehicle import levies huge tax on conventional cars whilecompletely waiving off any tax on electric and hybrid cars. The initial high cost of the electric cars compounded with the almost zero resale value of old electric cars are some of the factors retarding the growth of electric car sales in Bhutan. However, as a serious commitment to reduce our dependence on fossil fuel, perhaps all transport paid for by the public's taxes like local city buses and pool vehicles in government offices, should be made mandatory to run on electricity. Our unique advantage in the age of global warming and climate change should be to migrate fully to using electric power for our transport, cooking, and heating needs and thereby achieve energy independence.

Conclusion

With regard to Climate Change, Bhutan can participate in the focus area of knowledge sharing and technology transfer within the BIMSTEC region. As Bhutan has a rich forest and bio diversity conservation track record, Bhutan can share its experiences and best practices. As a steward of a rich and vibrant culture and environment, Bhutan can talk about her experience with high value, low volume tourism, and increasing eco-tourism. Bhutan will also be a storehouse of knowledge on local best practices on sustainable land management practices.

Another area Bhutan can share its expertise is on clean development technologies, especially renewable energy. It would also be interesting to work on archiving the traditional knowledge on climate change and compile a document from all the BIMSTEC countries. Community based disaster management practices would be one area we can collaborate. Bhutan also has a wide range of scientific data on glaciers and GLOF. Capacity building on climate change mitigation and adaption is another area where we can collaborate as fighting climate change requires strengthened linkages and integrated, resilient solutions.

Myanmar

Toe Aung

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Mr. Toe Aung has been serving as the Assistant Director, Forest Department, Ministry of Natural Resources and Environmental Conservation, Myanmar. He is responsible to oversee and development of Mangrove Section, mangrove rehabilitation projects by JICA and Integrated Water Resources Management for Pago and Sittaung Rivers by Norwegian Water Institute, and Meikhtila Lake Integrated Development Project by the Government of Netherlands.

Currently he is the member of Worldview International Foundation, ASEAN Mangrove Network AMNet, and Mangroves for the Future MFF/IUCN.

A Coast Without Mangroves: Lessons on Climate Change Mitigation and Coastal Protection

Toe Aung & Conor MacDonnell, ***Myanmar***

Abstract

Myanmar, with its long coastline, possesses approximately one-fifth of the combined coastal length of the Bay of Bengal Large Marine Ecosystem. Myanmar has been ranked the second most climate change affected country in the world in the Munich Re's 2015 Global Climate Risk Index. Indeed, the coastlines in Myanmar are frequently affected by tropical storms that regularly develop in the Bay of Bengal during the monsoon season, threatening the vulnerable, often unprotected, coastline and the people – half of Myanmar's population lives? on the coasts and deltas. Hence, climate change and its adverse consequences have been among major concerns to be dealt with in order to secure the livelihoods of coastal communities in Myanmar.

While the coastal communities are predominantly exposed to the impending impacts of climate change, one of the critical coastal ecosystem e.g. mangrove ecosystems plays a significant role in addressing climate change on two major aspects; one is mitigating climate change through carbon storage, and the other one is reducing the impacts of climate change both in terms of reducing physical exposure of coastal communities to natural hazards and providing them with the goods and services to withstand and recover from crises. The 2004 Indian Ocean tsunami that hit the Bay of Bengal region has shown clearly how mangroves could play a role in securing lives and livelihoods of the coastal people. Similarly, in Myanmar, during the deadly 2008 Cyclone Nargis, the national park Meinmahla Kyun Wildlife Sanctuary saved thousands of people that relied on marine resources in the Ayeyarwady Delta.

Recent observations show that the carbon storage in the vegetated mangrove ecosystem is comparatively high and play a vital role in mitigating climate change. Mangroves and connected vegetated coastal resources deserve urgent attention for conservation and restoration for their potential role in mitigating climate change as well as in building resilience.

This paper therefore aims to inform the policy- and decision-makers in the Bay of Bengal region about the significant coastal protection function of mangroves, their role and value in climate change mitigation and resilience-building.

Introduction

The Republic of the Union of Myanmar is geographically and politically at a strategic location among Southeast Asia, China and India –, three important regions in Asia. Myanmar with its 2,832 kilometer-long coastline possesses approximately one-fifth of the combined coastal length of the Bay of Bengal Large Marine Ecosystems (BOBLME, 2012). The coastal/delta areas cover six states and regions such as Rakhine and Mon States, and Ayeyarwady, Pago, Yangon and Tanintharyi regions. The most recent population census 2014 in Myanmar has shown that the population in the coastlines and deltas accounts for 23.95 million people, representing 46.58 percent of the country's population. Out of the coastal regions and states, the highest population density occurs in the Ayeyarwady Delta.

The key message here is that with respect to the impact of climate change, Myanmar has been ranked the second most affected country in the world on Munich Re's 2015 Global Climate Risk Index (Kreft et al., 2014). Accordingly, the coastlines in Myanmar are frequently affected by tropical storms that regularly develop in the Bay of Bengal between May and October, threatening the vulnerable, often unprotected coastline and the people living on the coasts. This paper therefore aims to highlight the context of Myanmar in the Bay of Bengal Region on the role of conservation and management of coastal resources, in particular, mangroves. The South and Southeast Asia regions comprise approximately 41 percent of the world's mangroves (Spalding et al., 2010; FAO 2015). These mangroves are unique ecosystems that provide incredible goods and services to local people, and enrich the Bay of Bengal large marine ecosystem. Maintaining this green belt of coastal mangroves is essential to securing coastal communities. If mangroves are protected, they in turn offer critical benefits both to the ecology and the economy in the short run, as well as climate change mitigation in the long run.

The 2004 Indian Ocean tsunami and 2008 Cyclone Nargis in Myanmar offer lessons about the role and value of mangroves in coastal protection. Myanmar, its coastlines accounting for the large part of the Bay of Bengal region, plays a crucial role in making the whole region environmentally sustainable, economically viable, and more interconnected on a regional and international scale. The information in this paper therefore is expected to reach out

to decision-makers and politicians and increase their awareness on mangroves and coastal resources, to support more investment options on conservation and sustainable management purpose

The Bay of Bengal and Myanmar Context

With a large share of the Bay of Bengal Large Marine Ecosystem, Myanmar shares common maritime boundaries with Bangladesh, India and Thailand. The continental shelf covers approximately 230,000 km2 with a relatively wider portion in the central and southern parts. The Exclusive Economic Zone (EEZ) is about 486,000 km2 (BOBLME, 2012). From north to south, Rakhine Coast, Ayeyarwady Delta and Tanintharyi Coast are the three coastal zones of Myanmar [Figure 1]. The Taninthary Coastal area has the longest coastline stretching over approximately 1,200 km from the Gulf of Mottama to Pakchan River. It is fringed in southern part by the Myeik Archipelago and is also home to more than 1,700 inshore and offshore islands (NSAP, 2015).

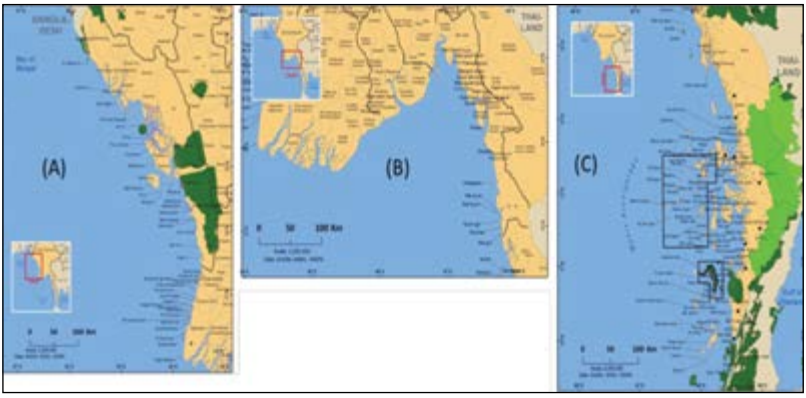

Figure 1. Three main coastlines in Myanmar (A) Rakhine Coast (B) Ayeyarwady Delta, and (C) Tanintharyi Coast.

Myanmar Key Coastal Habitats: Mangroves, Coral Reefs and Seagrass beds

With a long coastline of over 2,800 km, Myanmar is home to diverse ecological and socio-economic systems. Mangroves, coral reefs and seagrass beds flourish mainly in the Myeik Archipalago. Estuaries and mud flats are common in the Ayeyarwady delta while beach and dunes occur throughout the Myanmar coastline.

The World Atlas of Mangroves (Spalding et al., 2010) shows that mangroves cover most parts of Myanmar's coastlines with an estimated area of 502,900 ha, representing 3.3 percent of the global total and making Myanmar the third largest mangrove coverage in Asia, after Indonesia and Malaysia. In the past, the majority of mangroves occurred in the Ayeyarwady delta, with the remainder in Tanintharyi and a lesser portion in the Rakhine area. Currently, however, mangroves in the Ayeyarwady Delta have been alarmingly depleted, and almost 80 percent of mangroves have already disappeared (Table 1). Under such a severe rate, mangroves in Tanintharyi now represent the largest areal extent. The main causes of mangrove depletions are conversion to rice fields followed by conversion to shrimp ponds and rural development. Species distributions and compositions of mangroves differ amongst the three coastal regions. The number of trees, plants, shrubs, herbs and climbers that include true plus associate mangroves species are 148, and 34 out of them are true mangrove species (Giesen et al., 2006). The IUCN Red List shows 24 true mangrove species (Zhang and Aung, 2015).

Table 1.Trends of mangroves in three main regions in Myanmar

Region	**1980 (ha)**	**2010 (ha)**	**Remaining Percentage over three decades**
Rakine Coast	167,483	90,900	54 %
Ayeyarwady Delta	296,448	42,983	14 %
Tanintharyi Coast	195,103	192,629	99 %
Total	**659,033**	**326,513**	**50 %**

Coral reefs in Myanmar remain largely unexplored and the species diversity and health of this ecosystem is poorly known. An extrapolation of potential habitat area of coral reefs is suggested to be 187,000 ha (BOBLME, 2012). Recent studies suggest that Myanmar coral reefs have declined over 56 percent (Burke et al. 2011). The proximal cause of the ecological impoverishment is prolonged exposure to Malthusian fishing techniques, such as blast fishing, illegally small-meshed fishing nets, and unregulated marine product resource extraction such as sea cucumbers and clams.

Seagrass beds are found in shallow areas interacting with both mangrove and reef communities. There is little information on the status and distribution of seagrass in Myanmar, and the up-

to-date data show that 10 seagrass species are currently identified in Myanmar waters (Novak et al. 2009, Tint Tun & Bendell, 2010). Mining activities near the coasts or estuaries have been reported as a threat to sensitive seagrass species in many countries, including Thailand and Malaysia.

Mangroves, Climate Change and Coastal Protection

Mangroves at a glance

Mangroves lie in the transitional zone from land to sea, in particular in tropical regions. Its distribution is circum-global, with the majority of populations occurring between the latitudes of 30°N (Tomlinson 1986). The total area of mangroves has been assessed to be approximately 15,236,100 ha (Spalding et al. 2010). Ecologically, economically and socially, these mangroves play a crucial role to supporting goods and services to human beings. Their existence between land and sea are very significant if compared to other terrestrial and marine ecosystems. As their formation represents both ecosystems, mangroves highly produce timber, fuel, construction materials, seafood, fodder and medicine. More significantly, intangible services such as erosion control, coastline stabilization, protection from tsunami and storms are special functions of mangrove ecosystems. Recent findings have shown that mangroves sequester carbon more than other ecosystems, thereby helping environments and societies regulate climate patterns and combat global warming. Mangroves are also expected to support land building processes that are supposed to possess a linear relationship with sea level rise. Given that this hypothesis is true, a number of isolated countries would be relatively safe from sinking to the sea because of the gradual rise of sea level.

However, like tropical rain forests, mangroves are being degraded on a global scale through overexploitation of their potentially renewable products and conversion into single-use options such as agriculture. Due to the increasing impacts of biotic and abiotic disturbances, mangrove forests are becoming one of the world's most threatened ecosystems, and are rapidly disappearing in many tropical countries. The major impediments to sustainable management of mangroves and their associated resources in the worldwide condition summarized by International Society for

Mangrove Ecosystems (ISME, 2014) are: conversion to agriculture, conversion to aquaculture, pollution and sedimentation, hydrological modification, coastal land use changes, lack of appropriate legislation and enforcement of regulation, shortage of capacity, inadequate awareness and participation, climate change and sea level rise. Figure 2 shows the trends of mangroves in the world region by region from 1980 to 2005. The highest depletion rates occurred in Asia, more specifically in Southeast Asia, where sensitive socioeconomic issues remain unsolved.

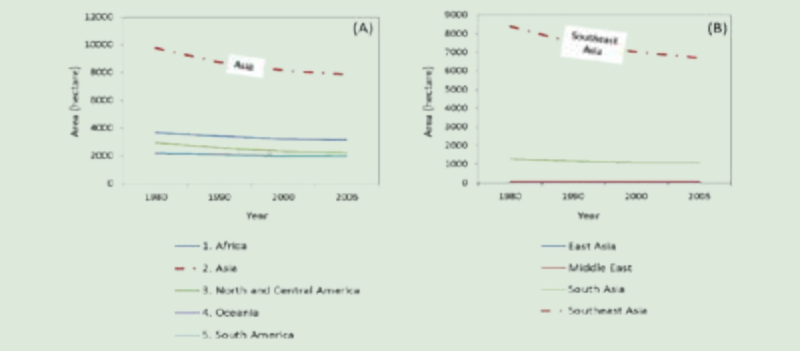

Figure 2. Mangrove covers by regions (A) Trends of mangroves in five major regions in the world, and (B) Trends of mangroves in Asia.

Note: Data adopted from World Atlas of Mangroves by Spalding et al. (2010) and Global Forest Resource Assessment 2015 by FAO (2015).

Under such decline condition, frequent and intense storms with climate change scenarios would affect the coastal population more severely. In this context, mangroves that are the only high-structure vegetation thriving across the tropical coastlines are expected to largely reduce the intensity of storms. Hence, the countries in the Bay of Bengal Region, India, Bangladesh, Myanmar, Thailand, Malaysia and Indonesia largely covered by mangroves should take opportunities of coastal protection functions produced by mangroves, and therefore conservation and restoration is a must.

Climate Change Mitigation and Mangroves

Regarding climate change in Myanmar, some key observed extreme events presented by the United Nations Environment Program (UNEP) 2012 are: a) an increase in mean temperature (~0.08°C per decade) with the prevalence of drought events, b) an increase in the

intensity and frequency of cyclones and strong winds, c) an increase in overall rainfall with a declining trend in some areas, late onset and early termination of the south-west monsoon, with rainfall variability including erratic and record-breaking rainfall events, d) an increase in the occurrence of flooding, and e) an increase in extreme high temperatures.

The main cause of climate change is increased atmospheric levels of carbon dioxide (CO_2), in association with high CO_2 emissions. Deforestation and forest degradation, mostly in developing countries, account for approximately 20 percent of global anthropogenic CO_2 emission, which are the second greatest source of CO_2 emissions after fossil fuels. From 1750 to 2011, emission from fossil fuel combustion and cement production have released 375 GtC to the atmosphere, while deforestation and other land use change are estimated to have released 180 GtC (IPCC, 2013). In this context, climate change experts and policymakers have considered the forest sector as one of the climate change mitigation measures.

In this matter, compared to other types of forests and ecosystems, wetlands have been given special attention for their enhanced functions as a carbon sink. Mitsch and Gosselink (2015) stated that wetlands are substantial storages of carbon (C) in the lithosphere; approximately 20 to 30 percent of the terrestrial total organic carbon (TOC) storage is found in wetland environments (Lal, 2005, 2008). More importantly, recent observations have shown that the biomass and deep sediment of vegetated coastal wetlands represent a high portion of carbon sink and storage, and these coastal carbon stocks gained from marine environments are referred to as "blue carbon". However, these emissions are thus far relatively unappreciated in most policies relating to climate change mitigation. It is estimated that the conversion and degradation of vegetated coastal wetlands including mangroves, tidal marshes, and seagrass beds each year may ultimately release 0.45Pg (billion tons) of CO_2 to the atmosphere, in which mangroves alone contribute 0.24 Pg of CO_2 (Pendleton et al., 2012). The emissions from the mentioned three vegetated coastal ecosystems approach the annual CO_2 emissions (2014) of the United Kingdom, and the emission from mangroves is roughly equivalent to that of the Netherlands (Olivier et al., 2015). In terms of carbon storage, Siikamaki et al. (2012) divided the

world's mangroves into three regions by longitude, and found that the Asia and Oceania regions have the largest potential emissions offset supply, comprising roughly two-thirds of potential global offset availability. Considering the emission rate from mangroves lost in the Bay of Bengal region being home to approximately over one-third of mangroves worldwide, the region urgently needs to stop conversion of mangroves to other unsustainable land uses for high potential carbon benefits.

Information on mangroves therefore should be carefully pursued because they have the greatest potential to be incorporated into climate policy frameworks. If these mangroves are left undisturbed, the carbon storage by mangroves will continue to expand through biological sequestration of CO_2 and carbon burial (Kristensen, 2008). If the current trends in degradation continue, however, much of the carbon stored in mangroves, along with its future accumulation, could be lost (Donato et al. 2011). Such a phenomenon are said to be "sinks to sources". In addition, in parallel to preserving mangroves simply on the basis of reducing carbon emissions, coastal conservation would also bring other benefits, such as biodiversity protection and livelihood opportunities to local communities. The South and Southeast Asia regions connecting to the Bay of Bengal have the largest potential emissions offset supply, and investments in reducing emissions from mangroves lost in these regions could be economically viable and reasonable. For example, clean development mechanisms (CDM), reducing emissions from deforestation and forest degradation (REDD+), community-based Ecotourism, and payment for ecosystem services (PES) could become programs well fitted with the conservation of mangroves.

Coastal Protection and Mangroves

The Indian Ocean tsunami hit the Bay of Bengal region on December 26th 2004, produced by the largest earthquake to have occurred with a massive magnitude of 9.3 since the 1964 Alaska earthquake, and the second largest ever recorded since 1960 M. 9.3 Chile Earthquake (Fehr et al. 2005). During the tsunami, more than 200,000 people are thought to have died (Satake et al. 2006).

After experiencing the impact of that tsunami, many case studies reported that the areas covered with mangrove vegetation were

less affected than those without. Danielsen et al. (2004) stated that mangrove plantations attenuated tsunami-induced waves and protected shorelines against damage. After the 2004 Indian Ocean tsunami, simulation models were done by Yanagisawa et al. (2010) in the most tsunami-affected sites in Southeast Asia. Banda Aceh, Indonesia, was used for the study. Results showed preliminary evidence for the protective role of mangroves for smaller tsunami waves. The model attempted to show scenarios with and without mangroves. The model supported that 10-year-old mangroves performed best for tsunami waves < 3m, reducing maximum inundation depth by 38 performed and hydrodynamic force by 70 percent behind the forest. Furthermore, 20- and 30-year-old mangroves performed better for greater tsunami wave heights, indicating the possible importance of conserving mangroves over long periods of time to enhance the protection they provide.

An integrated approach includes the analysis of satellite imagery, field surveys, and numerical modeling of the 2004 Indian Ocean tsunami. Yanagisawa et al. (2009) also provided basic information for the establishment of mangrove forests to help mitigate the damage from tsunamis. Their results showed that a mangrove forest of Rhizophora sp. with a density of 0.2 trees m^2, and a stem diameter of 15 cm in a 400 m wide area, can reduce the tsunami inundation depth by 30 percent when the incident wave is assumed to have a 3.0 m inundation depth and a wave period of 30 minutes at the shoreline. The protective role of mangroves considered therefore should be based on the areal coverage, species, diameter, height, structure and composition of mangroves. More importantly, in order to reduce the impact of future tsunamis, mangrove restoration should also be coupled with early warning systems, infrastructure, emergency preparedness and environmental awareness.

Another deadly lesson was also left in Myanmar from cyclone Nargis that occurred on 2nd May 2008. Nargis was the worst natural disaster in the history of Myanmar, and the most devastating cyclone to strike Asia since 1991 (TCG, 2008a). It was also the 10th deadliest cyclone in the world on record (www.wunderground.com), and had significant effects on 37 townships in the Ayeyarwady and Yangon Regions. Damage was most severe in the Ayeyarwady

Delta (where the most extensive mangroves existed in the past), an area covering some 23,500 square kilometers, known as the country's rice bowl. The effects of cyclonic winds were compounded by a 3-4 meter storm surge, and the damage was on a scale approximately equal to that suffered by Aceh in Indonesia during the 2004 Indian Ocean tsunami. Nargis left almost 140,000 people dead and missing in the Delta. An estimated 2.4 million people lost, partially or completely, their homes, livelihoods and community structures (TCG, 2008b).

Once, the Ayeyarwady Delta was largely covered with mangrove vegetation. Even tigers were found in the healthy, dense mangrove forests, according to the World Atlas of Mangroves (2010), as well as anecdotal record. However, mangroves coverage dramatically fell from 1980 to 2010 compared to other regions in Myanmar; less than 20 percent of the mangroves in 1980 currently remain in the Ayeyarwady Delta. The majority of land has been converted to rice cultivation. There are seven reserved forests in the delta, and they all are supposed to have covered almost 100 percent with mangroves. However, some reserved "forests" have been stripped of mangroves and no longer exist as shown in Figure 3. Since the impacts of Nargis, people have become increasingly aware of the benefits of a healthy mangrove system, like the ones existing in the region 50 years ago, would have had in reducing the impacts of natural disasters and subsequent human suffering.

Due to a number of constraints in accessing the sites, scientific studies concerning the role of mangroves were not able to be carried out at that time. Most have been recorded with just field observations, apart from one source titled "the mitigation effects of mangroves during cyclone Nargis" by Thant et al. (2009). Their study is based on extensive interviews with 450 households in the cyclone-affected region, and concluded that many survivors escaped from the strong storm surge by clinging to trees in or near their communities. Those survivors believed that they might not have survived without mangrove vegetation.

The corresponding author of this current paper visited the region one month after Cyclone Nargis. During the field trip, we informally talked to a number of cyclone victims who survived in the mangrove forests. Most of their responses showed that they would not have

survived without mangroves. The geographical settings of the Ayeyarwady Delta, with a complex structure of rivers, streams, creeks, would have been extremely difficult for local people to evacuate from during natural disasters. Since that time of Nargis onwards, the local people have shown a strong interest in having mangrove vegetation around their communities. The government, in collaboration with international communities, has since established mangroves as natural shelter in concert with concrete structures.

There is limited scientific observation to explain the role of mangrove functions during cyclone Nargis. Given the lack of empirical data, this analysis was derived from the field observation and anecdotal records of the local community, and more scientific research is recommended. Perhaps the most telling anecdote comes from the Meinmahla Kyun Wildlife Sanctuary (MKWS), which was established in 1986. It is also an ASEAN world heritage site. It is located at Bogalay township in the Ayeyarwady Delta. Figure 3 shows that the core zone and dark green in color inside the MKWS represents dense mangrove vegetation despite almost all other reserved forests being converted to other land use types. During Cyclone Nargis, half of the villagers were living at the western sites of the MKWS. According to Thant (2013) and our field observations, even the survivors were carried away by the storm surge. After several hours, their lives were saved as they clung to mangroves at the edge of the wildlife sanctuary.

Inside the MKWS, all staff who worked and stayed at the camps survived, and no fatalities were reported. Such condition encouraged us to listen to their sufferings carefully. One of the survivors explained, "The tide was coming up at that night of strong storm, myself and my family escaped by climbing the mangroves. Then, the tides were down, and we went down to the camp, but next morning I was surprised to see that there were countless bodies at the western edge or rim of the MKWS. We did not expect how deadly the cyclone event happened last night here [unclear statement]". On the contrary to the western sites, in the villages located at the eastern sites of the MKWS, mortality was apparently decreased. Such observations should be combined with more detailed and scientific investigation. Although no scientific observations were made, local people understood that the dense

mangrove vegetation of MKWS reduced mortality in the park itself and in the sheltered eastern or leeward sites of the park. Tragically, the western sites with bare vegetation and large fields of rice cultivation faced a high human mortality rate.

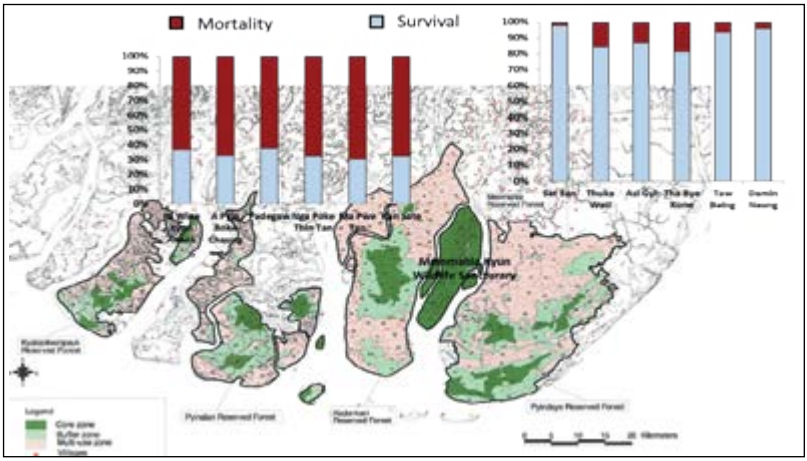

Figure 3. Different mortality rate of cyclone-affected villages located at the windward and leeward sites of Meinmahla Kyun Wildlife Sanctuary (Six selected villages from each side of the MKWS).

Cyclone Nargis has given invaluable lessons to society. There are almost no records of people's desire or official proposals for mangrove protection during the pre-cyclone period, but now there have been many claims by local people to effectively conserve mangroves, and if necessary, restore mangroves. So, the awareness of people on the conservation of mangroves has been apparently and increasingly raised. Cyclone Nargis offers a grim conservation milestone.

Mangroves for the Future Initiative

Myanmar took a first, important step to securing the livelihoods of coastal communities and mitigating climate change by becoming the 11th member of "Mangroves for the Future" (MFF), launched by the International Union for Conservation of Nature (IUCN) in 2014. The MFF program is a partnership-based initiative that was triggered and established as a strategic and long-term response to the devastating impacts of natural disasters and the continued degradation of coastal ecosystems. Its objective is to strengthen the

environmental sustainability of coastal development and promote sound investments in coastal ecosystem management, as a means of enhancing resilience and supporting local livelihoods throughout the Indian Ocean Region. The MFF began in 2006 by engaging the country's worst-affected areas and those recovering from the 2004 tsunami: India, Indonesia, Maldives, Seychelles, Sri Lanka and Thailand. Support has been extended to other countries for which poverty and vulnerability to natural disasters and climate change are major concerns.

This program has been bringing together almost all countries in the Bay of Bengal Region. Moving forward with this program will promote regional collaboration that will result in securing livelihoods, flourishing marine ecosystem and solving border issues. By taking opportunities to closely work with BOBLME, the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and the International Center for Integrated Mountain Development (ICIMOD), this partnership-based MFF program will produce more efficient collaboration.

Conclusion

Without any doubt, the Bay of Bengal Large Marine Ecosystems is comprised of critical ecosystems that play a vital role in the global climate change discussion. More than merely beautiful, unique parts of the region, they provide food security, livelihood promotion, coastal protection, and marine biodiversity enrichment. Millions of people rely on these ecosystems. In this regard, the environmental and socio-economic issues BOBLME faces will directly and indirectly become a global concern. In turn, Myanmar is a significant part of the BOBLME, which plays a crucial role in the region for both short-term socio-economic benefits and long-term value in combating climate change. This paper therefore aims to highlight what would happen to the coast of the region without mangroves, the region being home to the center of mangrove ecosystems in the world. Accordingly, Myanmar would benefit from sharing, learning and implementing the best practices from other partners by closely working not just with BIMSTEC, but BOBLME and MFF. Committing to mangrove preservation contributes to a healthier, more prosperous and secure future for all coastal communities facing the threat of climate change.

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India

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Why We Need Community-Level Responses to Climate Change: The Case of Odisha

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Abstract

All coastal nations bordering the Bay of Bengal are expected to be victims of global warming. The Indian government believes that an average of 1 mm rise in sea level per year is likely to occur along the country's coastline. Though the decision- makers in the top echelons are aware of these forthcoming changes, little work has been done to educate and prepare the coastal communities to adapt to climate change. A high percentage of coastal communities derive income from nature-dependent livelihood activities like farming or fishing. Yet no biodiversity assessment study has been carried out. There is also zero data on local salinity levels and the changes in the seasons as well as rainfall, humidity and ambient temperatures. There is a need for collecting baseline data at sample areas representative of the district that can be used as a reference point to record the expected changes in the future. The decline in livelihoods of affected communities should be properly researched and documented so that governments would pay serious attention in addressing the impacts of climate change. The paper seeks to lay down the strategy and methodology to prepare this vulnerable population for the deep impacts of climate change on local livelihoods dependent upon aquatic biodiversity and fresh water resources. It is crucial to involve marginalized coastal communities in the debate and mitigation plans, which is now confined to scientists and senior government levels. Increased participation as deeply interested stakeholders in government planning will enable better adaptation to climate change's impact.

Introduction

Global warming causing climate change has hit the entire world, and India is no exception to this phenomenon. Coastal communities like fishermen and cultivators are projected to be directly affected by climate change-related Sea Level Rise (SLR) and saline influx by increasing vulnerability of coastal ecosystems. (Senapati & Gupta, 2014). India's 8,118 km coastline and its adjacent inland and estuarine aquatic and terrestrial bodies are livelihood sources of fishing and agriculture-dependent communities. About eight percent of the world's population, or about 540 million people, depend on marine fishery.

Recent studies reveal that the seas are rising much faster than they were rising in the 20th century. Worldwide estimate of SLR in the 20th century was an average rate of 1.7 + 0.5 mm/year (IPCC, 2001). It forecasts rise from 1990 to 2100 of 9-88 cm with a median of 48 cm. Estimates put the sea level rise by 2100 between 1 and 2 mm (Senapati & Gupta, 2014). However, this rise is not expected to be uniform globally since it will be influenced locally by land mass, oceanic currents and wind patterns (FAO, 2010). The rise in sea levels will cause loss of property and infrastructure, increase flood risks and loss of life. Tourism will be hit severely due to lost beaches. Flooding is expected to be a major impact also leading to loss of farm output. Many coastal communities live a fragile existence due to high dependence on depleted and over-exploited fishing base and also degraded coastal ecosystems (Senapati & Gupta, 2014). Climate change is expected to sharpen these impacts and lead to a huge decline in productivity and consequent loss of livelihood for marine fishers. High fuel costs are now imposed on artisanal fishermen who have to venture out to deeper waters for marine fish. According to the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report, there shall be an increase in cyclone frequency, intensity and sea level rise (IPCC, 2013). This will lead to coastal flooding, loss of corals and mangrove forests, thereby increasing the impact of waves which in turn could lead to erosion of coasts.

Already, due to the increasing level of anthropogenic activity, vast stretches of coastal patches are now degraded and have exhibited a decline in productive values of farm and fisheries. This has also lead to migration of farm and fish workers which is now seen in some parts of coastal Odisha.

Topography, Fauna and Climate of Odisha

Odisha in eastern India is located between the parallels of 17°49'N and 22°34'N latitudes and meridians of 81°27'E and 87°29'E longitudes. It is bounded by the Bay of Bengal on the east, Chattisgarh on the northwest, Jharkhand on the north and Andhra Pradesh on the south and southwest. It has a coastline of 480kms. It extends over an area of 155,707 square kms and has the fourth largest forest cover of 48,366 sq. kms in the country. The coastal plains stretch from the West Bengal border, i.e. from Subarnarekha river in the north to Rushikulya river in the south. The coastal plains form the "Hexadeltaic region" or the "Gift of Six Rivers" as six rivers flow through it.

The Mahanadi is the largest river of Odisha and sixth largest river in India. Older than the Ganges, the Mahanadi harbors ancient life forms. The river carries on an average about 92,600 million cubic metres of water. Chilika Lake in Odisha is the largest brackish water lagoon of India (second largest in the world).

Table 1 : Coast length of six Districts of Odisha (in km)

Balasore	Bhadrak	Kendrapada	Jagatsinghpur	Puri	Ganjam	Total
80	50	68	67	57	60	480

Source: Fisheries and Animal Husbandry Department, Government of Odisha

Odisha's fauna includes more than 90 species of reptiles (three species of crocodiles), 14 species of turtles, 22 species of lizards and 52 species of snakes (excluding the 20 species of sea snakes) 14 species of turtles (including four species of marine turtles). The coast is famous for the three sea turtle rookeries, Gahirmatha, Devi coast and Rushikulya. The Gahirmatha coast is one of the two largest mass-nesting site for Olive ridleys in the world. Every winter, an estimated 800,000 waterfowl are counted during the bird census at Chilika Lake. Bhittarkanika mangrove forests also host about 100,000 water- fowl as per census figures apart from being home to nearly 1,400 estuarine crocodiles (largest population in India). Mammals, including endangered ceteceans like Irrawady dolphin, and mammals like fishing cats and otters, are reported from the coast. Chilika Lake is home to the famous Irrawady dolphins.

The climate of the state is tropical, characterized by high temperature, high humidity, medium to high rainfall and short and mild winter. The normal rainfall is 1,451.2 mm. Most rainfall is concentrated in a period of four months of monsoon (June to September). The table below shows how erratic rainfall was in the region during 2011, compared to normal levels.

Table 2 : Rainfall Pattern in 2011 (in mm)

Month	Normal Rainfall	Actual Rainfall	% Variation
Jan-March 2011	59.8	22.4	-62.54
April-May 2011	96.4	133.1	38.08
June 2011	216.5	213.9	-1.20
July 2011	339.9	201.8	-40.63
August 2011	356.0	354.3	-0.48
September 2011	231.9	393.1	69.51
October-December 2011	150.7	19.5	-87.06

Source : Agriculture Statistics 2011-12, Government of Odisha

During 2011, the pre-monsoon rainfall (April 11 & May 11) was excess by 38 percent as per figures displayed in Table 2. The monsoon rainfall (June 11 to September 11) was excess by 2 percent where post-monsoon rainfall (October 11 to December 11) was deficient by 87 percent. The detailed rainfall scenario for the year 2011 is shown below.

Table 3: Rainfall in six Coastal Districts -2011

District	Actual Rainfall mm	Normal Rainfall mm	Deviation %
Balasore	1,487.5	1,592.0	-6.6
Bhadrak	1,549.6	1,427.9	8.5
Jagatsinghpur	1,320.7	1,514.6	-12.8
Kendrapada	1,509.5	1,556.0	5.5
Ganjam	913.8	1,276.2	-28.4
Puri	1,051.7	1,408.8	-25.3
Total (for state)	**1,451. 2**	**1,338.1**	**-7.8**

Source : Agriculture Statistics 2011-12, Govt. of Odisha

On a closer analysis of the rainfall, as shown in Table 3, it is clear that there were widespread variations in the coastal areas with Ganjam exhibiting a deficiency of as much as 28.4 percent!

Table 4: Rainfall Deviation years (20-year period)
(1992-2011) (June-September Kharif cropping season)

20-year Average	1995	1998	1999	2003	2005	2010
< 81.22%	57.5 %	69.7%	70.9%	74.9%	76.4%	73.7%

Source: Agriculture Statistics, 2011-12, Govt. of Odisha

An analysis of the 20-year rainfall pattern (1992-2011) in Table 4 reveals significant fluctuations. Rainfall is crucial during the kharif season from June to September when most paddies are grown. Non-irrigated paddy cropping areas are critically dependent upon rain and such negative fluctuations can ruin standing crops. 2015 was a drought year with 20 districts receiving deficient rainfall. Ironically, 10 districts had excessive rains. It is undisputed that rainfall has been erratic since the 1960s, with below-normal rainfall across districts being recorded for most years.

Table 5: Average Annual Rainfall (LT) Change

Time period	1901-1950	1951-2013
Average annual rainfall	1,503 mm	1,451 mm

Source: State Disaster Management Plan, Odisha, 2013.

Table 5 illustrates that over a long-term period of 113 years, there has been reduction in quantum of average annual rainfall by around 52 mm or nearly 3.46 percent of the first half of the 20th century. Though it is too early to predict the next level of change, an annual 120 days of monsoon rain has now shrunk to 60–70 days. There is skewed distribution of rainfall, including spikes in rainfall, which causes torrential rainfall of over 200– 250 mm per day leading to flash floods.

There is no change in the +40 mm of excess annual average rainfall during the 21st century in coastal and western Odisha. Southern Odisha will receive deficient rainfall (–35 mm to no change). Northwest and southwest Odisha would get higher rainfall annually, ranging from +40 mm to +72 mm (Anon, OCCAP-2015-2010). Since most parts of NW and SW Odisha are hilly districts, excess rainfall may lead to flash floods and sand casting. There could be occupational adaptation by way of more cereal farming and fisheries. Rivers are expected to change course, depriving some agro communities of traditional farm livelihood.

Natural Disasters

Odisha regularly faces weather-driven disasters like floods, cyclones, heat waves and drought. The state has to spend huge resources to tackle such disasters which hit the state at frequent intervals. The state government has identified 266 villages of the six coastal districts as vulnerable to tsunami (Anon, OSDMA Report).

In 1999, the Super Cyclone hit the state with wind speeds above 250 kms/hour, which devastated vast stretches of the coastal districts.

Recently, the State witnessed two severe cyclones – "Phailin" (October 2013) and "Hudhud" (October 2014). These cyclones had very adverse impacts on coastal districts and caused extensive damage of properties. These were followed by torrential rains and heavy floods, further aggravating people's suffering after damaging crops and infrastructure (Anon, Economic Survey, 2014-15).

Table 6: Weather Disasters (1891-1970)

Weather Events	No. of occurrences
Cyclones	952
Tornadoes	451

Source : Odisha State Disaster Management Authority Reports

Table 6 illustrates the historic weather disasters faced by the state when 952 cyclones and 451 tornadoes hit it during the 80-year period.

Table 7: Casualties /Loss due to Major Cyclones

YEAR	Human deaths	Persons affected	Cropped area affected	Houses destroyed
1971 Cyclone	9,658	4.9 million	N.A.	N.A.
1999 Super Cyclone	10,000	19.5 million	17,11,000 ha	2,75,000
2013 Phailin cyclone	43	13.2 million	6,51,000 ha	5,41,000

Source : Odisha State Disaster Management Authority Reports

The catastrophic super cyclone of 1999 caused a storm surge of 26 feet, which travelled 20 kms inland in Jagatsinghpur district. Thousands of people drowned. Millions of mud houses were destroyed and 2.5 million domestic animals were killed, while nine million trees were uprooted or damaged.

Drought-prone areas have more than doubled worldwide since the 1970s. Studies indicate the change stems from the increase of severity along with enhanced warming of both sea surface and land mass (Maity and Nagesh Kumar, 2006). Its impact is more severe in the Odisha region due to its coastal position. According to the OCCAP, during 2015-20, there is an increasing trend in the probability of severe and extreme droughts for Odisha toward the end of the 21st century. Already, western Odisha faces drought in most years leading to a large-scale migration of farmers for work.

Odisha with 33,400 sq.km. of flood-prone area is the fifth most flood-prone state in India. Cyclonic winds and tidal flows also flood coastal areas. Flooding lasts 5–15 days along the coastal belt (Anon, OCCAP-2015-2020). It causes loss of life and damage to property

and crops, thereby affecting food security and livelihoods. Table 8 reveals the damage caused by floods over the last decade.

Table 8: Loss Caused By Major Floods

Year	Districts	Villages Population	Affected deaths	Human damaged	Houses	Crop loss
2006	27	18,912	6.73 million	105	1,30,460	4,65,000 ha
2007	15	12,407	4.23 million	91	1,04,712	3,18,000 ha
2008	19	9,794	6.17 million	110	2,58,155	2,58,155 ha
2009	15	1,451	0.394 million	56	12,547	1,29,000 ha

Source : Odisha State Disaster Management Authority

The intensity and duration of flooding is expected to increase due to deforestation. Annual flooding leading to silt deposition in flat alluvial coastal plains was once welcome. Resident farmers were used to such floods for centuries and many villages in Odisha have high foundation houses. It is forecast that the level of floodwater will be higher than the normal level and its duration longer than the normal three-four day period. Moreover, new areas are now experiencing floods.

In 1998, the state of Odisha faced an unprecedented heat wave situation in which 2,042 people lost their lives. A total of 752 people have died due to heat waves from 1999 to 2009. The average annual casualty is 68 human lives consisting mostly of the old and infirm. The state follows a morning office system to beat the heat. Schools start early morning and end before noon. Offices are closed by 1.00 PM. Advertisements are issued urging the public about heat wave and to drink fluids like buttermilk and water.

Odisha Climate Change Action Plan (OCCAP) 2015-2020

Odisha was one of the first states in India to prepare a climate change action plan in 2009. Now the second OCCAP for 2015-2020 is in operation. Coastal Odisha is expected to remain less warm than the rest of the state though it shall breach the 2°C barrier. North-western, western and south-western Odisha are expected to exhibit higher temperatures. This is expected to have adverse consequences on terrestrial and marine ecosystems.

A Coastal vulnerability index (CVI) study by the Indian National Centre for Ocean Information Services (INCOIS) has revealed levels of vulnerability, loss and damage from sea level rise based on coastal geomorphology and tidal range. Table 9 breaks down the geography by sub-region:

Table 9: Vulnerability Index Probabilities for six Districts

Low CVI	Medium CVI	High CVI
76 kms - part of Ganjam, Puri and Kendrapada	297 kms - North Ganjam, Central Puri, Jagatsinghpur, Kendrapada, south Bhadrak and North Balasore	107 kms - covering Northern Puri, Parts of Jagatsinghpur, Kendrapada, North and Southern Bhadrak and Northern Balasore

Source : Odisha Climate Change Action Plan, 2015-2020

The carbon footprint study estimates that the state emitted 98.525 megatons of CO2-equivalent. Per capita emissions are 2.35 metric tonnes, which is higher than the national average of 1.7 metric tonnes (estimated as per 2007 baseline). To tackle climate change-induced impacts, the state government has prepared a budget of Rs.31,663.58 crores (USD 4.72 billion) (Anon, OCCAP-2015-2020).

Impact on Agriculture Livelihood:

Agriculture plays an important role in the socio-economic development of the State. Odisha is agrarian-based with Agriculture and Animal Husbandry sector contributing 17.49 percent to the Net State Domestic Product (NSDP) in 2011-12(Q) and 15.35 percent to the Gross State Domestic Product (GSDP) in 2011-12 price. More than 70 percent of the total work force, directly or indirectly, is involved in agriculture, pisciculture and allied activities, making it the largest employment sector. Cultivated land of the state is 61.80 lakh ha out of which:

- 29.14 lakh ha (47%) is high land;
- 17.55 lakh ha (28%) medium land; and
- 15.11 lakh ha (25%) low land.

The low lands are mostly situated in the coastal districts which form the rice bowl of the state. This area is vulnerable to direct impacts of climate change such as storms, tsunamis and cyclones that batter the coastal districts at regular intervals. Majority of the farmers are small and marginal with low levels of literacy and have high livelihood vulnerability. The state government has already taken note of the aberrant weather conditions. A government report says, "Department of Agriculture is in its toes to increase the production and productivity of different crops in spite of aberrant weather conditions and limited resources" (Anon, Economic survey 2014-15).

Table 10: Land use in six Coastal Districts (2011-12) (000's hectare)

District	Geographical Area	Land for Non-agro use	Barren/ Fallow	Net Sown Area
Balasore	381	33	53	212
Bhadrak	250	33	26	156
Jagatsinghpur	167	13	37	87
Kendrapada	264	49	34	137
Ganjam	821	21	75	357
Puri	348	115	67	131
Total	2,231	264	292	1,080

Source : Agriculture Statistics, 2011-12, Govt. of Odisha

Though these six districts comprise 14.32 percent (2,231,000 ha) out of the total geographical area of 155,771,000 ha, they have 28.65 percent (1,080,000 ha) of the total net sown area of the state (3,769,000 ha), underscoring their importance in the agro map of the state. Increasing trends of temperature for all the seasons might have adverse impact on the health of agriculture sector of coastal Odisha (Mishra & Sahu, 2014).

Table 11: No. Of villages with crop loss > 50% in Coastal Dists.

District	2004	2005	2006	2007	2008	2009	2010	2011
Balasore		508	995	2,141			202	
Bhadrak			436	778	116		386	43
Jagatsinghpur			722	849	220			
Kendrapada			738	1,485	821		208	
Ganjam	843	762	2,786	1,000		19		3,047
Puri	111		1,632	349	768		19	
TOTAL :	**954**	**1,270**	**7,309**	**6,602**	**1,925**	**19**	**815**	**3,090**
ALL ODISHA	1,615	1,706	16,248	9,321	4,630	2,063	10,674	14,119

Source : Agriculture Statistics, 2011-12, Govt. of Odisha

Table 11 shows the recurring crop loss occurring in many villages of the six coastal districts due to floods during the last 12 years.

Fishing Livelihood

Given the flat coastal plains with myriad water bodies, fishing has emerged as a major livelihood source of millions of inhabitants. The nutrient-rich waters of Chilika Lake attract a wide variety of pelagic and bottom feeders like shrimp and crabs, and yield lucrative harvests. If there is a shore erosion caused by rising water

levels, marine fisher folks that stay on beaches will be immediately affected by loss of home ground.

Climate change has an impact on fishery resources since some scientists believe that major carps like ruhi, katla and mirgal may mature early and spawn. This will lead to lesser survival and recruitment of wild stocks as they might be eaten up by predators. Cyclonic weather and tidal surges as well as high floods radically alter salinity levels of breeding estuarine areas leading to reduced survival of spawn and fingerlings especially of brackish water species. Relatively small temperature changes can set off changes in distribution and fish abundance which in turn affects livelihoods (Roessig, et.al., 2004),

Table 12: Growth of Fish Production (15 YEARS) (in metric tonnes)

Year	Fresh water	Brackish Water	Total	Marine	Total
2000-01	125,114	13,442	138,556	121,086	259,642
2014-15	300,964	35,373	336,337	133,211	469,548

Source: Fisheries and Animal Resources Department, Govt. of Odisha

It is interesting to note that as Table 13 shows, there has been a growth of 141 percent in fresh water fish catch; 163 percent in brackish water and 10 percent in marine fish catch in 15 years. Marine fish production has risen marginally, signalling overfishing. Almost 50 percent of the brackish water fish output is accounted for by cultured shrimp crops.

Table 13: Production of Brackish water Fish (15 Years)

Year	Cultured Shrimp	Estuary	Chilika	Total
2000-01	6,430 MT	2,029 MT	4,983 MT	13,442 MT
2014-15	19,254 MT	4,066 MT	12,054 MT	35,374 MT

Source: Fisheries and Animal Resources Department, Govt. of Odisha

The cultured shrimp output growth rate is 200 percent due to strong foreign demand. Estuary catch has doubled at 100 percent while the catch from Chilika has grown by 142 percent. It must be kept in mind that the lake was restored by a new mouth dug up in 2000. The maximum sustainable yield (MSY) as estimated by the Fisheries Survey of India is estimated at 160,931 MT annually from the continental shelf area up to a depth level of around 200 metres.

Chilika Lake: The lake has several unique characteristics that makes it stand out in the Indian subcontinent. It is the largest wintering ground for migratory waterfowl and a hotspot of biodiversity. Chilika was designated as the 1st "Ramsar Site" of India in 1981.

Rich fishing grounds provide livelihoods to nearly 1,50,000 fisher folks. The water spread varies between 1165 and 900 sq.km during monsoon and summer.

About 30 percent (46,500) of the total fishermen population of 1,50,000 are active fishermen, although many others depend indirectly. The salinity gradient is steep varying from 0 at the entry point of Daya river to 42 ppt in the sea mouth area.

No Trickle Down

Though decision-makers in top echelons are aware of climate change and its fearsome irreversible impacts, little effort is seen to disseminate this. There is no effort to educate, train, or prepare the directly-affected coastal communities to adapt. The discussion is now confined to high levels of government, and even the local self-government institutions are ignorant of the issue. There are opportunities for scaling up EBA (Ecosystem-Based Adaptation) and CBA (Community-Based Adaptation) through mainstreaming, replication and diversification to other sectors. This will benefit millions of poor facing climate change since they are highly dependent upon ecosystem services (Reid, 2016).

Odisha is one of the poorest states in India with almost 43 percent of the population living below poverty line. Among all the districts – Balasore, Kendrapada and Jajpur – occupy first, second and third rank respectively, in terms of vulnerability indices (Bahinipati, 2014). Climate change can adversely affect mangroves due to changes in coastal salinity balance. There is little study about impacts of ongoing climate change on Indian mangroves (Sandilyan, 2014). Conservation and regeneration of mangrove forests is of prime importance to tackle climate change.

The lives and livelihoods of millions of people will be impacted drastically, yet communities are completely unaware of the impending change and hence have not been able to claim their rightful place as vital stakeholders in government-driven mitigation/adaptation plan.

Community Based Action

At present there is no village-level micro data which reveals the levels of income from various livelihood activities like farming, fishing or animal husbandry. Similarly, no biodiversity assessment study has been carried out for each village. Third, there is little data on the local salinity levels and the changes in the seasons as well as

rainfall, humidity and ambient temperatures. Since the biggest gap is absence of baseline data for local ecological and climatological condition, it is difficult to measure and predict changes and impacts. The decline in livelihoods of affected communities apart from local ecological changes needs to be properly documented.

A community-based program for adaptation and mitigation of expected climate change effects could be launched in 266 villages vulnerable to climate change which lie in six coastal districts of Odisha. A sound action plan will have several components. An education and awareness campaign to make the local population aware of the impending threats will lead to greater participation of these marginalised communities in the planning and action plan process. The local community could then take up suggested adaptation measures.

There is a dire need for intervention in the government programs for climate change adaptation. In Odisha, selected poor families are provided a free government brick house. The design and budget for such houses is uniform for the whole state. In coastal areas they could be built on stilts six feet above the ground in order to protect them from tidal surges. The roofs could be made accessible by a staircase that could be used if water levels rise too much. These adaptations cost about 35 percent more than the current design.

Roads and bridges now built in coastal districts could incorporate special designs to prepare for the likely impacts of cyclones, tsunamis and tidal surges. Line departments like Animal Husbandry, Fisheries, Agriculture, Horticulture and Forests also need to ensure climate change concerns are considered into work plans. These adjustments could mean encouraging saline resistant paddy varieties, adopting cultured fisheries instead of capture fisheries, value addition to fishery products, encouraging suitable fruits and vegetables farming.

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Nepal

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A New Meaning for Glacial Pace: The Irony of Landlocked Himalayan Countries and Climate Change

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Abstract

Climate change forces landlocked Nepal and Bhutan to be further dependent on their neighbors who benefit from territorial access to the city. Already bearing extra costs and geographical isolation, landlocked countries face a paradox of less steady rainfall and lakes about to burst from snow melting in the mountains. As the risks of climate change rise, regional cooperation becomes all the more essential. Therefore, there must be strong ties and efforts between the countries of the region now to cope with the challenges of climate change as they emerge.

The hypothesis of this paper is that the developed countries are the major contributors to climate change, but the least developing countries like Nepal and Bhutan are very vulnerable as climate change has brought a new dimension to environmental security in these countries. Moreover, being landlocked, Nepal and Bhutan also suffer the effects of climate change where rising temperatures cause glacier melting, which can lead to floods, mudslides and avalanches.

The paper also discusses the politics behind it. The crafting of regional frameworks and their implementation prove to be much more difficult in instances where there are too many negotiating parties. Unfortunately, Nepal and Bhutan tend to have many external influences.

The Himalayan rivers, which transcend boundaries, are the common source of water in India, Pakistan, Nepal and Bangladesh. The paper also predicts a possible conflict in the region on water use if China is taken into account. Already, the signs of a potential conflict between China and India are generating new apprehensions.

Finally, the institutional, policy and legal frameworks on climate change are analyzed. Similarly, the causes of the regressions and the frictions are assessed. It suggests what Nepal and Bhutan can offer to the regional cooperation. Some future directions are recommended to advance the collective efforts on one of the most complex challenges ever to face by human beings.

Landlockedness: Boon or Bane

Climate change is the latest example of how landlocked Nepal and Bhutan benefit from regional integration and miss opportunities when there are barriers. The absence of direct access to a seaport, and the resulting international trade difficulties place Nepal and Bhutan on an inherent development-path disadvantage when compared to countries with coastlines and deep seaports. Nepal and Bhutan must rely on the goodwill of their neighbors, mainly India, and face substantially greater transport costs and longer time to send and receive merchandise from overseas markets. In addition, they face other factors that impair development, such as difficult mountain topography and pervasive dry land ecology. Nepal and Bhutan have underdeveloped markets, inefficient institutions, inadequate infrastructure and weak policies.

The full participation in international trade is thus hindered by both internal and external factors. They have to deal with inadequate transit facilities, cumbersome customs and border procedures, as well as other contingencies related to relying on another country.

On the other hand, despite a drop in transaction costs, these countries have not yet exploited the benefits of rapid digitalization. The limited connectivity to submarine communication has denied Nepal and Bhutan the technology and information dividends that stem from robust internet backbones and high-speed internet connectivity.

Conceptual Framework

The developed countries are the major contributors to climate change, but the least developing countries like Nepal and Bhutan are very vulnerable. Huge funds and a lot of programs have been generated and used to combat the challenges. However, the local people have very little or no awareness about it, and there is very little involvement of people. So addressing climate change both in terms of GHG emission reduction and resilience-building against the impacts have not been that successful in spite of hundreds of conferences and declarations.

According to scientists, concentrations of greenhouse gases in the atmosphere are increasing, and that this is causing global climate change. Human-driven emissions of carbon dioxide and other greenhouse gases, as well as unsustainable consumption patterns and land-use change, are primarily responsible for the increase.

Fig. 1. Heavy rain brings massive flood to Bhotekoshi River in Napel. 20 June 2016.

Concentrations of greenhouse gases, especially carbon dioxide, have risen over the past 250 years, largely due to the combustion of fossil fuels for energy production. The IPCC 4th Assessment Report estimates that by 2050, crop yields in South Asia can decrease by up to 30 percent. Increase in pests, diseases and invasive species owing to temperature change affect agricultural productivity, resulting in food insecurity and loss of livelihoods. Atmospheric CO_2 concentration will reduce Nepal's forest types from 15 to 12, and habitats and ecosystem. The adverse impacts on the Himalayas are expected to affect both the upland and lowland systems, especially threatening the vital biodiversity, water and energy as well as food security.

In Nepal and Bhutan climate change has brought a new dimension to environmental security. The series of environmental security issues have the potential to cause conflict. Nepal and Bhutan are vulnerable to climate change. Because of the impulsive geoclimatic and geopolitical situation, low level of economic development and high degree of mutual apathy and mistrust, environmental degradation, along with climate change, has the potential to give rise to instability. For example, some climate experts predict a sea level rise of 1.2m by the end of the century. This would flood the atoll island nation of Kiribati, which is already experiencing severe challenges with rising waters (Acharya).

Therefore, all this will not only affect Nepal and Bhutan but also the entire South Asian region as water insecurity in the greater-Himalayan river basin (Indus in the west and the Ganges-

Brahmaputra-Meghna in the east) due to melting of glaciers as a result of global warming can trigger conflicts here. Current trends indicate that the rivers in the Himalayan basin can become seasonal once the glaciers melt in the coming decades. One of the greatest threats to small island developing states is sea-level rise and submergence of territories. But the problems faced by Bhutan and Nepal now are more severe.

So landlocked developing countries (LLDCs) like Nepal and Bhutan have to face tremendous challenges. For them the impacts of climate change are unduly high as they stand on the forefront of climate change, and the impacts are real and measurable.

More Frequent Natural Disasters: The example of GLOF -Water

There is a clear sign of danger to nature and humans. Species are also going extinct. Sub-tropical diseases which were unknown to them are beginning to emerge in the temperate climate of Bhutan and Nepal. Mosquitoes are becoming a big problem in Thimpu and Kathmandu.

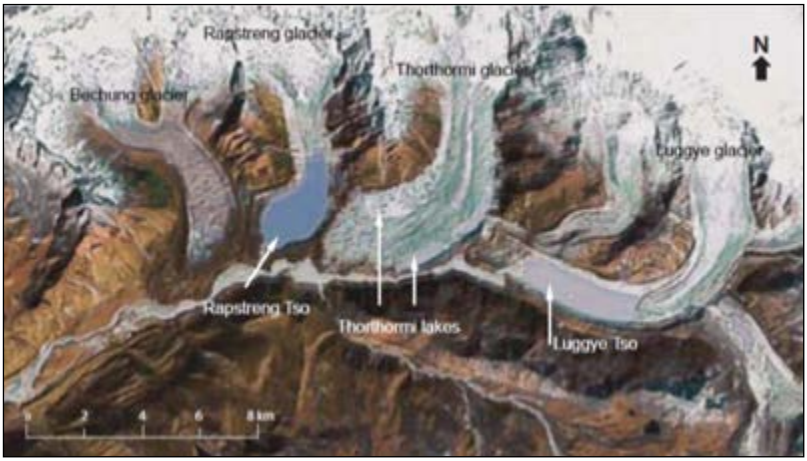

Fig. 2. "Glacier retreat in the Pho Chu sub-basin of Bhutan: The Luggye Glacier retreated by 160m per year from 1988 to 1993, resulting in a high growth rate of Lake Luggye Tso", ICIMOD, 2007.

The accelerating melting rate of snow and glacier will have an impact on water flows in rivers, public health and food and biomass productivity, which depends on the water from the Himalayas (Duwadee and Adhikari, 2013). As a mountainous country in which the lives and livelihoods of millions of people are directly affected by climate change, Nepal views the Paris

Agreement as a beacon of hope for safe and shared destiny of humanity. The Agreement is a culmination of our search for a binding instrument on climate change (Thapa, 2016).

Glaciers and ice-caps are important long-term reserves of fresh water. For instance, water from glaciers contributes 10-20 percent of runoff in Tajikistan's large rivers, particularly in hot and dry years (UNDP, 2009). Evidence shows glaciers across the world are shrinking significantly, though it varies across time and place. Several landlocked developing countries are also at the risk of melting glaciers that has been blamed on climate change. In Central Asia, average degradation rates are thought to have varied between 30 and 35 percent in the last century, and between 20 and 30 percent in the last 50 years (UNDP, 2009). A sustained melting of glaciers increases the volume of water in rivers and sedimentation, the latter often chocking up water supply and affecting agriculture. In many places, melting glacier is giving rise to unstable water bodies, including lakes.

While climate change threatens landlocked developing countries on multiple fronts, it is the impact of extreme weather on the agricultural sector in particular that is especially dire. As an economy mainstay, agricultural value-added proportion to GDP, constituted more than 20 percent for half of the 26 countries, according to 2011 data. The agricultural sector is especially critical to the economies of Burkina Faso, Burundi, Ethiopia, Laos, Malawi, Nepal and Rwanda. Just 14.5 percent of the total land area of the LLDCs is arable. Arable land comprise of at least 20 percent of total land area in just seven of the 31 LLDCs. But about 70 percent of the people are dependent on agriculture. For most of them, however, the agricultural sector is largely unmechanized, smallholder farming, which means low productivity due to inadequate use of fertilizer, unreliable precipitation and poor soil quality, among other factors. Majority of the farmers are unprotected from crop failure and other associated risks.

Nepal and Bhutan remain vulnerable to climate change-related extreme weather events, such as droughts, floods and landslides. The direct impact of these occurrences includes loss of human life, displacement, repeated crop failures, worsening food crisis, destruction of critical infrastructure and disruption of economic activities. The main Himalayan range runs west to east, from the Indus river valley to the Brahmaputra river valley, forming an arc of 2,400 km (1,500 mi) long, which varies in width from 400 km (250

mi) in the western Kashmir-Xinjiang region to 150 km (93 mi) in the eastern Tibet-Arunachal Pradesh region.

The Himalayan Rivers, which transcend boundaries, are the common source of water in India, Pakistan, Nepal and Bangladesh. If China is taken into account, signs of a potential conflict between Beijing and New Delhi are generating new apprehensions. Strategically China's position as an upper riparian nation gives it a strategic advantage that has wider implications for the rest of the region. Nepal is one of the most vulnerable (4th) countries because of climate change. Globally Nepal emits only 0.025 percent of total GHG emissions (Malla, 2009). Climate change impacts both on upland and lowland ecosystems, especially threatening the vital biodiversity, water and energy and food security. Rapid melting of glaciers, formation of new supraglacial lakes, expansion of existing lakes and disappearing of some small lakes have been noticed.

The Strategic Foresight Group, an India-based think-tank that works on global issues, had published a report (Himalayan Challenge: Water Insecurity in Emerging Asia) in 2010, saying that in the next 30-40 years water will be one of the major factors influencing Asian political and security agenda. The battle for water has already begun. China has plans to divert the upper flow of the Brahmaputra (the Yarlong Tsangpo river in Tibet) to overcome water shortage in its western part. The move has sent out ripples of anxiety among India, Nepal and Bangladesh.

Fig. 3. "The Himalayan Rivers: Most of the Himalayan Rivers are perennial" Web. 23 June 2016.

India and Bangladesh share 54 trans-boundary rivers between them. India being the upper riparian country has always caused anxiety in Bangladesh over the issue of water sharing. A lot of misperception and mistrust has been generated as a result. The demand for water resources in India is expected to exceed 1.4 trillion cubic meters by 2050. With population explosion, water sharing is going to create conflicts in the region. India's river-linking project and its environmental ramifications are also a major concern in the region with Bangladesh showing signs of apprehension and anxiety.

Researchers resorted to glacier mass balance and ice redistribution model to examine the "sensitivity of glaciers in the Everest region of Nepal to climate change". According to the study, high-elevation snow and ice cover play pivotal roles in the Himalayan hydrologic system ("Most Mount Everest glaciers will disappear with climate change," warns the 2015 study). In those Himalayan regions affected by monsoon, melting water from glaciers provides an important source of stream flow during pre-and post-monsoon seasons. In view of this, changes in glacier area and volume are expected to affect water availability during dry seasons, the study warns. This, in turn, will affect agriculture, hydropower generation and local water availability. The study was conducted in Dudh Koshi basin in central Nepal which has a total glaciered area of over 400 sq. km. The region contains some of the world's highest mountain peaks, including Mount Everest, Cho Oyu, Makalu, Lhotse and Nuptse.

Fig. 4. "Climb Mount Everest – on a Bike". Web. 1 July2016.

"The Dudh Koshi river is a major contributor to the Koshi river, which contains nearly one-quarter of Nepal's exploitable hydroelectric potential," the study adds. The current status of glaciers varies across the HKH region. Most areas have seen glacier retreat and down wasting in recent years, though areas such as the Karakoram and Pamir ranges have experienced equilibrium or even slight mass gain, the paper says.

Nepal and Bhutan being landlocked also suffer the effects of climate change where rising temperatures cause glacier melting, which can lead to floods, mudslides and avalanches. The most distinguishing and obvious features of Nepal and Bhutan include the lack of territorial access to the sea, remoteness from major world markets, and relatively small geographical, population and economy sizes. The absence of direct access to a seaport, and ensuing international trade difficulties place Nepal and Bhutan on an inherent development-path disadvantage when compared to countries with coastlines and deep seaports. Nepal and Bhutan must rely on the goodwill of their neighbors, mainly India, and require substantially greater transport costs and longer time to send and receive merchandise from overseas markets. In addition, they face other factors that impair development, such as difficult mountain topography and pervasive dry land ecology.

Nepal and Bhutan have underdeveloped markets, inefficient institutions, inadequate infrastructure and weak policy formulations. The full participation in international trade is thus hindered by both internal and external factors. They have to deal with inadequate transit facilities, cumbersome customs and border procedures, as well as other contingencies related to relying on another country.

Inadequate equipment and facilities, weak institutions and a widespread lack of human and productive capacities along with a host of other challenges common in Nepal and Bhutan have contributed to their low level of economic growth. The proliferation of advanced transport and communication technology, including mobile telephony, and high speed internet continues to drive transaction costs downwards. This trend has given rise to optimism that as international transport costs fall, they could finally begin to make significant progress in scaling the hurdle of smallness, landlockedness, remoteness and isolation. However, the reality for Nepal and Bhutan is different: transit, transaction and communication costs remain prohibitively high due, in part,

to the factors already outlined. Limited connectivity to submarine communication has denied Nepal and Bhutan the technology and information dividends that stem from robust internet backbones and high-speed internet connectivity. In fact, it's substantially expensive for households in Nepal and Bhutan to access high speed internet of decent bandwidth than those in countries located closer to submarine communication cables.

For Nepal and Bhutan, besides the classical benefits such as trade creation and mutual support, regional cooperation should provide a platform for more effective integration and participation in the world economy. Free trade agreements concluded within the frameworks of regional and bilateral integration reduce trade barriers considerably, and could ultimately result in unrestricted trade among participating members. With greater regional integration, economies of scale in the production and distribution of goods and services that is unattainable for individual countries due to their small size may eventually become feasible when countries work collaboratively.

The crafting of regional frameworks and the achievement of consensus on the same can prove to be much more difficult in instances where there are too many negotiating parties. Unfortunately, Nepal and Bhutan tend to have relatively many external influences, and are thus often caught up in unwieldy and competing regional integration discussions, which often times contribute to the slow progress in implementing agreements that are designed, for instance, to eliminate tariffs and non-tariff barriers. But the relatively small population and economy sizes put these countries at a disadvantage when it comes to pursuing their priorities and interests.

Institutional, Policy and Legal Framework on Climate Change

Nepal has been combating climate change with several policy measures and strategies, institutional support, adaptation programs and mitigation actions. The climate change policy (2011) aims to protect the country from the adverse impacts of climate change. Mainstreaming climate change has been an important part of the new plans, policies and strategies of the government. The National Adaptation Programme of Action (NAPA) and the Local Adaptation Plan of Action (LAPA), with inbuilt gender and community perspectives, offer urgent and immediate adaptation

options to address the impacts of climate change. A National Adaptation Plan (NAP) is being formulated to address medium and long-term adaptation needs. Also, Climate Change Budget Code has been introduced. Nepal is now in the process of finalizing a new national development plan, seeking to integrate SDGs and considering the comprehensive climate plan of the country, for implementation beginning mid-July this year. More specifically, Nepal aims to formulate the Low Carbon Economic Development Strategy and national REDD plus strategy and maintain 40 percent land under forest covers. She aims to achieve 80 percent electrification through renewable energy sources by 2050 and strive to decrease the rate of air pollution by 2025.

Nepal has created an enabling environment to promote private sector and foreign direct investments in low carbon economic development. While the impending climate change vulnerability of Nepal as LDC, LLDC and a mountainous country is very high and our pathway for sustainable development is both difficult and costly, our abundant renewable resources offer prospects for the development of a climate-friendly regional cooperative partnership. The following were the milestones for the same: Ministry of Population and Environment established in 1995; Environmental Protection Act (EPA) 1997 and Environmental Protection Rules (EPR) 1997 were reenacted; Environment Council under the Chairmanship of Rt. Honourable Prime Minister; Interim constitution of Nepal (2007); Sustainable Development Agenda for Nepal (2003); Sustainable Development Agenda for Nepal; National Conservation Strategy (1988); Master Plan for Forestry Sector (1989); Environmental Policy and Action Plan (1993); Agriculture Perspective Plan (1995); Water Resources Strategy (2002); Forest Sector Policy (2002); Nepal Biodiversity Strategy 2002; formation of a 28-member Climate Change Council in July 2009; a 38-member multi-stakeholder Climate Change Initiatives Coordination Committee (MCCICC) in 2010; Climate Change Management Division within the Ministry in 2010; Knowledge Management Center in 2011; Climate Change Policy in 2011; and many more.

Bhutan also has endorsed many green economy-friendly policies in recent decades. Bhutan has strict laws to combat climate change. She has National Environment Protection Act that covers climate change. And she is drafting a National Environment Impact Assessment law. There are many technical committees in Bhutan that develop mechanisms and bylaws on how to implement various

mitigation and adaptation measures to cope with climate change. In the international arena, over 100 countries are working on climate change in addition to the United Nations' own high priority on it. The latest conference organized by the UN is the COP 21 Paris talks that give the international community the chance to demonstrate that it is indeed leaving no one behind, that all voices are heard and understood. There will be hundreds of them again. However, are there any changes in reality? If not, what are the causes?

Causes of the Regressions

It is a sad reality that while the world's most vulnerable countries have contributed the least to climate change, they are most at risk from its negative effects and the least equipped to withstand and adapt to it (Acharya). According to Seth Borenstein, the complex politics of global warming results from numerous cofactors arising from the global economy's interdependence on carbon dioxide, emitting hydrocarbon energy sources and because carbon dioxide is directly implicated in global warming, making global warming a non-traditional environmental challenge. This intimate linkage between global warming and economic vitality implicates almost every aspect of a nation-state's economy (Gillis). Mary S. Booth argues that fossil fuel abundance and low prices continue to put pressure on the development of adequate advanced energy technologies that can realistically replace the role of fossil fuels – as of 2010, over 91 percent of the world's energy is derived from fossil fuels and non-carbon-neutral technologies".

Some developing nations like Nepal and Bhutan blame the developed world for having created the global warming crisis because it was the developed countries that emitted most of the carbon dioxide over the 20th century; and vulnerable countries perceive that it should be the developed countries that should pay to address the challenge. The global governance institutions that evolved during the 20th century are all consensus-driven deliberative forums where agreement is difficult to achieve and even when agreement is achieved it is almost impossible to enforce. Although there is a consensus on the science of global warming and its likely effects – some special interest groups work to suppress the consensus while others work to amplify the alarm of global warming. Distrust between developed and developing countries at most international conferences emerge visibly that further add to the challenges.

While different institutions can provide for more or less cumbersome rules on decision-making, advocate different levels

of ambition, or address relevant issues at the level of experts or of heads of state and government, none will be able to eradicate the current divisions among major players. In the end, it does not matter which forum is chosen to address the mitigation challenge if the parties do not bring with them sufficient will to act; and even the best regime design will not achieve the necessary mitigation levels if it is not followed up with robust implementation. Both aspects are strongly contingent on the domestic politics of the parties.

Undoubtedly, climate change is linked to insecurity both at national and international level. It can activate violent conflicts, contribute to vulnerability and inequality. These events won't have a single impact, but will involve multiple and complex relationship and will have spillover effect on other sectors of the society.

Nepal's offer to Regional Cooperation

Nepal can provide renewable energy to its neighbors India and China, as it has thousands of rivers. These rivers having a huge hydropower potential. The perennial nature of the Nepali rivers and the steep gradient of the country's topography provide ideal conditions for the development of some of the world's largest hydroelectric projects in Nepal. Current estimates are that Nepal has approximately 80,000 MW of economically feasible hydropower potential. It does help in carbon sequestration, the process of capture and long-term storage of atmospheric carbon dioxide (CO_2) in the biosphere such as the oceans, terrestrial biomass, soils and geologic formation. Moreover, Nepal can supply good drinking water to the world besides leading the tourism industry. Therefore, Nepal has been playing an active role in the process, including as LDCs lead negotiator in the past.

The Future Directions

National leaders with a strong vision and a will to act have a unique opportunity to advance our collective efforts on one of the most complex challenges ever to face humankind (Bausch and Mehling, 2011). In South Asia, besides their political and civic leaders, the people from the grassroots level too, have to lend supports and their moral voice to a robust, ambitious and meaningful climate change agreement that is not only sensible of the challenges they are facing, but effective – and includes mitigation and adaptation measures. Only such an ambitious outcome safeguards the future of vulnerable countries and the world at large as nothing will happen without the participation of those. Therefore, our future direction should be like these:

- Plant new trees.
- Develop a comprehensive security approach to the crises in the South Asia region as climate change needs a proper response from all the countries of South Asia.
- Compel developed countries to show a lot more reduction in global emissions.
- Undertake investments and policy re-orientations that would create new and alternative sectors capable of supporting economic growth, in tandem with the preponderant agriculture and mining sectors.
- Sign/reach a comprehensive agreement that caps global warming at less than 1.5°C.
- Maintain a substantive reorganization of the economy.
- Use innovation and invention to adapt and mitigate external shocks, especially those that relate to climate change.
- Address weaknesses and develop new tools.
- Open alternative routes are often prevented by distance, cost and difficult geography which include desert and mountainous terrain.
- Make a commitment to develop institutions and policies critical in promoting growth and addressing external shocks.
- Achieve coordination at sub-regional, regional and global levels.
- Build a mechanism through which developing countries that suffer receive compensation and support to recover.
- Start an insurance scheme, under international support measures.
- Develop humanitarian assistance.
- Strengthen the development strategies and implementation of National Action Plans.
- Establish 'global catastrophic climate change disaster insurance facility' fund for LLDCs.
- Raise public awareness and increase access to information.
- Establish strong research links.
- Start an enhanced collaboration and partnership with private sector, civil society and other actors.
- Expedite institutional and human capacity building.
- Promote sustainable energy with a focus on renewable energy.
- Diversify the economic base of LLDCs.
- Integrate finance, technology and capacity-building as they have to be an integral part of the solution.
- Enable vulnerable countries to develop resilience to climate change.

- Reflect honestly on where we stand and what we are doing as a global community to support the most vulnerable communities and individuals among us.
- Give top primacy to agriculture, livelihood sustenance and food security in LLDCs.
- Use renewable energy.
- Build strong and genuine partnerships with neighboring countries.
- Establish strong connectivity at the people's level. [Establish strong people to people contact]

Conclusions

In spite of the various conferences and hundreds of declarations, mitigation of climate change has been a mirage till today. Snow and glacier has been melting; has bad effects on agriculture and health; worsened the condition of water resources – hydropower, irrigation, recreation, etc.; deteriorated forest and biodiversity; weakened infrastructures; and rattled urban areas.

Nepal and Bhutan are impacted by the climate change and natural disasters. Since they are vulnerable and poor in resource, they are increasingly faced with difficult challenges of dealing with direct and indirect impacts of climate change. When climate change-related impacts would directly be felt in these countries, the ill consequences would have spillover within South Asia. They are merely the elements of an ecosystem. These problems call for concerted efforts to develop a holistic and comprehensive response to the challenges of climate change. In such a scenario, the developed countries ought to support Nepal through capacity-building, technology transfer and other needed resources.

The vital resources of Nepal and Bhutan like land, water, forests, biodiversity and rich ecosystems that are being degraded and threatened due to climate change, and are likely to undermine food, water and energy security. Predicted climate change is likely to create challenges not only to future poverty reduction measures but also might reverse many of the important socioeconomic gain achieved by the countries. Although uncertainties about the rate and magnitude of climate change and potential impacts prevail, there is no question that climate change is gradually and powerfully changing the ecological and socioeconomic landscape, particularly in relation to water. In transboundary water sharing issues, joint watershed management concept will be a sustainable

approach to reduce climate change vulnerabilities and its impacts on common water resources.

Connectivity must be established at people to people level, and they should be involved enthusiastically. Necessary financial and technology support in this regard are required. So, transparent and direct access to climate finance and technology should be ensured for the countries like Nepal and Bhutan. Together with the collective strength of global efforts, understanding, cooperation, partnership and support are also needed to combat the challenges to triumph now.

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Sri Lanka

Sanjiv De Silva

Graduating with an LL.M. in Environmental Law in 1997, Sanjiv has worked on natural resources governance over the past 17 years. From an initial focus on biodiversity conservation, Sanjiv has used water resources management as an entry point after joining the International Water Management Institute (IWMI) in 2004 where he works as a Researcher. He has worked and published on an array of issues linked to food security, poverty, gender and equity and wetlands wise use in Asia, including Bangladesh, Cambodia, Sri Lanka, India and China. Specific areas of interest include institutions to promote wetlands wise use; water resources management and climate adaptation; balancing trade-offs inherent in groundwater development; the political economies influencing integrated water resources management; women's agency in building resilient social ecological systems; impacts of migration on rural food production systems, and the architecture of power that must often be understood and negotiated if collaborative, equitable and sustainable natural resource governance institutions are to emerge. Sanjiv is a member of the National Wetlands Steering Committee of Sri Lanka, and is IWMI's representative at the Scientific and Technical Review Panel of the Ramsar Convention on Wetlands. In 2011, Sanjiv attended the U.S. Exchange Program Transboundary Water Resources Management.

Groundwater Rising: Agrarian Resilience Against Climatic Impacts on Water Resources

Sanjiv de Silva with Jayne Curnow & Ranjith Ariyatne
Sri Lanka

Abstract

The Bay of Bengal region faces a double challenge of feeding its citizens while climate change undermines its all-important water resources. This paper examines the case of Sri Lanka with a comparison to Bangladesh. Sri Lanka depends primarily on surface water resources for agricultural, domestic and industrial uses. Consuming over 87 percent of surface water, agriculture is by far the dominant user, sustained largely by direct rainfall and a sophisticated hydraulic civilization based around networks of irrigation tanks for rainfall storage. Agriculture in turn drives food security by way of the staple rice crop, and still accounts for 30 percent of employment in Sri Lanka. Rice accounts for 82 percent of all surface water usage by agriculture. Surface water resources are already under pressure by economic and demographic changes that increase water demands. Climate change threatens to intensify this pressure further by altering surface water availability. Despite a lack of consensus as to whether total rainfall will decline or increase given multiple predictions using varying scenarios, there is greater agreement that variability will increase, causing even greater uncertainty and longer dry spells. Particularly affected will be parts of Sri Lanka's dry zone, including the North-Central Province (NCP), a major rice production region, but heavily dependent on rainfall and surface irrigation. Similarly, northern and parts of eastern Bangladesh already possess low surface water flows. Increases in temperature will further impact water resources in such regions by raising evaporation rates. The strong link between national food security and water intensive rice production therefore poses important policy and practical challenges within a climate change context. In Sri Lanka, current experiences in the water sector and climate impact projections have not raised the profile of groundwater as a critical resource in meeting these challenges. While groundwater is also

increasingly used for large-scale commercial agriculture, industry and rural drinking water, current groundwater capacities, withdrawals and contributions to various sectors are unknown. Through a case study on agro-well driven high value vegetable cultivation in Sri Lanka's NCP, this paper demonstrates the considerable resilience to water stress and poverty alleviation potential of groundwater, while also highlighting existing challenges to be reconciled if groundwater is to sustainably support the dual policy objectives of relieving water stress and alleviating rural poverty.

The research was conducted in four villages in the NCP between November 2013 and October 2014, under the "Groundwater-based Agrarian Change in North Central Province, Sri Lanka" project funded by the Land, Water and Ecosystems (LWE) program led by the International Water Management Institute (IWMI).

Introduction

The Agriculture, Water and Climate Contexts

With a population of almost 21 million and an economy averaging a GDP growth rate of 6.4 percent between 2010 and 2015 (World Bank), Sri Lanka is classified as a low middle-income country. About 6.5 percent of the population is estimated to still live below the poverty line. Services, industry and agriculture are the dominant economic sectors, accounting for 56 percent, 33 percent and 11 percent of GDP, respectively. Despite a declining share of GDP, agriculture remains a key sector overall given its centrality to food production and employment for many of the 81.6 percent of the country's population that is rural.

Agriculture is intimately linked to an overall high annual precipitation level coupled with an extensive hydrological civilization based on rainwater storage and water conveyancing over at least 1,500 years (the small tank system). This system has ensured not only year-long water availability to much of the island, but also a hydraulic culture focused almost exclusively on surface water resources. Although Sri Lanka has six major types of aquifer systems across its 65,000 km2 extent, and a variety of geological and hydrogeological settings, extraction of groundwater for agriculture has traditionally been limited to the northern and eastern provinces which lack perennial surface water resources. Paddy has been the mainstay of agrarian livelihoods, with typically one major rain-fed (maha) crop and one surface irrigated crop in the dry (yala) season, traditionally utilizing water stored in the man-made tanks. Much of the paddy production occurs in the country's dry zone (Figure 1) comprising roughly a third of the land area and receiving on average less than 1,750mm of rainfall, of which very little falls between May and September (the dry season). The majority of the 12,000-16,000 irrigation tanks are also distributed across the same landscape (Panabokke, 2009).The majority of these are 'small' in scale (less than 80 ha). Many villages have several such tanks, though some are abandoned due to poor maintenance, while others' water holding capacity has diminished due to siltation (Panabokke, 2009). The effectiveness of this network has consequently diminished also in relation to growing water demand in agriculture, industry and urban sectors. Consequently, unless served by a modern irrigation scheme, many dry zone villages can in fact only cultivate rain-fed rice, with agriculture in the dry season limited to slash and burn subsistence highland cultivation

that hardly generates economic returns, and is vulnerable to climatic conditions.

Although the predicted impacts of climate change in Sri Lanka vary according to the models used, Ahmed and Suphachalasai (2014) conclude that under a Business as Usual scenario, the impact would be an annual loss of 1.2 percent of GDP by 2050, which would increase to 6.5 percent in the long-term. Impacts on agriculture predict both increases and decreases in yield, depending on the location of production and time-scale. Of particular relevance is Seo et al.'s (2005) prediction that changes to net income from rice production could decrease by 27 percent to 46 percent. Decreased precipitation in the central highlands are also expected to lead to a loss in the catchment for the multipurpose Mahaweli Complex, by far the largest investment in providing dry season irrigation to paddy farmers in the northern and north-central provinces. With respect to groundwater resources, Eriyagama et al. (2010) note that this has been the subject of only limited studies. Overall, the impact of climate change on the water sector in Sri Lanka will be felt more strongly by those dependent on the agriculture sector for livelihood and food security, with Anuradhapura District (where our study sites are located) considered one of the most at risk areas Eriyagama (2010).

Study Methodology

To understand the evolution of agro-wells and associated production systems, their socio-economic impacts and enabling drivers, a combination of quantitative and qualitative data was collected from October 2013 to October 2014. Primary data collection consisted of field observation and semi-structured interviews with government bureaucrats, female and male farmers, village elders, and other residents comprising a sample size of 120 individuals across four villages. Data collection spanned the spatial evolution of each village prior to and after the introduction of agro-wells in relation to living conditions; household and agricultural assets; employment; changes in land cover and agricultural practices; current cropping practices and their production and economies; local institutions and interactions with local government; social change including the position of women in society; and gender relations linked to altered agricultural practices. The results of data analysis were verified through a meeting in each study. This was supplemented by secondary village data from local government; national agriculture commodity prices and associated policies, and the introduction of agro-wells in Sri Lanka through a literature review.

Study Location

The four study villages in the Anuradhapura District of the North Central Province (Figure 1) belong to the dry zone. Each typically contains several small tanks, with a history of a main rain-fed paddy crop and a more limited dry season crop. Until the relatively recent introduction of a parallel agro-well based highland cultivation, households in these and adjacent villages remained poor, with few employment opportunities outside of cultivation. The introduction of agro-wells to this area through the National Agro-well Program (1989) was a direct policy response to communities' economic stagnation. At a time when the country was transitioning to a more monetized society, agro-wells were to provide an additional means of production and income to communities unserved by modern surface irrigation schemes. The program subsidised construction of open wells and diesel pump acquisition, and its timing coincided with the groundwater-driven Green Revolution (Giodarno, 2014) that made pumping technologies available and affordable. Groundwater was pumped from the shallow regolith aquifer that lies under the NCP and much of the dry zone, offering limited and spatially irregularly located pockets of water (Panabokke and Perera, 2005).

Figure 1. Agro-climatic zones of Sri Lanka

Agro-Well Production: Its Evolution, Impacts and Drivers

Introduced to the NCP through a government subsidy program in the late 1980s, agro-wells, as evidenced by Figure 1, are typically 20 feet in diameter and between 20 and 30 feet deep. Originally dug by hand and mainly unlined, these are now dug by machines, and mostly lined, as seen in Figure 1. The wells are generally situated close to the land they will irrigate, and water is accessed by small diesel pumps conveyed to the land via plastic pipes, all of which are mainly owned by the farmer. Each well will irrigate one acre on average, depending on the crop.

With agro-wells, farmers were for the first time able to irrigate up to an acre of crops such as soya, chili and onions on highland areas (Panabokke, 2003) for profit during the dry season. Early signs of success attracted further support from donors, NGOs and provincial

ministries, although investments by farmers themselves soon became a major driver in agro-well expansion (Karunaratne and Pathmarajah, 2003). This is illustrated in Puliyankulama village (one of the study sites), where a few wells were first introduced between 1988 and 1990 with financial support from a provincial department. Following a period of observation by farmers, adoption escalated after 1996, driven mainly by private investments, often enabled by the sale or pawning of belongings. Over the 10years from 2002-2012, the number of agro-wells in the four study villages consequently increased by between 64 percent and 179 percent.

Figure 1. A typical lined agro-well in the authors' study area.

With irrigation from agro-wells, dry season crop choices on highland plots have evolved from traditional crops such as mustard, finger millet, mung bean and sesame seed chosen for their drought tolerant properties, to chili and onions today for their profitability. Maize is grown in the wet season giving rise to a mainly two-crop cropping calendar on highland plots. This occurs in parallel with the two paddy crops on lowland plots, irrigated by rain and limited quantities of water from small tanks. This shift from subsistence to profit-oriented cropping also spurred the expansion of highland area brought under cultivation. In Puliankulama village for example, this area increased by 470 percent between the 1980s and 2012, mainly at the expense of forest land. The extent of highland land ownership also rose from about an acre per household to up to 10 acres in some cases, although such acreage often consists of several smaller land parcels distributed in different locations.

Impacts: Economic, Social and Climate-Proofing

These changes have culminated in transformative socio-economic impacts. As illustrated by Table 1, the average net annual income today from an acre of paddy (the scenario prior to agro-wells) is only USD 1,567, with the majority of this income generated by the wet season crop. In contrast, total annual net income from an acre of highland cultivation (wet season maize and dry season onion and chili) is an estimated USD 6,554, accounting for 80.71 percent of net annual income from agriculture per acre. Of particular importance is that most importantly, the contribution of agro-wells to total household net income per acre (from chili and onions) is an estimated USD 4,855 or almost 60 percent of annual agricultural income, suggesting a more than doubling of household income. This is all the more important given that farmers had virtually no earnings from highland cultivation during this season prior to the agro-wells. Considering that an acre of dry season paddy would yield only USD 237 net income to cover almost six months of living, the income from an acre of either chili or onion represents a 10-fold increase in income over the same period.

Table 1. Net income per acre from lowland paddy and highland cultivation (USD).

Season	**Lowland**	**Highland**			**Annual Total**
	Paddy	Maize	Chili	Large Onion	
Wet	1,330	1,699	Not cultivated	Not cultivated	3,029
Dry	237	Not cultivated	2,098	2,757	5,092
Annual Totals	**1,567**		**6,554**		**8,121**

These changes in the agrarian economy have translated into significant improvements in several other dimensions of well-being such as access to diverse food sources and resulting in improved nutrition, and increased household assets as evidenced from the high incidence of mechanization (e.g. 2-wheel and 4-wheel tractors, motorbikes) and well-built houses. That such changes can be attributed to agro-well production is confirmed by official employment statistics (Thirappane Divisional Secretary Division 2012) that confirm that only 16 percent of the population in the study villages between 18 and 60 years of age are employed outside of farming in public or private employment, and also by the attributions made by farmers themselves. In contrast to the virtually full engagement of households in the study villages in

agriculture, Gamage and Damayanthi (2012) found that in the smallholder agriculture sector overall, as much as 35.2 percent of farmers who focused on paddy cultivation were 'unemployed.' Several social changes have also resulted, not least in terms of women's mobility given the constant engagement of men in year-round agriculture. While it was rare to see a woman riding a motorbike or operating agricultural equipment, this is now commonplace as the demands and practicalities of commercial highland cultivation requires both women and men to be mobile and able to work independently. In addition to personal autonomy, economic opportunities for women have been greatly enhanced, including for female heads of households for whom the high economic returns and relatively less labor intensity of highland cropping is critical.

A key determinant of these benefits is the significant resilience this agro-well driven production system appears to provide in the face of water stress, at current levels of extraction. This was demonstrated during the extended dry conditions experienced in the latter half of 2013 and first half of 2014 when net income from chili and onion rose despite two failed monsoons. The abandonment of dry season cropping in many parts of the dry zone where agro-wells are absent resulted in supply shortages in chili in particular. This meant that farmers in the study villages irrigating from agro-wells were able to sell some part of their chili crop at LKR 600/kg (USD 4.06) or approximately three times the peak farm gate price during normal seasons. Another dimension to the robustness of this highland cultivation arises from the availability of profits from both the wet season maize and dry season chili and onion. This is important if losses are incurred in paddy cultivation, and to minimize cultivation based on debt. For example, while much of the paddy crop was lost when the 2013-14 monsoon failed, the less water intensive maize grown concurrently on the highland plots yielded an additional 500kg/acre worth approximately LKR 18,000 (USD 138.50) in the drier-than-usual conditions that partially off-set the financial loss linked to the paddy crop. Much of the debt incurred by farmers results less from the purchase of consumable production inputs such as seeds and chemicals, and more much larger investments such as farm machinery and transport vehicles.

Contextual Drivers

Underlying this agro-well driven production system is a diverse but inter-related set of contextual enabling factors that cover social, political, institutional, economic, ecological and physical dimensions. Many of these elements, discussed below, have a similar temporal evolutionary trajectory to the production system itself that reflects broader developmental processes in the country.

Government policy and subsidies provided the original impetus through the structured agro-well program. While this initiative was time-bound, external support has continued through mainly processes of political patronage, whereby especially during elections financial or in-kind support is provided by candidates to constituents. This often constitutes gifts of agricultural tools or subsidies to acquire the same, since farming remains a dominant livelihood. Such infusions occur at regular intervals given the cycles of national and provincial elections over time. Land availability has been critical given an increase in households and their demand for more highland plots over time. This expansion has been underwritten by conversion of state land (mainly forests) until other village and protected area boundaries were reached. This loss of forests has given rise to a negative feedback loop in the form of acute conflict between people and wildlife (e.g. elephants), posing a threat to crops, physical property and life.

Such large-scale conversion of forests could not have occurred without purposefully lax rule enforcement by line agencies and local government. Interviews with relevant officers from these agencies confirm that poverty alleviation was consciously prioritized over rule enforcement, given the poverty of these villages in the early 1990s. This tacit support is linked to strong kinship and other social relationships since many local government and line agency staff were local recruits, with close social ties to these farming communities. Social networks have also helped maintain low labor costs as what was once abundant labor sourced from adjacent villages became scarce, as the farm hands became highland cultivators themselves after observing the production system in the study villages. Labor scarcity triggered the resurgence of traditional reciprocal forms of free labor (attham) amongst farming households during land preparation, transplanting and harvesting, as observed during fieldwork. The availability of agricultural mechanization has saved on labor and time. Mechanization has also become symbols of prosperity. The diversification and accessibility of credit sources

has facilitated mechanization, following the entry of several private lending institutions and the penetration of service delivery to nearby towns, if not the villages themselves. Similarly, the spread of affordable communication technology has linked farmers to diverse service providers, including markets, credit suppliers and state sector service providers.

While the above factors deal primarily with the growth of production capacity, the concurrent development of agricultural markets has been critical not only in absorbing production, but doing so at prices that have thus far outstripped costs of production and farmers' perceptions of risk. Government investments in a wholesale market in Dambulla from which most other parts of the country are supplied represent a major asset. Its proximity to the study villages, especially following improvements in the rural road network, combined with mobile communication that enable farmer-buyer negotiations, has provided a ready market for particularly the dry season highland chilies and onions. The market for rain-fed maize grown on the same highland plots has also evolved with the entry of several private companies for which maize constitutes a key ingredient in local breakfast cereals they produce. Their sourcing network based on forward contracts has gradually replaced a more exploitative market controlled by local middlemen. Farm gate prices for maize have consequently almost doubled from approximately USD 0.13 to USD 0.25/kg. The forward contract system also means an important structural change to the maize market by assuring the purchase of a minimum quantity from each farmer registered with each company, as well as a minimum price, irrespective of what the market price may be at the point of sale. This has meant that the net income derived from an acre of highland maize is now also higher than from an acre of paddy (Table 1).

Market structure is also central to the current profitability of chilies and onions. Their markets are characterized by domestic production deficits to the order of almost 50 percent of demand (Sri Lanka Government, 2008). While the deficit is addressed through imports, changes in domestic output produces sharp price fluctuations through the dry season, especially with chili, when short-term price spikes grant farmers significant profit margins. This is possible also because of the nature of the specific crop, since chili allows for continuous harvesting once the plant reaches maturity, compared to paddy where harvesting occurs only at the season's end. A further factor is government fiscal policy linked to its desire to reduce the

financial burden of high food imports (Sri Lanka Government, 2008). This prompts fiscal interventions at the time of local harvests to ensure imports of onions and other crops will be high, thereby creating sufficient profit margins for local farmers as encouragement for increasing their investments in production.

While the above discussion addresses aspects of production growth and profitability, other factors come into play when considering the system's sustainability. The three to five small tanks located in different parts of each study village provide a major advantage by providing a pre-existing groundwater recharge mechanism that underwrites the continued supply of groundwater (Panabokke et al., 2001). Another particularly interesting dimension is that groundwater appears to be well governed despite the absence of any formal or discernible informal institutions. Central to current self-management is farmers' willingness to adjust cropping areas each season according to their observation of groundwater behavior linked to their perception of climatic conditions. This was observed when virtually all farmers interviewed had decided to halve their highland cropping area in the 2014 dry season following failure of the late 2013 to early 2014 monsoon and the longer time it was taking for their wells to fill following each irrigation. This self-regulatory behavior has been central to the resilience sustainable groundwater management has provided during normal dry seasons as well as periods of intensified water stress. What is especially notable is that despite the absence of purpose-built formal mechanisms to facilitate collective decision-making, what appears to be an individual farmer decision is nevertheless also represented at village scale, most likely through vibrant kinship and other social networks.

Discussion: Lessons Learned, Their Scalability in Sri Lanka and Applicability in the Asia-Pacific Region

The details presented above suggest that agro-well-based highland production offers significant potential for transforming rural livelihoods in water deficient areas of Sri Lanka's dry zone. It can provide a win-win scenario by concurrently helping realize government objectives around domestic food security and easing of fiscal burdens by increasing domestic production of high value crops, thereby reducing the large domestic demand-supply deficit that needs to be bridged through imports. The case study also demonstrates that this production model based on sound

groundwater use has also successfully overcome the historical constraints to profitable cultivation in the dry zone of the country, demonstrating considerable resilience during normal seasonal and exacerbated water stress conditions. The expected lengthening of the dry season due to climate change is likely to bring this resilience into play more often, and test currently sustainable practices.

Within Sri Lanka, the scalability of this production system is an obvious question. The characteristics of the regolith aquifer in terms of the volume and spatial spread of groundwater is a fundamental consideration in this respect. Current opinion based mainly on a study of 50 tank cascades in the Anuradhapura district commissioned by IWMI (Senaratne, 1996) suggests this shallow groundwater table is limited in its quantity, with Dharmasena (2001) recommending that only 25 percent of the potential groundwater storage be exploited. An important challenge is to identify the more promising areas of the aquifer, given the patchy distribution of groundwater. In the absence of a more precise and spatially nuanced understanding of groundwater availability in this aquifer, agro-well adoption is likely to continue on an ad-hoc basis, driven for the most part by farmer investments. While agro-wells clearly cannot constitute a panacea for all areas of the NCP and other regions that share the regolith aquifer, research to update current knowledge of groundwater quantitative and spatial availability could likely facilitate a more spatially targeted approach in the NCP and elsewhere. Recognizing the above stated limitations, Panabokke and Perera (2005) believe that this aquifer nevertheless represents a highly renewable groundwater supply due to an abundance of small tanks in many parts of the dry zone that continuously replenish the aquifer well into the dry season. Agro-wells are already emerging as an important source of supplementary irrigation even in the major Mahaveli surface irrigation scheme in northern and north central provinces where dry season canal flows are no longer sufficient (Kamaladasa pers com).

The high economic values supported by agro-wells and the resilience to drought and rainfall fluctuations, echo the impacts of groundwater on food production and agrarian livelihoods across the world where groundwater buffers against droughts, helps intensify cropping, and allows farmers to diversify to high-value crops (Shah, 2014). Success, however, has often sown the seeds of trouble (Shah, 2014) as over-exploitation and ineffective governance given diffused pump ownership, have led to declining

groundwater tables. Examples from the region include many parts of India where groundwater dominates irrigation, and northern and northeastern Bangladesh where groundwater-irrigated boro rice production, whilst contributing significantly to realizing government's goal of rice self-sufficiency, has generated serious concerns over the sustainability of groundwater tables. Despite the seeming abundance of surface water in Bangladesh, groundwater is the most important water source for domestic, industrial and agriculture sectors, with 85 percent of irrigation sourced from groundwater (Faruque and Ali, 2005). Much of this sustains a single crop: rice, which accounts for 93 percent of the increase in gross cropped area, and 77 percent of gross irrigated area in the country between 1990 and 2010 (Amarasinghe et al. 2014). Nearly 54 percent of rice production accrues from the dry season boro crop (World Bank, 2016b), and 80 percent of this crop is irrigated with groundwater Amarasinghe et al. (2014), made possible by the rapid adoption of affordable mostly diesel-powered shallow tube wells or STWs (Shamsudduha et al. 2011) since the 1970s, and more recently, the state-sponsored electric deep tube wells (DTWs).

Consequently, on the one hand, groundwater plays a pivotal role in Bangladesh's agricultural economy as recently noted by the World Bank (2016a) which believes agriculture to be the primary driver behind the dramatic decline in the country's poverty incidence from 58.8 percent in 1991-1992 to 24.8 percent in 2015. On the other hand, the impact on aquifers has, however, been significant, as seen in declines in groundwater levels in Rangpur, Thakurgaon and especially Rajshahi districts-key regions for boro rice production. In a large part of the former two districts, the water table has dropped from 0-5.3m to 5.4-7.6m while the water table in Rajshahi has fallen from 11.3-15.0m to 15.0-20.0m, as DTWs have replaced STWs in many parts providing greater water access at faster pumping rates and about half the cost compared to STWs. Qureshi et al. (2014) also point out that the quality of groundwater accessed is likely to decline, while Amarasinghe et al. (2014) in fact conclude that a number of areas in Rajshahi district have already passed the sustainable thresholds of groundwater use. Qureshi et al. (2014) therefore correctly conclude that reigning back groundwater consumption will require more imaginative approaches than through direct regulation (e.g. permits) due to farmers' strong cultural bonds to rice and the high transaction costs of regulating DTWs and STWs. Concern over groundwater levels is such that a moratorium on the installation of new DTWs is currently in effect.

It is from these global and regional contexts of a groundwater 'governance deficit' that the seemingly sustainable self-regulatory mechanism observed in this case study derives significance. Central to this approach is the high economic returns from other high value field crops which provide an 'economic space' for farmers to modulate groundwater use in response to different climatic conditions. Reference to high value crops alludes to a second key feature of this production model, namely crop diversification. Diversification has also been possible due to the broader development of domestic markets and associated investments such as roads, distribution systems and communications. This contrasts with a dearth of diversification options in northern Bangladesh for both farmers seeking higher income and a government desiring a reduction in boro rice cropping to ease pressure on groundwater tables in the dry season. The World Bank (2016a), while recognizing agriculture's continued positive impact on rural poverty reduction in Bangladesh, highlights diversification as the critical need if current gains in poverty reduction are to be sustained.

Why high economic returns in the study villages have not incentivized further intensification remains unclear, and it warrants further research, along with the exact mechanisms underlying farmer self-regulation around cropping and irrigation through seemingly self-organizing processes. Here, the notion of self-producing communication that gives rise to a social system (Luhmann, 1995) is of particular interest given its links to informal social networks as possible communication pathways. What is clear, however, is the strong relationship between the use of open wells that enables almost daily observation by farmers of groundwater behavior. It is their view that years of such observation has afforded them a profound practical understanding of and respect for this resource which underlies their willingness to in effect apply the Precautionary Principle in how they exploit the resource. The replicability of such a self-regulatory groundwater management system is yet another key condition for the successful adoption of agro-well based production in other areas. The two central determinants appear to be the existence of sufficient social capital (Uphoff and Wijayaratne, 2000) and a level of farmer maturity which, in terms of groundwater utilization, may well require several years of resource observation, although cross-village mentoring through modern communication technologies may circumvent this temporal dimension.

In addition to the diverse conditions underlying agro-well based production, another important consideration must be the concerns over groundwater quality and attendant health and economic implications. High agro-chemical use in this production system (a feature shared with paddy cultivation) further adds to the pollution of water tables and soil, and represents a significant trade-off. Furthermore, while high profits from small land parcels is an important feature of this production model, especially for contexts with limited available land, the loss of forest cover and resulting human-wildlife conflicts due to the expansion of agro-wells represents another important trade-off. These externalities in conjunction with the diverse enabling factors discussed above highlight the importance of ensuring public policy, which is informed by multi-dimensional information. As such, while agro-well production in north-central Sri Lanka offers intriguing lessons on the value of groundwater, its replication or adoption in other contexts can be seen as a complex issue.

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Thailand

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Climate Change Challenges: Catalyst for Sustainable Development

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Abstract

"Saving our planet, lifting people out of poverty, advancing economic growth...these are the one and the same fight. We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women's empowerment. Solutions to one problem must be solutions for all." Ban Ki-moon, United Nations Secretary General.

This document is the final report of a study undertaken for the Bay of Bengal Initiative to assess the climate change impacts of options for municipal solid waste (MSW) management in the BIMSTEC region. Climate change impacts pose a formidable challenge to existence of life on Earth, yet it is also a key driver that promotes sustainable development. The paper reflects the current trends of MSW management, its associated climate change impacts and an exhaustive analysis on a case study of a private sector company, MK Aromatics Limited, which has operational facilities in this sector. The waste management sector has been estimated to contribute at least 5 percent of the total greenhouse gas (GHG) emissions annually. It is important to recognize that the waste sector is in a unique position to move from being a minor source of global emissions into becoming a major saver of emissions. While significant level of emissions are released through waste generation, transport, treatment and disposal, the prevention and recovery of waste (as energy or secondary materials) avoids emissions in all other sectors in the economy. This paper seeks: (a) to provide an overview and relationship between climate change and waste management activities, (b) knowledge sharing from macroeconomic analysis conducted by recognized institutions such as the International Environmental Technology Centre (IETC), where a UNEP-led framework strategy assists member countries to prioritize their resources in waste management and climate change mitigation, and (c) to present a detailed case study of an implemented solution through successful private-public sector partnership, thereby bringing to the forefront the importance of innovation and entrepreneurship to tackle climate change.

The Bay of Bengal Initiative is clearly positioned to assist and catalyze enhanced action for climate change mitigation in the waste sector, through collaboration with existing organizations to ensure more effective delivery of initiatives in the region. The leadership of the countries in the BIMSTEC region has a key role to play in encouraging partnerships in the fields of waste management and climate change. This paper is intended as a further step in the BIMSTEC dialogue to encourage domestic players to adopt out-of-the-box initiatives, engage the international waste community to partner in knowledge-sharing, and collectively create a strategy, which will deliver a sustainable and meaningful impact on the waste sector and address climate change.

Introduction

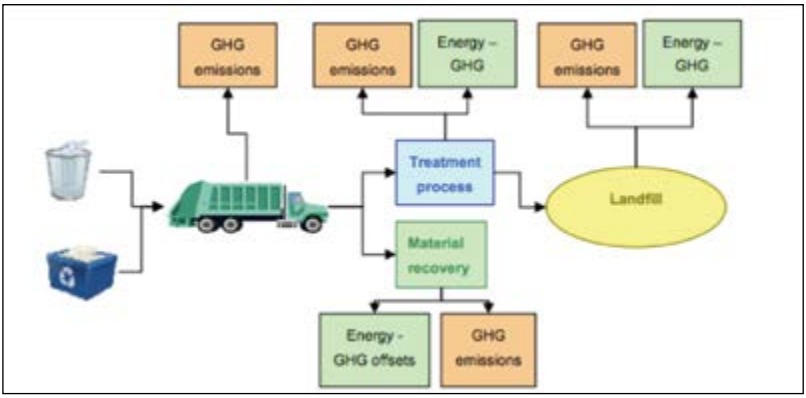
Regional cooperation is not an end in itself but a means to foster economic development. In this light, the latest effort to boost cooperation in the Asia Pacific region is BIMSTEC, which was previously known as the Bangladesh-India-Myanmar-Sri Lanka-Thailand Economic Cooperation, initiated in 1997 as a sub-regional grouping. Seven member countries share the common waters of the Bay of Bengal which are Bangladesh, Bhutan, India, Nepal and Sri Lanka from the South Asian Association for Regional Cooperation (SAARC) region and Myanmar and Thailand from the region of Association of South East Asian Nations (ASEAN). The Initiative brings together 1.5 billion people-21 percent of the world's population, and a combined GDP of over $2.5 trillion into the bloc. The BIMSTEC aims to promote harmonious economic development in the sub-region through expansion of trade. It acts as a bridge between the two major regional groupings in Asia which is ASEAN and SAARC. This cooperation received a major impetus after the signing of the framework agreement for free trade in 2004 and with the entry of Bhutan and Nepal as its newest members (Devi, 2005).

Climate change is one of the key concerns identified in the BIMSTEC Initiative. This is an important milestone in the wake of the widespread impacts that can be seen on human and natural systems. Extensive research has clearly indicated that the emission of greenhouse gases in recent times is the highest in history. Researchers with documented evidence state that the atmosphere and oceans have warmed, the amounts of snow and ice have diminished and sea level has risen. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1995 to 2015 has been the warmest 20-year period of the last 1,500 years where such assessment is grounded in an evaluation of underlying evidence and agreement. It is further stated in IPCC's Fifth Assessment Report (AR5) that greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other drivers, have been detected throughout the climate system and are evidenced to have been the dominant cause of climate change this century.

Relationship between waste management, GHG emissions and climate change

Energy security is essential for economic development and improvement of quality of life. A large proportion of energy is till date obtained from fossil fuels (petroleum, natural gas and coal) across the world. This has resulted in an increase in energy-related emissions which lead to global warming and accelerated climate change causing more frequent and intense floods and storms, excessive rainfall in some areas while drought in others, melting of polar ice sheets and rising sea levels. Agarwal's (2015) research outlines the limited results from efforts taken to contain energy-related emissions. His in-depth analysis further outlines the limited success of stronger policies to address climate change as energy is essential for development and its curtailment will throttle growth. In short, developing nations require energy inputs to further their development agenda and to alleviate poverty in comparison with the developed nations.

Despite a growing number of climate change mitigation policies, total GHG emissions have continued to increase with a reported 78 percent of total GHG emissions to have been contributed by fossil fuel consumption. On a global scale, economic and population growth continues to be the most important drivers of increases in CO2 emissions from fossil fuel combustion. Increased use of coal has reversed the long-standing trend of gradual de-carbonization (reduce the carbon intensity of energy) of the world's energy supply (UNEP, 2010). It is notable to recognize if the waste management sector were to be harnessed for its potential to generate petroleum, it would



GHG Emissions form Municipal Solid Waste System.

complement various climate change mitigation policies and create economic value.

With rapid urbanization, energy scarcity and environmental preservation remain the two most important challenges faced by most cities in the BIMSTEC region. Environmental preservation is often at risk with an increase in documented and undocumented landfill sites. Thailand is estimated to have only 40 percent of landfills that are compliant with standards specified by the government. Approximately 60 percent of its landfills are undocumented due to illegal dumping. Municipal Solid Waste is an issue that needs to be addressed, and the way forward for both LLDC's & Developing Countries on the Bay is economic value addition. The image below is a brief schematic that depicts the points of GHG emissions in the waste management supply chain from collection to disposal at landfill sites.

Every waste management practice from generation to disposal generates GHG, both directly (emissions from the process itself) and indirectly (through energy consumption). The overall climate impact or probable benefits of the waste management system is dependent on net GHGs. Literature review indicates that the actual magnitude of these emissions is difficult to determine because of poor data on worldwide waste generation, composition and management and inaccuracies in emissions models. The most widely used method to estimate GHG emissions from various waste management practices tend to be based on life-cycle assessment methods (LCA). These studies have provided useful analysis to map the potential impacts and evaluate various waste management options. Due to the significant gaps in data availability and resources, LCA studies have generally been conducted on scenarios for developed countries. This implies that the key assumptions upon which the assessments (such as local/regional waste composition, country-specific energy mix, technology performance, etc.) are carried out are not necessarily transferable to other countries. Hence, a global comparison regarding the GHG performance on different waste management technologies is limited in results generated. Thus, the approach undertaken in this paper was to set pre-defined criteria and select the best fit technology most suitable for the BIMSTEC region to address the challenges of GHG emissions and plastic waste management as a solution to tackle climate change.

Substantial climate benefits are recorded of waste practices that have resulted from avoided landfill emissions, reduced raw material extraction and manufacturing, recovered materials and energy

replacing virgin materials and fossil-fuel energy sources, carbon bound in soil through compost application and carbon storage due to recalcitrant materials in landfills. The climate benefits of waste avoidance and recycling are extremely limited in the age of consumerism and large-scale poverty alleviation, which is a key priority on the agendas of most governments in the region. A paradigm shift in global consensus is the need of the hour where the best available option to tackle the challenges of exponential waste growth due to rapid urbanization and population growth is recovery of energy from waste. Maximum resources and effort should be allocated to scale up innovative solutions and modernize the waste industry sector. There should be a merger between the informal and formal waste management sectors in the region. The informal waste sector makes a significant, but typically ignored, contribution to resource recovery and GHG savings in cities of developing nations. Through improved management of waste, there is a clear recognition of the many climate benefits that could be achieved.

The UNEP is involved in a variety of relevant partnerships and programs, such as integrated waste management, cleaner production and sustainable consumption and production in the BIMSTEC region. Clean Development Mechanism (CDM) projects in the waste sector are being given considerable attention. The CDM activity has focused mainly on landfill gas capture (where gas is flared or used to generate energy) due to the reduction in methane emissions that can be achieved (UNEP, 2010). There is considerable attention given to "plastic to fuel" technology as it is the most cost-effective and energy-efficient way to deal with post-consumer plastic waste that forms the bulk proportion of waste in landfills. However, there is a lack of a cohesive approach, which has resulted in gaps, duplication and regional disparity in the programs offered. A central mechanism is needed to collaborate with existing organizations in the region to ensure accessibility to and dissemination of relevant information from across the globe, effective use of local resources to tackle GHG emissions and climate change through integrated waste management, promotion of best practices and rapid transfer of simple, effective and proven technologies as well as knowledge in developing countries.

Developed nations often imply that the developing nations are required to reduce their GHG emissions through curtailment of their energy use or shift to alternative, renewable energy sources that include nuclear, hydro, biodiesel, wind, solar and Polymer Oil. The high cost of

alternative fuel sources, non-availability of appropriate technologies, limited financing options alongside the need to provide energy access to large poorer populations are common constraints faced by developing nations. It is important, though to recognize that carbon gas emissions affect nations universally without any differentiation. It is also important to recognize that it is the poor that will be affected most by the impacts of climate change. The Climate Conference, COP 21 that was held in December 2015 in Paris, was a beacon of hope for the ship of humanity where the Universal Climate Agreement was finalized between most developed and developing nations that agreed to a set of common principles, but with differentiated responsibilities.

	Upstream (indirect)	Direct (operating)	Dwonstream (Indirect)
Accounted	Production of fuel, electricity, heat, and ancillary materials	Collection and transport, intermediate facilities, recycling, aerobic/ anaerobic biological treatement, thermal treatment, landfill	Emissions and savings of energy/ material substitution, carbon sequestration /storage
Not acconted	Unaccounted GHGs, construction, maintenance, decommissioning, import export, embedded energy in waste	Unaccounted GHGs, unaccounted waste streams, histrical waste (in landfill), staf commuting and travel	Unaccounted GHGs, decommissioning (end-of-life)

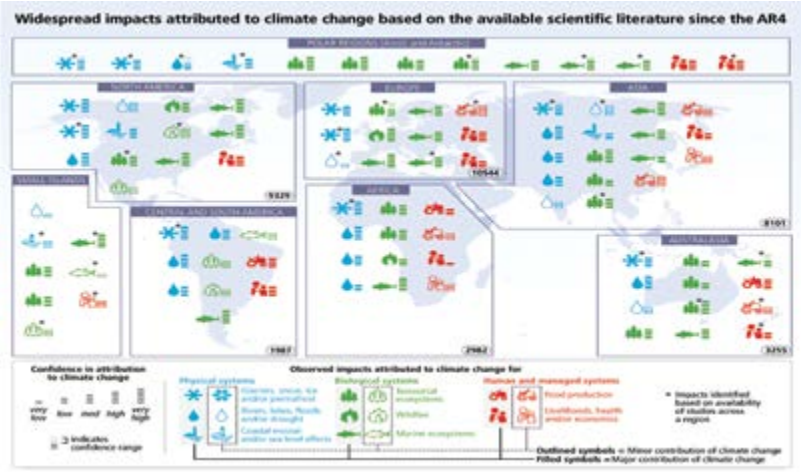
Accounted & unaccounted GHG emission from various stages of waste management

The above schematic sourced from a report by Ocean Recovery Alliance (2015) is a brief overview of accounted and unaccounted emissions in the waste management chain. Waste management is a crisis of growing proportions but is also an opportunity in disguise to further economic growth, creation of jobs, socio-economic upliftment of the poorest sections that work in the formal and informal waste industry in order to create a sustainable future for current and future generations. It is a sector which, if handled well, can transform into a major source of emission savings and be a key solution in a universal action response toward climate change.

Climate Change: Impacts, Causes & Risks

In recent decades, evidence and literature review conclude that changes in the climate have caused impacts on natural and human systems across continents and in the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate.

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report summarized in detail evidence of observed climate change impacts. The figure above summarizes the widespread impacts of climate change on a global scale. It was found that the impacts are strongest and most comprehensive for all natural systems. In many regions, changing precipitation or melting snow and ice are altering



Widespread impacts of climate change effects (Source: AR5. 2014).

hydrological systems, affecting water resources in terms of quantity and quality. Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to ongoing climate change. Assessments covered on a wide range of regions and crops shows that negative impacts of climate change on crop yields have been more common than positive impacts. Impacts of ocean acidification on marine organisms have been attributed to human influence.

In a cautionary advisory to policymakers in the AR5 Symposium, it was stated that continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. The table below puts into perspective the activities in the waste management sector and corresponding levels of GHG emissions that cause climate change.

Overview of waste management processes & levels of greenhouse gas emissions (Source: EPA)

Process	Increased GHG Emissions	Decreased GHG Emissions
Extraction	GHGs are emitted during the harvesting of resources and transport of raw materials.	Waste prevention and recycling delay the need to extract some raw materials, lowering GHG emission during extraction.
Manufacturing	Manufacturing products releases GHG during processing as energy is expended during product use.	Waste prevention means more efficient resource use, and making products from recycled materials requires less energy. Both of these? lower greenhouse emissions during manufacturing.
Combustion	Burning different kinds of waste in an incinerator increases GHG.	Waste prevention and recycling reduce the amount of waste sent to incinerators, lowering the greenhouse gases emitted during combustion.
Landfilling	GHG are emitted as waste decomposes in landfills.	Waste prevention and recycling reduce the amount of waste sent to landfills, lowering the greenhouse gases emitted during decomposition.

Future Risks Caused by Warmer Temperatures and a Changing Climate

Cumulative emissions of GHGs & CO_2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary by a wide range, depending on both socio-economic development and climate policy, but mutually reflect a common set of challenges of rising sea levels, warmer climates, disappearance of ice sheets and ocean acidification. Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development (AR5, 2014).

The risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems, including their ability to adapt. The increase in temperatures, magnitudes of warming and other changes in the climate system, accompanied by ocean acidification, increase the risk of irreversible detrimental impacts. The overall risks of future climate change impacts can be reduced by limiting the rate and

magnitude of climate change. The precise levels of climate change sufficient to trigger abrupt and irreversible change remain uncertain, but the risk associated with crossing thresholds (such as limiting rise in temperatures to a maximum of 2 degrees Celsius) increases with rising temperature. For risk assessment, it is important to evaluate the widest possible range of impacts, including low-probability outcomes with large consequences.

Literature review suggests that a large fraction of species face increased extinction risk due to climate change during the 21st century. Most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change in most landscapes. Future risk is indicated to be high by the observation that natural global climate change at rates lower than current climate change has caused significant ecosystem shifts and extinctions of species during the past millions of years. Marine organisms will face progressively lower oxygen levels and high rates and magnitudes of ocean acidification with associated risks exacerbated by rising ocean temperature extremes. Coral reefs and polar ecosystems are especially vulnerable. Coastal systems and low-lying areas are at risk from sea level rise, which will continue for centuries even if the global mean temperature is stabilized today.

Climate change is projected to undermine food security. Due to projected climate change by the mid-21st century and beyond, global marine species redistribution and marine biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services. For wheat, rice and maize in tropical and temperate regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late 20th century levels, although individual locations may benefit. Global temperature increases combined with increasing food demand would pose large risks to food security globally. Climate change is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions that will result in intense competition for water among various regions.

The biggest risk in the author's opinion is that climate change is a threat to sustainable development. Opportunities to take advantage of positive synergies between implementable solutions and mitigation may decrease with time, in absence of a timely response today. Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, encompassing connections among human health, water, energy, land use

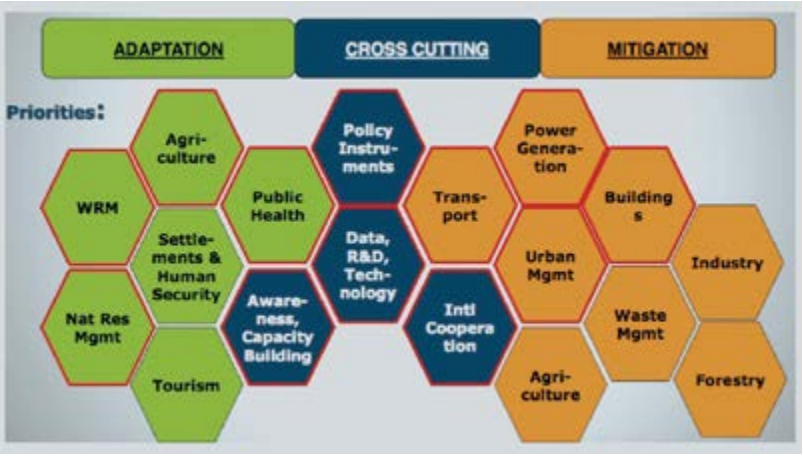
and biodiversity. With optimistic foresight, nonetheless, many opportunities are to be recognized to link mitigation, adaptation and the pursuit of other societal objectives through integrated responses. Successful implementation relies on relevant tools, suitable governance structures and enhanced capacity to respond through engagement of civil society organizations, private and public sectors.

Thailand's perspective on Climate Change

Public Policy Considerations, Constraints and Outlook

Thailand has recognized and given importance to climate change issues both at the national and international level. The 11th Plan (2012-2016) outlines global warming as a key concern that will influence future national development. Thailand has identified various approaches to enhance efficiency in energy conservation, generation of renewable energy and adaptation to climate change. Key factors which will determine the country's development strategy outline are energy scarcity, demographics and an ageing society and global warming.

Sector-level policies have been formulated to address the need to adapt to the impact of climate change. Various spheres which include water management, irrigation and agriculture in the face of increased frequency of droughts and floods are prioritized. For example, in the agriculture sector, seed varieties with water stress resistant characteristics are being researched to ensure food security.



Snapshot of Thailand's Climate Policy.

Thailand's mitigation policy is aimed at reduction of carbon emissions from both production and consumption activities. In the sphere of production, it can be seen that several policy measures have been introduced by the Ministry of Energy. Sirinapaporn (2015) has stated that mitigation activities can benefit from the structure of the proposed 'feed-in-tariffs' and the existing 'adders' placed on top of the selling price per unit of electricity (kWh) if they use energy inputs from biomass, bio-gas, solar and wind. With this alternative energy price, private sector developers can bundle a Clean Development Mechanism (CDM) project with electricity production and sell to the national grid. On the consumption side, carbon footprint labeling is now shown on products to raise awareness among consumers. There is also an ongoing effort between large private companies and government research to look for second and third generation bio-fuels.

The public are also being made aware of climate change via media and dissemination of information through various media channels which include books, newspapers radio and television and websites. Capacity-building among bureaucrats is reflected in the national and local government budget. The recent extreme flooding event that occurred in Thailand in 2011 caused policymakers to invest more resources to address climate change. This event was catastrophic as it was measured to have received the highest rainfall in the last 100 years. Heavy flooding in the central plains area, including the Bangkok Metropolitan Region during the third and fourth quarters of 2011 led to a substantial loss of life and assets.

The Office of Natural Resources and Environmental Policy and Planning (ONEP) has also prepared the Thailand Climate Change Master Plan B.E. 2555-2593 (2012-2050). This Master Plan identifies three strategies on (i) climate change adaptation; (ii) mitigation of GHG emissions and increasing carbon sinks; and (iii) capacity-building for climate change risk management. Each of these strategies proposes short-medium-and long-term objectives to be undertaken by lead government agencies.

However, climate change impacts are not remedied by policy measures without a complete analysis to finance possible response. The National Economic and Social Development Board (NESDB) has recognized this risk of climate change in conjunction with limited financing options. It is stated that Thailand will be required to turn climate risk into a 'benefit' of economic development and GHG emission reduction. The NESDB, which is based on the economics

of climate change, has attempted to identify long-term maximum welfare, measured by economic growth potential (2010-2050) as constrained by climate change scenarios for Thailand. In association with various stakeholders, various solutions to prevent Thailand from the possibility of negative economic impacts of climate change are being evaluated with an emphasis on reduction in impact on energy and food prices. This is critical as it would have an adverse effect on the long-term economic growth potential of the country and welfare of the Thai people.

Thailand places great emphasis on preparedness, solution and adaptation to mitigate the impacts of climate change. In the sphere of public policy, sectors that are at high risk and exposed to biological, physical, social and economic and livelihood vulnerability such as small-scale agriculture and traditional fishing are given impetus. Thailand utilizes the crisis and effects of climate change as an opportunity to actively promote sustainable development. Furthermore, the concept of public sector stewardship to induce change, as well as encouragement of partnerships between the public, private and civil society sectors on the basis of the Polluter-Pay Principle (PPP).

The philosophy of a self-sufficient economy is also given substantial consideration in policy measures laid out to address climate change from the perspective of the Kingdom of Thailand. In short, Thailand has an effective climate change master plan with a vision to achieve sustainable development with a low carbon growth in accordance with the sustainable development agenda. Thailand Climate Change Master Plan is a framework of integrated policies and action plans relating to climate change.

Case Study on "MK Aromatics Limited"

Public-Private Sector Partnership for Successful Implementation of Solution focusing on a single waste Stream of Post-Consumer Waste Plastics to Mitigate Climate Change (Technology & Financing)

In a public-private partnership (PPP), each party contributes financial, human and technical resources and has shared responsibility for the decision-making process. There are five primary types of PPPs: service contracts, management contracts, lease contracts, build-operate-transfer contracts and concessions. Under each contract structure, the project owner is able to enter into contract with an independent operator for the day-to-day management of the

project. MK Aromatics Limited is the only private sector company that has developing systems under a PPP project structure with successfully operational plants in the BIMSTEC region. (Ocean Recovery Alliance, 2015).

The PTF technologies have the potential to address a unique set of environment and energy challenges. In Thailand, plastics represented approximately 20 percent of the total MSW stream, or approximately 4 million tons in 2012. Of the amount generated, only around 7 percent was recovered–either through waste-to-energy or recycling which leaves a significant missed opportunity to recoup value from end-of-life plastics. The criteria for selection of a private sector company as a case study for this paper were the following:

1. A company that had a presence in both SAARC & ASEAN markets;
2. A company that had a successful operational track record to address waste management in a manner that contributed to reduction in carbon emissions;
3. A company that had ongoing projects with local municipalities and/or regional governments;
4. A techno commercial feasibility study that validated the economics of the proposition to implement solution(s) to mitigate climate change; and
5. A strong record of socio-economic upliftment of the poorest sections of society.

Two other companies were identified for the case study, Agilyx & Cynar Plc. Agilyx plants are currently reported as non-operational. Cynar Plc is reported to have plants in developed countries (EU region). It is important to recognize that the waste industry in the BIMSTEC region is highly unorganized and market conditions play an important role in determining the viability of the process and technology being implemented. Companies in the "plastic to fuel" sector with a focus to sell equipment with no track record of operations were excluded from consideration.

MK Aromatics Limited (MKAL) is a company that operates in the niche industry of specialty chemicals and hydrocarbon derivatives. It expanded into the waste industry focusing on a single waste stream of post-consumer waste plastics, to address a growing challenge through application of the principles of economic value addition to create a more sustainable future out of a moral conscience for a need to do so. MKAL developed an innovative, environmentally

MK Aromatics Limited state of the art "waste plastic to fuel" facility.
Source: (www.mkaromatics.com)

responsible system for processing post consumer plastic waste into energy, specifically hydrocarbons or crude oil. MKAL has produced approximately 4 million liters of quality crude oil from 6,000 tons of non-recyclable plastic waste, resulting in a reduction of approximately 10,000+ tons of greenhouse gas emissions.

The Polymer Energy Systems uses Transverse Flow Catalytic Conversion Technology to efficiently convert waste plastics to crude oil. The system provides an integrated plastic waste processing system that offers an alternative to landfill disposal, incineration and uncontrolled burning. The company has an operational state of the art facility in Chennai, India. It has further in collaboration with private sector parties installed two facilities in Thailand. In the most recent development, the foundation stone for two additional state of the art facilities in Goa was inaugurated on June 9, 2016, with the plants expected to be commissioned within six months. MKAL has also received a Letter of Acceptance from GAIL Limited, the largest state-owned natural gas processing and distribution company in India, for setting up two plants at Haridwar and Ujjain. MKAL has also received a Letter of Acceptance from Government of Karnataka (BBMP), to set up a facility at Bangalore, India. MK Aromatic Limited has also received a Letter of Acceptance from The Royal Government of Bhutan to set up a waste plastic to fuel facilities at Thimphu landfill site to address the concerns of environmental preservation from waste plastics and produce valuable fuel oil.

An exhaustive analysis presented in the Capability Report prepared by Unilever on Plastic Waste to Fuel technology operated by MK Aromatics Limited shows that there is enormous potential for multinational corporations to engage in Corporate Social Responsibility projects with two objectives:

- Socio-economic upliftment of the poorest sections of the society through economic empowerment; and
- Closed loop cycle for manufacturing companies through creation of facilities to address the waste produced by consumers after consumption and produce valuable fuel oil.

The process adopted is based on random de-polymerization of waste plastics into liquid fuel in presence of a catalyst. The entire process is undertaken in a closed reactor vessel followed by condensation. Waste plastics while heating up to 350-400 C is converted into liquid-vapor state, which is collected in condensation chamber in the form of liquid fuel called polymer oil (PO). The entire process has zero air emissions and zero water discharge. In principle, the project is eligible for carbon credits, but due to an underdeveloped carbon market trading system in the region, this analysis on mitigating climate change has been excluded.

Financing a Plastic to Fuel system is one of the most important and challenging tasks that a project developer faces. It is particularly difficult for emerging PTF technologies given that they do not fit a traditional project finance model. Project finance firms' desire projects with:

1. Proven technology with multiple commercially operational reference facilities;
2. Long-term supply agreements;
3. Long-term offtake agreements; and
4. High investment costs.

The PTF technology inherently involves high risk due to the limited number of applications. Full project costs are generally $6 million with minor variations depending on location, making fixed transaction costs a higher percentage of the total and more difficult to absorb. Additionally, the duration of feedstock supply and offtake agreements that project developers are able to secure are short compared with other large-scale waste processing systems. This is due to the fluctuating market prices for petroleum products compared with MSW streams and the variability in end product by technology and feedstock composition. The predominant method for financing a PTF system is by viable gap funding (VGF) or direct equity investment. Under this model, an equity investor will provide a portion or all of the capital required to develop a plant in exchange for a share in the company. After the project meets the desired internal rate of return (IRR), the percent of free cash that flows to the project developer increases.

Key Highlights from the Case Study

Climate change presents a unique set of challenges that have far-reaching implications and consequences. Nonetheless, these challenges present a unique opportunity that can accelerate sustainable development and socio-economically uplift the poorest sections of the society. Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emission reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term and contribute to climate change resilient pathways for sustainable development. Furthermore, entrepreneurship and innovation play a very important role in mitigation of the contributing factors to climate change. Resource allocations must be made in the manner of the novel approach adopted by MK Aromatics Limited, which results in a mutually beneficial model for all stakeholders. In the case of non-recyclable post-consumer plastic waste, the business model adopted by MK Aromatics Limited uplifts the ragpickers and a large section of the informal workforce in the waste industry, restores the environment through elimination of landfills and creation of a zero waste society, and produces valuable fuel oil to meet the nation's energy needs. This is a clear example of a solution from? and implemented in the Bay of Bengal bloc that reflects the successful integration of a climate change challenge and its transformation into a unique opportunity for sustainable development.

Recommendations on Climate Change
Adaption, Mitigation & Sustainable Development

Evidence suggests that effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments and diverse perceptions and responses to risk and uncertainty.

Sustainable development and equity provide a basis for assessing climate policies. Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. Countries' past and future contributions to the accumulation of GHGs in the atmosphere are different. Countries also face varying challenges and circumstances and have different

capacities to address mitigation and adaptation. Mitigation and adaptation raise issues of equity, justice and fairness. Many of those most vulnerable to climate change have contributed and contribute little to GHG emissions. Delaying mitigation shifts burdens from the present to the future, and insufficient adaptation responses to emerging impacts are already eroding the basis for sustainable development. Comprehensive strategies in response to climate change that are consistent with sustainable development take into account the co-benefits, adverse side effects and risks that may arise both from adaptation and mitigation options.

The design of climate policy is influenced by how individuals and organizations, including governments, at all levels perceive risks and uncertainties and take them into account. Methods of valuation from economic, social and ethical analysis are available to assist decision-making. These methods can take into account a wide range of possible impacts, including low-probability outcomes with large consequences. The constraint from outcomes of various methodologies is that they cannot identify a single best balance between mitigation, adaptation and residual climate impacts.

Climate change has the characteristics of a collective action problem on the global scale, because most GHGs accumulate over time and mix globally, and emissions by any agent (individual, community, company, country) affect other agents. Effective mitigation will not be achieved if individual agents advance their own interests independently. Cooperative responses, including international cooperation, are therefore required to effectively mitigate GHG emissions and address other climate change issues. The effectiveness of adaptation can be enhanced through complementary actions across various levels, including international cooperation. The evidence suggests that outcomes seen as equitable can lead to more effective cooperation (AR5, 2014).

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead from high to very high risk of severe, widespread and irreversible impacts globally. Mitigation involves some level of co-benefits and also risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts.

Policy Approaches for Adaptation, Mitigation, Technology and Finance

Effective adaptation and mitigation responses will depend on policies and measures across multiple scales: international, regional, national and sub-national. Policies across all scales supporting technology development, diffusion and transfer, as well as finance for responses to climate change, can complement and enhance the effectiveness of policies that directly promote adaptation and mitigation.

International cooperation is critical for effective mitigation, even though mitigation can also have local co-benefits. Adaptation focuses primarily on local to national scale outcomes, but its effectiveness can be enhanced through coordination across governance scales, including international cooperation (Agarwal, 2015). They are summarized below:

1. The United Nations Framework Convention on Climate Change (UNFCCC) is the main multilateral forum focused on addressing climate change, with nearly universal participation. Other institutions organized at different levels of governance have resulted in diversifying international climate change cooperation.
2. The Kyoto Protocol offers lessons toward achieving the ultimate objective of the UNFCCC, particularly with respect to participation, implementation, flexibility mechanisms and environmental effectiveness (medium evidence, low agreement).
3. Policy linkages among regional, national, and sub-national climate policies offer potential climate change mitigation benefits. Potential advantages include lower mitigation costs, decreased emission leakage and increased market liquidity.
4. International cooperation for supporting adaptation planning and implementation has received less attention historically than mitigation but is increasing and has assisted in the creation of adaptation strategies, plans and actions at the national, sub-national and local level. There has been a considerable increase in national and sub-national plans and strategies on both adaptation and mitigation since the AR4, with an increased focus on policies designed to integrate multiple objectives, increase co-benefits and reduce adverse side effects.
5. National governments play key roles in adaptation planning and implementation through coordinating actions and providing frameworks and support. While local government and the private sector have different functions, which vary regionally, they are increasingly recognized as critical to progress in adaptation, given

their roles in scaling up adaptation of communities, households and civil society and in managing risk information and financing.

Other Approaches-Carbon Pricing, Taxes, Regulations and Alternative Financing

In principle, mechanisms that set a carbon price, including cap and trade systems and carbon taxes, can achieve mitigation in a cost-effective way but have been implemented with diverse effects due in part to national circumstances as well as policy design. The short-run effects of cap and trade systems have been limited as a result of loose caps or caps that have not proved to be constraining. In some countries, tax-based policies specifically aimed at reducing GHG emissions alongside technology and other policies have helped to weaken the link between GHG emissions and GDP.

Regulatory approaches and information measures are widely used and are often environmentally effective. Examples of regulatory approaches include energy efficiency standards; examples of information programs include labeling programs that can help consumers make better-informed decisions.

Sector-specific mitigation policies have been more widely used than economy-wide policies. Sector-specific policies may be better suited to address sector-specific barriers or market failures and may be bundled in packages of complementary policies. Although, theoretically, more cost-effective, administrative and political barriers may make economy-wide policies harder to implement. Interactions between or among mitigation policies may be synergistic or may have no additive effect on reducing emissions.

Economic instruments in the form of subsidies may be applied across sectors, and include a variety of policy designs, such as tax rebates or exemptions, grants, loans and credit lines. An increasing number and variety of renewable energy (RE) policies including subsidies motivated by many factors have driven escalated growth of RE technologies in recent years. At the same time, reducing subsidies for GHG-related activities in various sectors can achieve emission reductions, depending on the social and economic context.

Co-benefits and adverse side effects of mitigation could affect achievement of other objectives such as those related to human health, food security, biodiversity, local environmental quality, energy access, livelihoods and equitable sustainable development. The potential for co-benefits for energy end-use measures outweighs the potential

for adverse side effects whereas the evidence suggests this may not be the case for all energy supply and agriculture, forestry and other land use measures. Some mitigation policies raise the prices for some energy services and could hamper the ability of societies to expand access to modern energy services to underserved populations. These potential adverse side effects on energy access can be avoided with the adoption of complementary policies such as income tax rebates or other benefit transfer mechanisms. Whether or not side effects materialize, and to what extent side effects materialize, will be case and site-specific, and depend on local circumstances and the scale, scope and pace of implementation. Many co-benefits and adverse side effects are yet to be quantified well.

Technology policy (development, diffusion and transfer) complements other mitigation policies across all scales, from international to sub-national; many adaptation efforts also critically rely on diffusion and transfer of technologies and management practices. Policies exist to address market failures in R&D, but the effective use of technologies can also depend on capacities to adopt technologies appropriate to local circumstances.

Substantial reductions in emissions would require large changes in investment patterns annual investments in low carbon electricity supply and energy efficiency in key sectors (transport, industry and buildings) are projected in the scenarios to rise by several hundred billion dollars per year before 2030. Within appropriate enabling environments, the private sector, along with the public sector, can play important roles in financing mitigation and adaptation in an adequate response to tackle climate change.

Financial resources for adaptation have become available more slowly than for mitigation in both developed and developing countries. Limited evidence indicates that there is a gap between global adaptation needs and the funds available for adaptation. There is a need for better assessment of global adaptation costs, funding and investment. Potential synergies between international finance for disaster risk management and adaptation have not yet been fully realized.

Conclusion

Climate change exacerbates other threats to social and natural systems, placing additional burdens particularly on the poor. It is imperative that climate change policy be aligned with sustainable development and backed with financing models that stress on

performance and delivery in a time-bound response. This paper supports the commercialization and adoption of conversion of post-consumer waste plastic to fuel at landfill sites as a sustainable solution for mitigation of a key contributor of carbon gas emissions to climate change. With the literature available, a thorough understanding of the causes, risks and impacts of climate change were summarized to give the reader an insight into the urgency of a unified response to tackle climate change.

A holistic approach in strategies and actions can be pursued now that can channel climate change concerns in the direction for sustainable development, while at the same time helping to improve livelihoods, social and economic wellbeing and effective environmental management. In some cases, economic diversification can be an important element of such strategies. The effectiveness of integrated responses can be enhanced by relevant tools, suitable governance structures and adequate institutional and human capacity. Integrated responses are especially relevant to energy planning and implementation; interactions among water, food, energy and biological carbon sequestration; and urban planning, which provides substantial opportunities for enhanced resilience, reduced emissions and more sustainable development.

Furthermore, one issue of significant importance based on the author's experience in the industry has been highlighted. A solution in response to the highlighted issue has also been presented with evidence from a detailed case study on a company called "MK Aromatics Limited" that operates in the BIMSTEC region. Summaries of techno-commercial feasibility studies on plastic to fuel technology conducted by Multi-National Corporations and Independent Organizations were reviewed and used as a basis to justify the extent of impact created. Certain gaps in the region's climate change policy were identified and outlined in order to provide a scope for researchers to investigate. From a technical view point, it is justified that innovative technologies with a successful operational track record should be scaled up as part of the response to mitigate the crisis of climate change. Commercialization of polymer energy technology provides solutions to many a problem that affects our environment today. The product from plastic catalytic breakdown process, which is high quality crude oil, is also a promising solution to our energy needs in the near future. From a commercial point of view, a look into the payback period from time of investment, a rate of return and the corresponding corporate and social responsibility

benefits attached to the project are very lucrative. A supporting case for governments and corporate companies to enter plastic waste management and adopt this technology forms the basis of this proposal.

In short, this technology has the ability to solve two problems that we are faced with today, scarcity of land for further disposal of waste and energy-starved cities. In context of waste management and GHG emissions, a promising solution exists in the implementation of an "end to life" solution for the conversion of non-recyclable post-consumer plastic waste to valuable fuel oil. Climate change challenges can be a catalyst to bring about a holistic transformation through sustainable development.

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