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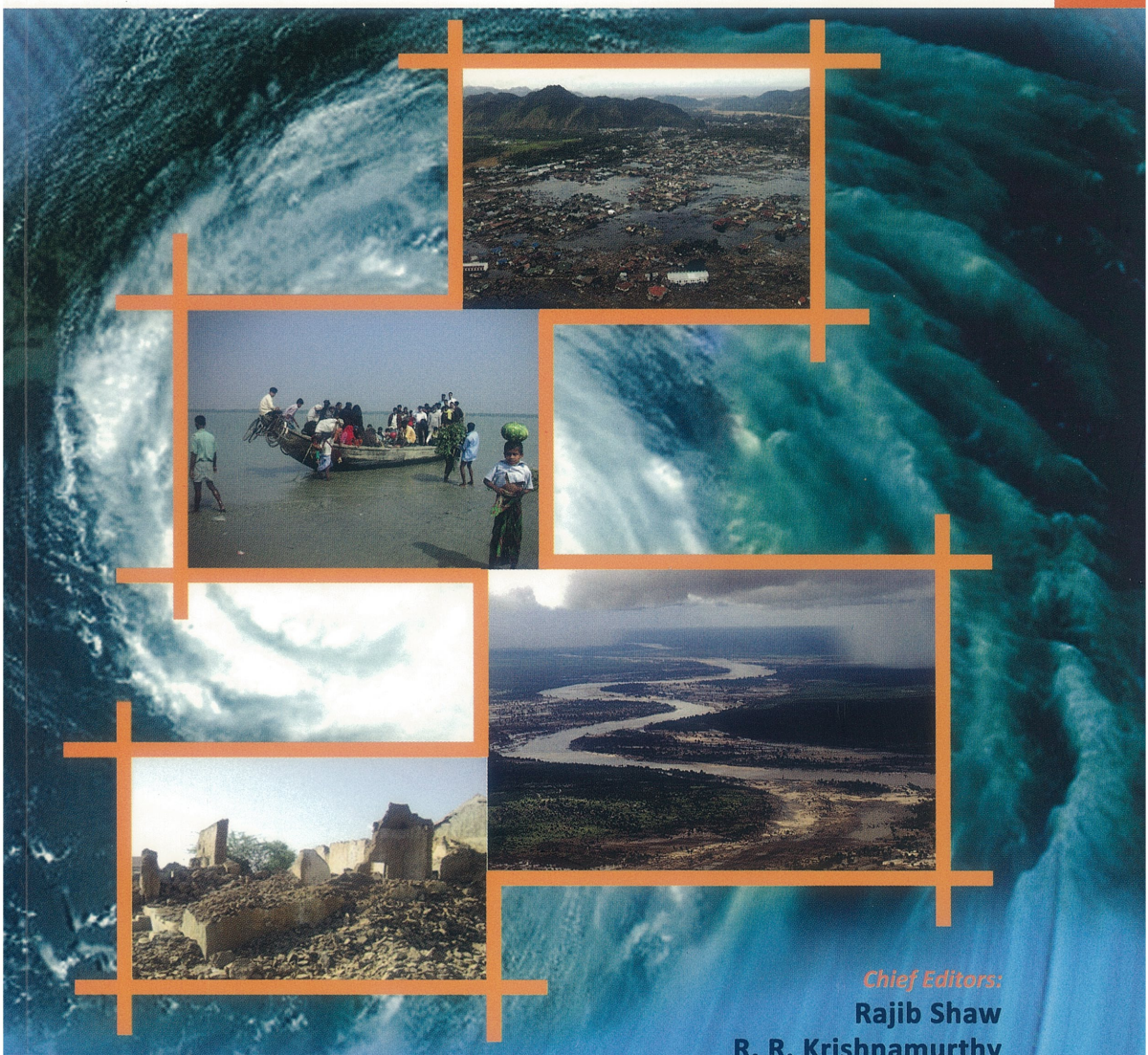
Focusing on Pro-active Risk Reduction in Asia

Climate Change Adaptation: Perspectives in the Asia Pacific



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Aims & Scope

This is the first journal focusing on the environment and disaster related issues in the Asian region. Asia, being the center of urban growth in the last few decades, has also created severe environmental problems, and is prone to different types of natural disasters. This journal provides a forum to communicate research findings, not only through academic research, but also incorporating field based action research.

Goal

Theory of environment and disaster management is complex, and it becomes even challenging when it is linked to field practice. There often observed a gap between the theory and practice in the field of environment and disaster management. The goal of this journal is to establish academic linkages of field practices with specific emphasis on environment and disaster management in the Asian context.

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Preface

The Asia-Pacific Network (APN) for Global Change Research is an international network of member governments whose mission is to enable investigation of change in the Earth's life support systems as it occurs in the Asia-Pacific region to (a) identify, explain, and predict changes in the context of both natural and anthropogenic forcing; (b) assess potential regional and global vulnerability of natural and human systems; and (c) contribute, from the science perspective, to the development of policy options for appropriate responses to global change that will also contribute to sustainable development. Recent research and supporting observations have provided new insights into some changes in the Earth system and their impacts but have, at the same time, opened a number of new and challenging scientific issues. The APN seeks to identify such emerging issues and to promote and encourage regional cooperative research to address these through the Annual Regional Call for Research Proposals (ARCP) and its Capacity Development Program, CAPaBLE.

"Strengthening Capacity for Policy Research on Mainstreaming Adaptation to Climate Change in Agriculture and Water Sectors" is an APN CAPaBLE project (Reference Number: CRP200902NMY-Pereira). It was initiated in August 2009 by the Institute for Environment and Development, Universiti Kebangsaan Malaysia (LESTARI-UKM), in collaboration with the Institute for Global Environmental Strategies (IGES), Japan, M.S. Swaminathan Research Foundation (MSSRF), India, and the Institute of Meteorology, Hydrology and Environment (IMHEN), Vietnam. The project aims to strengthen research capacity on mainstreaming climate change adaptation concerns into agricultural and water policies and create a network for adaptation policy research in Asia.

The project partners have participated in two workshops organized in Malaysia, in 2009 and 2010, in collaboration with principal linkages — the Asian University Network on Environment and Disaster Management (AUEDM) and ORBICOM, the Network of UNESCO Chairs in Communication — as well as national partners. Workshop participants were from government, intergovernmental bodies, academia, research institutes, business, and non-government organizations in the Asia Pacific. The workshops served as a platform to disseminate project findings, build capacity, and lay the foundation for the proposed network for adaptation policy research.

Volume 2, Issue 4 of the *Asian Journal of Environment and Disaster Management* is the first collection of 10 peer-reviewed papers from the two workshops. It represents findings of the project, documenting climate change adaptation perspectives in the Asia Pacific, and country experiences in the water and agriculture sectors. The target group is practitioners and researchers. In publishing the papers, the APN assures that the results of the research project contribute to the development of a sound scientific base for decision- and policy-making related to climate change adaptation in the region.

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Executive Science Officer
Asia-Pacific Network for Global Change Research

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Mainstreaming Climate Change Adaptation in Agriculture and Water Sectors in the Asia-Pacific Region: Current Status, Issues, and Way Forward

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Limited efforts have been made in assessing the status of mainstreaming adaptation in agriculture and water sectors globally and in the Asia-Pacific region. This paper reviews various ongoing adaptation initiatives implemented at the national level in agriculture and water sectors in some of the countries of the Asia-Pacific region and identifies issues and way forward. The review suggested that many governments have a number of initiatives, either planned or currently implemented, to adapt to climatic change in agriculture and water sectors, with a considerable progress in terms of number and nature of initiatives carried out. Most of these initiatives can be placed in categories of serendipitous adaptation and climate-proofing of development. However, most of the initiatives are in their infancy, which do not provide a clear indication of how much risk they intend to reduce in the course of their implementation, and it is difficult to assess how different they are when compared to "usual" developmental projects. This paper identifies the need for choosing win–win adaptation options, that can hold well under a broad range of climate change scenarios in the future, as a possible way forward in the absence of dependable climate change projections and vulnerability assessments.

Keywords: Mainstreaming, Agriculture, Water, Win-win adaptation.

1. Introduction

It is now widely recognized that warming of the climate system is unequivocal, as is evident from observations of increase in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.[5] According to the Working Group I of the IPCC, the global mean surface temperature has risen by $0.74°C \pm 0.18°C$ in the past 100 years.[10] As a result, some significant climate change impacts have been observed in the natural systems, which include reduction in mountain glaciers, such as those in Himalayas, which feed perennial rivers, such as Ganges in South Asia, and substantial increase in extreme events such as heavy precipitation, droughts, and tropical cyclones. Specific projected impacts of climate change on Asia-Pacific region include[5]: decrease

in crop yields up to 30% in Central and South Asia by the mid-21st century; decreased river flows as the glaciers recede in the Himalayas; decreased fresh water availability in Central, South, East, and Southeast Asia, increased pressure on natural resources and environment; and increased risk of flooding in the coastal areas, especially heavily populated mega-delta regions in South, East and Southeast Asia. It is apparent from the above-projected impacts that the agriculture and water sectors are the most vulnerable to climate change impacts.

The Asia-Pacific region is vulnerable to climate change impacts due to high proportion of population dependent on primary sectors such as agriculture and allied sectors that are directly impacted by the climate change;[1] high rural poverty;[3] prevalence of historically drought-prone regions in countries such as Afghanistan, Iran, Myanmar, Pakistan, Nepal, India, China, Sri Lanka, and parts of Bangladesh, Philippines, Thailand, Australia and the Pacific islands of Fiji, Vanuatu, and Samoa with high proportion of farmers dependent on subsistence farming;[13] and poor progress in development as reflected from the Millennium Development Goals (MDGs).[12] Hence, adaptation to climate change in agriculture and water sectors is a priority for the sustainable development of the Asia-Pacific region.

Various national governments in the Asia-Pacific region have already initiated efforts to respond to climate change threats by initiating programs and projects that address climate change impacts. However, there are no efforts in the published literature that takes stock of the ongoing efforts and analyze strengths and weaknesses of the same in the light of climate change adaptation. Hence, this paper reviews some of the ongoing adaptation initiatives in the Asia-Pacific region, identifies issues, and provides a way forward.

2. Understanding Mainstreaming

Several definitions exist to explain the concept of mainstreaming. Some of them are given below:

- "Integration of policies and measures that address climate change into developmental planning and sectoral decision making"[6] (p. 4).
- "...information, policies and measures addressing climate change are streamed into ongoing, general development planning and decision making"[2] (p. 1).
- "...encompassing the process(es) by which environmental considerations are brought to the attention of organisations and individuals involved in decision-making ..."[4] (p. 1).
- "...mainstreaming refers to the integration of environmental considerations into core institutional thinking and decision-making"[11] (p. 9).
- "...a process to fully incorporate disaster risk reduction into relief and development policy and practice"[9] (p. 16).

A glimpse at the above definitions of mainstreaming, derived from climate change, environment, and disaster risk reduction literature, indicate that the mainstreaming is integrating some consideration (climate change or environmental management or disaster risk reduction) into institutional or sectoral or policy processes such that the aspect integrated becomes part of the operations of the entity it is integrated into. Hence, in this paper, mainstreaming climate change considerations in agriculture and water sectors means that the developmental plans and programs in these sectors are aware about the imminent risks of climate change and that suitable countermeasures are planned and implemented.

3. Current Status of Mainstreaming Adaptation and Challenges

A review of current adaptation interventions in agriculture and water sectors in the Asia-Pacific region indicates that many countries have number of initiatives to deal with the climate change related challenges (Table 1). Vulnerability assessment is the first and foremost important step before planning any kind of adaptation initiatives. Some of the countries have already initiated vulnerability assessments with respect to the climate change. These vulnerability assessments consisted of identifying and analyzing the impact of climate change and variability on natural ecosystems, socioeconomic systems, and human health. Some assessments also considered the institutional and financial capacities of the local communities, assessing the spontaneous and planned adaptation measures already taken up, and developing technical, institutional and financial strategies to reduce vulnerabilities. The current adaptation initiatives in agriculture sector can be grouped into five broad categories listed below.

- **Development of crop varieties**, which are tolerant to perceived threats that includes droughts, pests, and diseases (Australia, India, Indonesia, Malaysia, Vietnam).
- **Expanding area under irrigation** and efforts for better water management including watershed management practices (Australia, Bangladesh, China, India, Indonesia, Malaysia, Russia, Vietnam).
- **Improving weather forecasts** and linking with farm decision-making (Australia and India).
- **Drought monitoring systems** are being put in place though do not completely cover the entire country or are in inception stage (China, India, Vietnam, Australia).
- **Investment in rural infrastructure** that promotes access to markets that in turn enhances the resilience of rural communities which is more relevant for the developing countries in the region (India, China, Srilanka).

In addition to the above sectoral approach to vulnerability reduction, countries in the region have also approached the problem through land and rural

Table 1 List of significant initiatives to deal with water scarcity in some Asia-Pacific countries.

Country	Initiatives
Bangladesh	• National level comprehensive disaster management initiative that encompasses drought as a theme which in turn brings together various stakeholders • Promotion of groundwater use in Barind region • Development of appropriate land and crop management practices to reduce the drought risk
China	• Drought monitoring using ground-based observatories and remote sensing • Drought risk zoning classification in place • Massive plantations being planned and implemented to stabilize the desertification process
India	• National crop weather watch group that monitors drought during monsoon season • Integrated watershed development projects being taken up in drought-prone areas • Desert development program (DDP) has been implemented in areas prone to desertification
Indonesia	• Integrated water resource management in Citarum river basin, climate field schools, SRI
Vietnam	• Laws and decrees exist that provides for drought and water management • People's participation in water resource management • Development of water resource monitoring network • International cooperation in water resource management • Establishment of Mekong River Commission
Australia	• Drought relief payment system put in place for the affected farmers • National water initiative by Australian Water Fund • Water-proofing projects, water strategies at state level, improving water use efficiency in various water-dependent sectors, emphasis on water recycling, water conservation measures are in place

Source: Ref. 8.

development, recognizing the fact that the natural resource governance related issues, such as absence of land tenure, would put rural poor to reduced access to natural resources (as in the case of China) resulting in high vulnerability as large number of people in these countries depend on natural resources for their livelihood. These initiatives are largely development-driven initiatives with adaptation as a co-benefit. Some of the significant initiatives targeting land and rural development are listed in Table 2.

A meta-analysis of adaptation initiatives by World Resources Institute (WRI) suggests that the mainstreaming adaptation in development can happen in three stages, i.e., serendipitous adaptation (where adaptation is an accidental rather than designed outcome of development), climate-proofing of development (where adaptation is a planned intervention however the main focus is on development),

Table 2 Land and rural development initiatives that have adaptation as a co-benefit in selected Asian counrties.

Country	Land and rural development initiatives
Bangladesh	• Livestock enterprise development
	• Microfinance through self-help groups
China	• Legal changes that would give farmers long-term security on the land (to provide tenure security)
India	• Secure drinking water supply
	• Wage employment, employment assurance, food for work, rural housing, social security programs, land, reforms, etc.
	• Watershed development programs such as Drought-Prone Areas Program (DPAP) and Desert Development Program (DDP)
Indonesia	• Food security enhancement program
Vietnam	• Agricultural diversification
	• Strengthening the agriculture extension programs
	• Ongoing efforts to improve access to rural water supply and sanitation
Srilanka	• Significant investment in natural resource management

Source: Ref. 8

and discrete adaptation (where adaptation is the sole intended outcome of the intervention).[7] On this scale, the current level of adaptation in agriculture and water sectors in the Asia-Pacific region can best be placed between serendipitous adaptation and climate-proofing of development since there are very few adaptation-only initiatives taken up so far, as discussed in the next section.

The current approach to adaptation decision-making and mainstreaming faces several challenges. One of the major challenges is that most of the above listed initiatives are based on the experiences and observations of the past climate. This approach seems to assume that general developmental programs would suffice to take care of climate change impacts, as inferred from the developmental programs listed in many national communications under adaptation initiatives. These initiatives also do not provide information on how much risk and vulnerabilities they intend to reduce during the course of their implementation, making it difficult to answer the question of "what more need to be done." This could be due to lack of comprehensive quantification of vulnerabilities and risks and partly due to the absence of reliable projected climate change impacts. In some cases, the adaptation initiatives could in fact increase the vulnerabilities of the local communities (what is called maladaptation) (e.g., as in the case of Bangladesh, promoting groundwater use in Barind region without putting in place appropriate legal framework to limit overexploitation and introducing groundwater recharging schemes could further enhance the local vulnerabilities).

4. Ways Forward

This study review suggests that many governments have number of initiatives, either planned or currently implemented, to adapt to climate change impacts. This scale of review is far from conclusive to say whether or not these initiatives are sufficient to adapt to the future climate change impacts due to the following reasons: the climate change projects and programs are still in infancy stage, the ongoing projects and programs do not provide an estimation of how much risk they aim to reduce, absence of reliable climate impact projections to compare the reduced risks against the projected impacts, and absence of metadata on these projects to estimate possible risks reduced.

In the context of climate change adaptation, decisions that are valid for the future are needed. High emphasis on the past experiences while identifying the future interventions may not be a good strategy since the past experiences may not hold good for the future as the climate change impacts in the future could be different from what was observed in the past. Increasing efforts on climate change forecasts could help but actions cannot wait until the climate science gets it right. Hence, it is high priority to identify win–win adaptation options, that can hold good under a broad range of climate change scenarios in the future. In the word win–win, win-stands for the current climatic conditions, including climatic variability, and win for the broad range of climate change scenarios in the future. Some examples of such win–win adaptation options include resource-conserving technologies such as zero and reduced tillage; moving from *ad hoc* measures to planned relief interventions that aims at creating long term livelihood options; integrated river basin management; complete water balance approaches that consider water-sharing mechanisms between various water-using sectors and regions; streamlining land tenure arrangements; enhancing the coordination between various institutions, and governments at the local, national and regional levels; regional cooperation in the areas of drought and desertification monitoring due to its transboundary nature; and promoting participatory processes at all stages of project and program management.

Acknowledgements

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References

1. FAO, *The State of Food and Agriculture 2003–2004* (Food and Agriculture, Rome, 2004).
2. S. Huq and J. Ayers, *Taking Steps: Mainstreaming National Adaptation*, IIED Briefing, November 2008 (International Institute for Environment and Development, UK, London, 2008).

3. IFAD, *Assessment of Rural Poverty in Asia and the Pacific Region* (IFAD, Rome, 2002).
4. IIED, *Environmental Mainstreaming* (International Institute for Environment and Development, UK, London, 2008). Available at http://www.environmental-mainstreaming.org/ (Accessed 10 November 2009).
5. IPCC, Summary for policymakers, in *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007).
6. R. J. T. Klein, Mainstreaming adaptation to climate change into official development assistance. Promoting synergy or diverting money? *GECHGS News*, Spring 2006, 4–6.
7. H. McGray, A. Hammill, R. Bradley, E. L. Schipper, and J. Parry, *Weathering the Storm: Options for Framing Adaptation and Development* (World Resources Institute, Washington DC, 2007).
8. S. V. R. K. Prabhakar, *Climate Change Implications for Sustainable Development: Need for Holistic and Inclusive Policies in Agriculture, Land, Rural Development, Desertification, and Drought* (UNESCAP, Bangkok, Thailand, 2007).
9. Tearfund, *Mainstreaming Disaster Risk Reduction. A Tool for Development Organizations.* (Tearfund, UK, 2005).
10. K. E. Trenberth, P. D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J. A. Renwick, M. Rusticucci, B. Soden, and P. Zhai, Observations: Surface and atmospheric climate change, in *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007).
11. UNDP, *UNDP Environmental Mainstreaming Strategy: A Strategy for Enhanced Environmental Soundness and Sustainability in UNDP Policies, Programs, and Operational Processes* (UNDP, New York, 2004).
12. UNDP, *Millennium Development Report 2007–2008* (United Nations Development Program, New York, 2007).
13. UN-ESCAP, *State of the Environment in Asia and Pacific 2005: Economic Growth and Sustainability* (United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand, 2005).

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Climate Change Adaptation: An Overview of Southeast Asia

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Adaptation to climate change is a critical issue in Southeast Asia. Academic and policy attention are increasing sharply as a result of the growing evidence on unavoidable impacts in the region. Southeast Asia is one of the most vulnerable regions to climatic hazards globally. Most, if not all, countries already are experiencing stresses from climate-related events and phenomena. The situation could be exacerbated by future climate change, which would lead to an increase in frequency and intensity of extreme events. Vulnerability to climatic hazards is expected to increase, especially in island states and countries with long coastlines and low-lying areas. The key vulnerable concerns encompass agriculture and food security, water resources, coastal zones and marine ecosystems, terrestrial ecosystems, human health, settlements, fisheries, and others. Already, initiatives have been carried out and planned in the regions, especially within national boundaries, to either reduce vulnerability or cope and adapt to future climatic hazards. However, there are several factors affecting adaptation in the regions. The constraints are wide-ranging and may differ in specific to country circumstances, encompassing methodological issues, biophysical limitations, socioeconomic factors, technological barriers, and institutional and technical aspects. More efforts are required to drive further responses, covering such aspects as vulnerability and adaptation assessments; methodology and approaches for modeling and data gathering; building of human and institutional capacity; financial and technical support; education, training and public awareness; and networking and information. Adaptation is a knowledge-intensive undertaking, which requires provision of access to relevant and usable knowledge to ensure effective implementation and outcome. There are a number of key priorities for the region in moving forward on adaptation responses, including improvement of data collection, management and dissemination; advancing integrated assessments covering biophysical and socioeconomic impacts as well as sectoral and cross-sectoral analysis; enhancement in the understanding of the relationship between climate change and disaster; and policy measures supporting implementation in an integrated and balanced manner.

1. Introduction

Climate change has undoubtedly become the most contentious issues in the international environmental debates. The discussions and negotiations, which began since 1980s, had evolved United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and Kyoto Protocol in 1997. Article 4.1(b)

of the Convention refers to two options to address climate change: adaptation to the impacts of climate change and mitigation of climate change by reducing GHG emissions and enhancing sinks. Adaptation and mitigation are two related but distinct ways that relate to different policy domains under the UNFCCC and the Intergovernmental Panel on Climate Change (IPCC). Adaptation is referred by the process for reduction of vulnerability to climate change, whereas mitigation is referred in the ultimate objective of the Convention to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.[49]

Adaptation has gained more importance politically and scientifically at the international and national levels during recent years. With increasing evidence on anthropogenic interference being responsible for climate change and that some impacts can no longer be avoided, academic and policy attention with regard to adaptation has increased sharply. The challenge ahead is not only about switching the research from meeting the needs of the mitigation policy agenda to supporting adaptation response to future climate change, but also to one that responds explicitly to the needs of the present day.

This paper aims to provide an insight to critical issues and challenges in the Southeast Asia when dealing with climate change adaptation. Section 2 gives an overview of background and assessment of climate change policy responses especially adaptation. Sections 3 and 4 summarize information on current and future climate conditions, vulnerability and adaptation response in the region. Section 5 describes the constraints faced by the Southeast Asian countries when addressing climate change adaptation, while Section 6 highlights the needs in order to drive further responses on adaptation. Finally, Section 7 concludes the paper with recommendations on several research areas that should be prioritized.

2. Overview of Climate Change Adaptation

The IPCC Fourth Assessment Report revealed the projected climate change in future are expected to include increasing temperatures, rising sea levels, increased intensity of storms, greater frequency of heat waves, floods and droughts, more rapid spread of diseases, and accelerated loss of biodiversity. Economic growth will be impacted and poverty exacerbated. The existing coping mechanisms in many developing countries in Southeast Asian regions, particularly the densely populated river deltas and coastal areas, to natural disasters are likely inadequate to cope with negative impacts of climate change, which in turn will increase their vulnerability to climatic hazards.

2.1. *Climate change adaptation and mitigation*

IPCC[20] defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm

or exploits beneficial opportunities". The issues on adaptation to the impacts of climate change have not been attracting as great attention and interest as the mitigation and relatively less developed than mitigation as a policy response,[6,16] which is evident from the Kyoto Protocol itself as its main concern is on the reduction of greenhouse gas emissions particularly from the developed countries. On the one hand this reflected the concern of some that a stronger focus on adaptation would weaken society's willingness to mitigate climate change, and on the other hand it signified the belief of others of natural selection and market forces would bring about adaptation without the need for policy intervention. However, the lag times in the global climate system mean that no mitigation effort, however rigorous, will prevent climate change from occurring in the next few decades. The warming now being experienced is the result of emissions that took place over many decades. Adaptation is therefore necessary, and should be implemented hand-in-hand with mitigation measures in order to reduce the risks of climate change.

2.2. *Assessment of climate change adaptation*

The early research on adaptation mainly surrounds the assessment of climate change impacts in general, with limited analysis on adaptation measures.[46] The limitation in the assessment of biophysical aspects alone is progressively recognized with more analysis on vulnerability being seen as an important component of any attempt to define the magnitude of climate change.[16] Vulnerability assessment provides a starting point for the determination of effective means of promoting remedial action to limit impacts by supporting coping strategies and facilitating adaptation.[26] Identification of particularly vulnerable nations or regions can act as an entry point for both understanding and addressing the processes that cause and exacerbate vulnerability.[8] As a factor determining level of vulnerability,[20] adaptive capacity is often used when assessing the potential to adapt to future climate change, although it is important to remember that whether or not such adaptive capacity is drawn upon to bring about adaptation will be dependent upon a range of uncertain variables.[48] Understanding different adaptive capacities is thus crucial in determining the impacts of climate change and necessary adaptation responses.

3. Vulnerability and Adaptation in Southeast Asia

Southeast Asia is characterized by tropical rainforests, monsoon climates with high and constant rainfall, heavily leached soils, and diverse ethnic groups. Despite the diversity in politics, economy, and culture, the region shares a common challenge in the face of climate change: it is one of the most vulnerable regions in the world. Its vulnerability is attributable to a number of reasons, including geographical (tropical climate, long coastlines, etc.), demographically (highly dense population in coastal and delta areas), economically (major economic activity in coastal

areas), and livelihood (heavy reliance on climate-sensitive sectors and millions trapped in poverty with low-adaptive capacity). According to the IPCC Fourth Assessment Report,[12] warming is likely to be above the global mean in Southeast Asia. Precipitation in boreal winter is likely to increase in the southern parts of Southeast Asia, whereas in summer precipitation is likely to increase in most parts of Southeast Asia. Extreme rainfall and winds associated with tropical cyclones are likely to increase in Southeast Asia. In addition to impacts of climatic change and variability, the region also faces increasing vulnerabilities arising from rapid urbanisation, degradation of resources, and unsustainable development.

Given the expected significant impacts of climate change in Southeast Asia, adaptation is already underway. In fact, the region has made significant efforts in adapting to climate change impact, but more needs to be done. One's priority is to strengthen overall adaptive capacity through greater efforts to raise public awareness; more research to better understand climate change and its impact, especially at local level; enhance policy and planning coordination; and mainstream adaptation in development planning.

3.1. *Observed climate trends and variability*

Past and present climate trends and variability in Asia are generally characterized by increasing surface air temperature which is more pronounced during winter than in summer. Increasing trends have been observed across the seven subregions of Asia. The observed increases in some parts of Asia during recent decades ranged between less than 0.1°C to 0.3°C per decade. Interseasonal, interannual, and spatial variability in rainfall trends have been observed during the past few decades across all parts of Asia. Decreasing trends in annual mean rainfall are observed in Indonesia and Philippines, while annual mean rainfall exhibits increasing trends along the western coasts of the Philippines. Table 1 lists more details on the observed characteristics in surface air temperature and rainfall in Southeast Asian region.[13,14,18,23,33,38]

There are new evidences on recent trends, particularly on the increasing tendency in the intensity and frequency of extreme weather events in Asia over the last century and into the 21st century (Table 2).[13] In Southeast Asia, extreme weather events associated with El-Nino were reported to be more frequent and intense in the past 20 years. Significantly longer heatwave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heat waves. Generally, the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation have decreased. However, there are reports that the frequency of extreme rainfall in some countries has exhibited a decreasing tendency. Increasing frequency and intensity of droughts in many parts of Asia are attributed largely to a rise in temperature, particularly during the summer

Table 1 Summary of key observed past and present climate trends and variability in Southeast Asia.

Country	Change in temperature	Change in precipitation
General	0.1°C to 0.3°C increase per decade reported between 1951 to 2000.	Decreasing trend between 1961 and 1998. Number of rainy days have declined throughout the region.
Indonesia	Increase of 1.04°C–1.40°C per century.	Decline in rainfall in southern and increase in northern region.
Malaysia	Warming trends (0.18°C per decade) from 1951 to 1996.	More frequent ENSO warm phase episodes since 1977 significantly influenced rainfall in Malaysia.
Philippines	Increase in mean annual, maximum and minimum temperatures by 0.14°C between 1971 to 2000.	Increase in annual mean rainfall since 1980s and in number of rainy days since 1990s, increase in interannual variability of onset of rainfall.
Singapore	Increase by about 0.3°C per decade between 1987 and 2007.	Decrease in annual rainfall in the past three decades.
Thailand	Increase of 1.04°–1.80°C per century.	Decreasing annual rainfall for the last five decades.
Viet Nam	Increase of 1.0°C per century.	Decrease in monthly rainfall during July–August and increase in September–November.

Table 2 Summary of observed changes in extreme events and severe climate anomalies in Southeast Asia.

Extreme climatic events	Key trends
Heatwaves	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998.
Intense rains and floods	Increased occurrence of extreme rains causing flash floods in Vietnam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000.
Droughts	Droughts normally associated with ENSO years in Myanmar, Laos, Philippines, Indonesia, and Vietnam; droughts in 1997 to 1998 caused massive crop failures and water shortages and forest fires in various parts of Philippines, Laos, and Indonesia.
Cyclones/Typhoons	On an average, 20 cyclones cross the Philippines Area of Responsibility with about eight to nine landfalls each year; with an increase of 4.2 in the frequency of cyclones entering PAR during the period 1990–2003.

and normally drier months, and during ENSO event. Recent studies indicate that the frequency and intensity of tropical cyclones originating in the Pacific have

increased over the last few decades. The damage caused by intense cyclones has risen significantly in the affected countries, particularly the Philippines, Vietnam and Cambodia.

3.2. *Climate projections*

According to the MMD-A1B simulations in the IPCC Fourth Assessment Report, Southeast Asia will encounter a warming trend toward the end of the 21st century, with little seasonal variation.[12] Simulations by the CSIRO Division of Atmospheric Research Limited Area Model and more recently by the CSIRO stretched-grid model centered on the Indochina Peninsula at a resolution of 14 km have demonstrated the potential for significant local variation in warming, particularly the tendency for warming to be significantly stronger over the interior of the landmasses than over the surrounding coastal regions. A tendency for the warming to be stronger over Indochina and the larger landmasses of the archipelago is also visible in the MMD models. As in other regions, the magnitude of the warming depends on the forcing scenario.

Area–mean precipitation over Southeast Asia increases in most MMD model simulations, with a median change of about 7% in all seasons, but the projected seasonal changes vary strongly within the region. The strongest and most consistent increases broadly follow the Inter-Tropical Convergence Zone (ITCZ), lying over northern Indonesia and Indochina during June–August, and over southern Indonesia and Papua New Guinea in December–February. The pattern is broadly one of wet season rainfall increase and dry season decrease. Compositing the projections from a range of earlier simulations forced by the IS92a scenario, a pattern of rainfall increase was found across northern Indonesia and the Philippines, and decrease over the southern Indonesian archipelago. The regional high-resolution simulations have demonstrated the potential for significant local variation in projected precipitation change.

Rainfall variability will be affected by changes in ENSO and its effect on monsoon variability, but this is not well understood. However, those parts of Indonesia that experience a mean rainfall decrease are likely to also experience increases in drought risk. The region is also likely to share the general tendency for daily extreme precipitation to become more intense under enhanced greenhouse conditions, particularly where the mean precipitation is projected to increase. This has been demonstrated in a range of global and regional studies, but needs explicit study for the Southeast Asian region.

The northern part of the Southeast Asian region will be affected by any change in tropical cyclone characteristics. There is evidence in general of likely increases in tropical cyclone intensity, but less consistency about how occurrence will change. The likely increase in intensity (precipitation and winds) is supported for the northwest Pacific (and other regions) by the recent modeling study. Since most

of the tropical cyclones form along the monsoon trough and are also influenced by ENSO, changes in the occurrence, intensity and characteristics of tropical cyclones and their interannual variability will be affected by changes in ENSO.

3.3. *Biophysical vulnerability*

Many of the populations in Southeast Asian countries live on or near the coastline. Coastal areas in Southeast Asia are extremely vulnerable to climate impacts, including increase in frequency and intensity of tropical storms, increased flooding, sea water intrusion, coastal and beach erosion leading to loss of livelihoods, land and property, and infrastructure. The region's dependency on coastal resources, such as mangroves and coral reefs, for at least part of their livelihoods, exacerbates risks of climatic hazards. Tropical storms continue to devastate the region, leading to extensive trails of destruction, killing and injuring people, damaging homes, and fishing boats and destroying crops despite efforts to mitigate risk. Temperature changes and flooding will lead to changes in the vectors of insect-borne infectious diseases across the region, such as malaria, schistosomiasis, and dengue fever.[29] Increases and changes in diarrhoeal and infectious diseases are not only of concern in coastal areas, but also across the region.

The delta areas near coastline in several Southeast Asian countries are densely populated and are the key rice cultivation areas. These areas are particularly vulnerable to sea level rise, storms, flooding, and salt water intrusion. The poor in urban and peri-urban coastal areas are often located in urban slums that may be situated in flood plains, and that may also be areas of waste disposal, which on flooding face lead to loss of property, dislocation, and spread of diseases.[1] In more rural areas, vulnerability is often exacerbated by lack of access to basic services, early warning systems, and disaster management.

Drought and variable rainfall patterns are significantly impacting agricultural production in these areas, with direct implications for food and nutritional security. Increases in droughts and warm temperatures are also leading to increases in forest fires limiting access to forest resources by the poor, and contributing to smog and pollution domestically and across boundaries. Longer spells and more frequent severe droughts are being experienced in various parts of the region, reducing food crop outputs, which has led to food insecurity at the household level, eroding the nutrition and health status of local population.

3.4. *Socioeconomic vulnerability*

Accelerated urbanization in the last two decades is a major development transformation in many countries in Southeast Asia.[5] The demographic and development shift is important in identifying and evaluating both new sources of adaptive capacity and new types of vulnerability in the context of climate change, as well as

adaptation to climate change in particular, and other non-climatic stressors in general. Future predictions of climate change impact and adaptive capacities in Southeast Asia should foresee this clear trend as one major premise.

Climate changes may act as an additional stressor in an already disadvantageous situation as well as the creator of new conflicts in existing water management and allocation practices.[13] Water levels and flows may become more variable, especially during longer dry spells, causing competition among different services. The envisaged patterns of a shorter, more intense wet season will increase the number and severity of floods. Climate change compounds the existing challenges of managing annual floods that have become adaptive strategies in most low-lying areas in Southeast Asia.

Demand for food and industrial crops has been increasing in recent years due to growing population, rising incomes, and changing consumption patterns.[4] This has led to intensification of agricultural production, generating considerable environmental pressure, particularly on water resources that are already under stress from high population and economic growth.

In some Southeast Asian countries, adaptation responses at community and household levels include external linkages and off-site options to reinforce their multiple livelihood portfolios as well as formal and informal credit, or (micro-) insurance options that can enhance the resilience of vulnerable families. However, little consideration has been given on the effects of remittance, labor mobility, and migration as well as credit/loan and insurance facilities as adaptive measures.[39]

Health condition in the low-income countries will be most adversely affected in the face of climate change. Changes in temperature and rainfall patterns, flooding and water-logging will increase or change vectors for diseases such as malaria and dengue. Impacts of increased heat stress and pollution in urban centers will be worst on the elderly, and on marginalized groups and informal workers who lack clean, spacious, and sanitized settlements.

Existing conventional institutional arrangements and priorities, and dominant institutional cultures of governments at various levels influence the shaping of policy and public sector work on adaptation. There are several key challenges constraining effective governance of adaptation, including interministry coordination (initiatives may be hampered by interministerial competition and turf wars); sectoral and departmental silos (stymie flexible ways of planning, implementation, and problem-solving at various levels); participatory governance mechanisms (lack of meaningful multistakeholder engagement); and disconnection across scales (disjuncture between national and local levels and lack of interlinkage of macro- and micro-scale analyses).[39]

3.5. *Regional adaptation responses and initiatives*

There are significant efforts on planning for and research on adaptation in the context of climate change underway in Southeast Asia.[5] Resurreccion *et al.*[39] categorize the policy and research approaches to adaptation in the region into

five categories: national efforts to meet obligations of the UNFCCC; assessment of climate change impacts and vulnerabilities; community-based adaptation and integrated approaches; disaster risk reduction and climate change adaptation; and economic analyses and adaptation research. The authors further recommended a number of specific themes as points of entry to strengthening adaptation research in Southeast Asia, especially on people's adaptation to climate change. The themes include migration, social security mechanism; livelihood security of small-scale fishers and farmers; strengthening resilience to health-related impacts; and governance of adaptation across scales. Working on the identified aspects is expected to enhance adaptive capacity of the vulnerable people in the region. However, there are wide variations across Southeast Asia and significant gaps between the region and the developed world, which require continuous efforts to enhance resilience at a more fundamental level.[5] Several factors that need to be addressed in ensuring a country's adaptive capacity include (i) income, inequality, poverty, literacy, and regional disparity; (ii) capacity and governance of public institutions and public finance; (iii) availability or adequacy of public services including education, health, social protection, and social safety nets; and (iv) capacity for economic diversification, especially at local levels.

4. Constraints to Adaptation in Southeast Asia

There are several factors affecting effective adaptation in Southeast Asia. The constraints are wide-ranging and may differ in specific to country circumstances, encompassing methodological issues, biophysical limitations, socioeconomic factors, technological barriers, and institutional and technical aspects. Some of such constraints, pointed out by Glantz,[17] include spatial and temporal uncertainties associated with forecasts of regional climate, low level of awareness among decision-makers of the local and regional impacts of El Nino, limited national capacities in climate monitoring and forecasting, and lack of coordination in the formulation of responses.

4.1. *Uncertainties of climate modeling*

Modeling of climate change is a complex activity. Despite progressively improving knowledge accumulated through research over the years, the understanding of the precise magnitude of human-induced climate change is still limited by various sources of uncertainties. This can be attributed to a number of reasons, including imperfect knowledge and/or representation of physical processes, limitations due to the numerical approximation of the model's equations, simplifications and assumptions in the models and/or approaches, internal model variability, and intermodel or intermethod differences in the simulation of climate response to given forcing.[5,13] In addition to the methodological factors, availability of and/or access to reliable time series data are also limiting more robust modeling process.

Uncertainties accumulate in model-based assessments from the methodologies for establishment of socioeconomic scenarios, environmental scenarios, climate scenarios and climate impact assessment.[11]

4.2. *Biophysical limitations*

The adaptive capacity of a system has its limits due either to internal properties or external factors. Some ecosystems, habitats, and species may have narrow ranges of biogeographic adaptability that constrains the options and effectiveness of adaptation, while in other cases impacts of climate change may overstretch the ability of some ecosystems to adapt without dramatic changes in their functions and resilience.[13]

4.3. *Economic constraints*

Adaptive capacity is uneven within a country, with the more affluent components being generally better able to respond, while the greatest impacts may fall on those currently least able to adapt effectively. Poverty limits effective adaptation as the poor individuals and groups within the country usually have a low adaptive capacity due to limited access to information, technology, and other capital assets.[13] When combined with other limitations, poverty also constrains the adaptation in other sectors.[41]

4.4. *Technological barriers*

Identifying the role of technology in adaptation to climate change correctly is critical to ensure actions are able to reduce vulnerability to the impacts of climate change successfully. This warrants technology fits into the process of adaptation. Klein *et al.*[27] elaborate the roles of technology within the four-stage process of adaptation, which are information development, planning and design, implementation, and monitoring and evaluation. Nevertheless, the technology transfer process could be inhibited by many different factors. Table 3 categorizes such barriers that also have effect in the context of climate change.[50] van Aalst[47] summarizes several barriers to the transfer of technologies for adaptation:

- Uncertainty about the location, rate, and magnitude of impacts is considerable, which hampers effective anticipatory adaptation and complicates early-stage private-sector intervention.
- Adaptation as such is often not considered a development objective. Cross-linkages with other sectors can be instrumental in improving access to public and private financing.
- Technologies for adaptation will often be initiated for site-specific reasons and keeping local conditions in mind. However, design and implementation can be structured by taking into account lessons learnt from similar situations elsewhere.

Table 3 Barriers to technology transfer process.

Category	Barriers
Institutional	Lack of legal and regulatory frameworks, limited institutional capacity, and excessive bureaucratic procedures.
Political	Instability, interventions in domestic markets, corruption, and lack of civil society.
Technological	Lack of infrastructure, lack of technical standards and institutions for supporting the standards, low technical capabilities of firms and lack of a technology knowledge base.
Economic	Instability, inflation, poor macroeconomic conditions, and disturbed and/or non-transparent markets.
Information	Lack of technical and financial information and of a demonstrated track record for many environmentally sound technologies.
Financial	Uncertainty about the effects of an investment, lack of investment capital and financing instruments, limited financial return (primarily local rather than global benefits), and difficulty to create ownership of the results.
Cultural	Consumer preferences and social biases.
General	Intellectual property protection and unclear arbitration procedures.

- The direct benefits of adaptation, such as crops suited to more arid conditions, are primarily local, as opposed to the direct benefits of mitigation, such as avoided emissions, which are global.

4.5. *Availability of information and knowledge*

Effective adaptation requires sufficient information and knowledge on vulnerability to and impacts of climate change.[42] This poses challenges to Southeast Asian countries as systems for monitoring and research on climate and responses of natural and human systems to climate are yet the priority areas in governments' developmental plans. Furthermore, studies on the interconnections between adaptation and mitigation options, costs and benefits of adaptation, and trade-offs between various courses of actions are also lacking. As a result, it is difficult to enhance public perception of the risks and dangers associated with climate change as well as to undertake the best and cost-effective adaptation option.[13]

4.6. *Inadequate legal and institutional framework*

Cruz *et al.*[13] noted the inadequacy in existing legal and institutional framework in most Asian countries to facilitate integrated response to climate change, and if political and institutional landscape is changing in response to climate change, it is slow and could limit future adaptation. In countries already faced with other

pressing and urgent domestic concerns, attention may be drawn away from the dangers of climate change and the need to implement adaptation.

4.7. *Improving and relating future climate and socioeconomic scenarios*

The SRES scenarios developed by the IPCC were mainly aimed to support climate projection activities. The scenarios of greenhouse gases emission are strongly related to socioeconomic change, environmental change, land-use change, and technological advancement. To facilitate assessment of the most plausible impacts of climate change in future studies, it is necessary to design future social development scenarios by various models, which will input to the projection of future regional and local changes in climate and its variability.[5,13] The need is recognized and works are already underway in the IPCC process.[34]

4.8. *Challenges of abrupt or unexpected climate change*

One of the greatest concerns emerges from possible "surprises" in the future as adaptive capacity will be under great challenge due to abrupt or unexpected changes in climate, leading to increase in vulnerability to significant impacts.[37] Such abrupt and catastrophic climatic change may include a shutdown of the "ocean conveyor belt" in less than a decade and collapse of ice sheet over a couple of centuries if polar water temperatures warm by a few degrees. In addition to studying change of climate in gradual manner, it is also necessary to shift the research to cover rapid or abrupt change even if it cannot be predicted with a high degree of confidence.[13]

5. Needs for Adaptation in Southeast Asia

Most, if not all, countries already are experiencing stresses from climate-related events and phenomena, including severe floods and drought, adverse effects from changes in the El Niño Southern Oscillation (ENSO) phenomenon, tropical storms and changes in their patterns, saltwater intrusion, storm surges, coral reef damage, and changes in migratory patterns of important species.[13] The situation could be exacerbated by future climate change, which would lead to an increase in frequency and intensity of extreme events, such as droughts, floods, hurricanes and El Niño effects. Vulnerability to climatic hazards is expected to increase, especially in island states and countries with long coastlines and low-lying areas. The key vulnerable concerns encompass agriculture and food security, water resources, coastal zones, and marine ecosystems, terrestrial ecosystems, human health, settlements, fisheries, among others.

5.1. *Scenarios and projections*

Further understanding of the relationships between climate change and the frequency and intensity of extreme events is hampered by high levels of uncertainty surrounding the magnitude of the changes that have been projected using global climate models (GCMs). On the other hand, future changes in the socioeconomic situation, such as rapid population growth, high food demand, and land and ecological degradation, would most likely exacerbate vulnerability to the adverse effects of climate change.

5.2. *Data, capacity, and methodology*

The main constraints to the assessment of vulnerability and adaptation relate to data and capacity. Data available are insufficient to meet the demands of the methodologies for the assessments. The data required as input to impact models and assessments were either not present (uncollected), inaccessible, or inappropriate. On the other hand, there is also inability to conduct the type of assessments that would generate results reliable enough to be incorporated into national planning processes. This may be due to the lack of appropriate institutions and infrastructure to conduct systematic data collection, poor coordination within and/or between government departments and agencies, the absence of universities and/or research centers in smaller, poorer countries, among others. Even if institutional arrangements had been established to carry out vulnerability and adaptation assessment, many of these institutions lack the capacity and resources to fully engage in such work. The participation and involvement of technical teams could be hampered by lack of coordination and lack of clarity over roles and responsibilities.

While need is recognized for more work to be carried out on integrated assessments, socioeconomic assessments, identification of adaptation options, and costing implications, there are methodological problems that would need to be addressed. These include the lack or inadequacy of local, specific environmental and socioeconomic data and methodologies; methodologies for integrated and socioeconomic assessments; and understanding of the magnitude of climate change impacts on water resources, human health, fisheries, coral reefs, some local ecosystems, etc.[43] Other limitations included unsuitability of methods and tools, lack of national capacity, lack of data, lack of financial resources, and lack of appropriate institutional frameworks.

5.3. *Research and systematic observation*

Scientific data and information are fundamental inputs to integrating climate consideration into knowledge-based decision-making. Research and systematic observation activities increase understanding of the possible impacts of climate change and support in preparing for the development of sound climate change

strategies. For many developing countries, climate change is an issue yet to be mainstreamed into national planning; thus limited resources are allocated in support of scientific research and climatic observation activities. Table 4 summarizes the needs of developing countries on research and observation as well as the institutional arrangement that facilitate relevant activities.[44]

5.4. *Education, training, and public awareness*

Education, training, and public awareness are important in implementing climate change projects and programs. Although the specific objectives and priorities for public education differ according to the needs of the target sector, the overall goal is still to ensure that most persons understand the problems associated with climate change and assume some responsibility to address these problems. The main objectives of education, training, and public awareness programs are to strengthen national capacity to develop and implement climate change action plans. These can be supported by raising the level of awareness of policy- and decision-makers on climate change, building and/or enhancing the skills and knowledge of local experts as well as educating the public on the causes and effects of climate change. Through such initiatives, institutions involved in project implementation and coordination can be built and/or strengthened, while mobilizing communities/public to implement projects.

Sustaining the activities aimed at training experts and educating and raising the awareness of the public continues to be a challenge in most countrie due to limited financial and human resources and competing priorities. The lack of experts working on climate change issues is partly due to the high turnover of experts involved in climate change. Therefore, there is a need for strengthening governmental, nongovernmental and academic institutions in order to sustain the programs aimed at building and enhancing local capacities to respond to climate change. Table 5 summarzes the needs relating to education, training and public awareness, particularly in developing countries.[43]

5.5. *Mainstreaming climate change adaptation*

Adaptation to climate change is not a "standalone" agenda. It needs to be considered not only when designing various development projects but more importantly in policy-making and planning. Responses on adaptation should be coordinated with social and economic development in an integrated manner.[5] There are several factors that would drive effective integration of climate change considerations into sustainable development in many developing countries[45]:

- Capacity to mainstream adaptation strategy into broader national development;
- Ability to incorporate climate change and other environmental issues in socioeconomic and/or sectoral plans and in achieving Millennium Development Goals;

Table 4 Needs on research and systematic observation in relation to climate change adaptation in developing countries.

Issue	Needs
Research	• Develop regional data for vulnerability and adaptation; • Strengthen the research capacity and observation capability in climate, environment, natural resources, and land-use and cover change; • Strengthen the research capacity in understanding the impacts of climate change, and developing appropriate adaptation strategies and measures; • Tailor research and systematic observation to better understanding of the impacts of and adaptation to climate change in water resources, coastal zones and resources, agriculture, forest, and biodiversity, fisheries and human health; • Modernize the technology (equipment and capacity) used in the current networks; and • Coordinate efforts regionally and internationally.
Observation	• Currently no comprehensive marine/oceanographic observation programs in place; • Upgrade meteorological and hydrological monitoring programs; • Rehabilitate and expand the existing station networks for more representative monitoring of weather, climate, and other environmental variables; • Upgrade and expand climate observation networks at the national level and to improve the contribution to the global observing systems through development, utilization, and accessibility of databases; • Climate data are scanty and unreliable due to the lack of observation stations; • Strengthen existing stations for data to enhance understanding of impacts of future climate change on agriculture, marine ecosystem, land use and forestry, biodiversity, waste and water resources; and • Improve maintenance of observation equipment coverage of systems through the provision of more resources (financial and technical).
Institutional strengthening	• Establishment of strong and effective institutions to manage observation systems including development of human resources and information technology; • Invest resources to support observation programs; • More programs that facilitate the exchange of experts from developing countries' institutions to those of developed countries; and • Lack of availability/accessibility to good quality data and poor research facilities and opportunities to undertake research.

- Ability to formulate, analyze, and implement integrated strategies and policies;
- Need to strengthen coordination and support mechanisms at national and local levels;
- Ability to assess and plan adaptation and integrated actions;

Table 5 Needs on climate change education, training and public awareness.

Issue	Needs
Education	• Development and integration of climate change into curricula at all levels; • Development of educational materials; • Training of teachers; and • Scholarship programs.
Training	• Technical training on vulnerability and adaptation; • Training for policy- and decision-makers; • Training directed at target sectors (media, nongovernmental organizations, community-based organizations, etc.); and • Trainers training.
Public awareness	• General public awareness; • Production of print and audiovisual materials; and • Seminars/lectures/workshops.
Others	• National, regional and international cooperation; • Translation of materials into local languages; • Institutional support; and • Establishment/strengthening of regional centers.

- Data collecting, processing, and management for integrated assessment and decision-making;
- Ability to assess technology transfer needs and capacity for project and program development;
- Human resources in policy design and analysis, and negotiation and technical skills;
- Institutional strengthening and capacity to seek synergy among conventions at national level;
- Education, public awareness, and continuous training on the integration of climate change into sustainable development.
- Coherence and consistency of relevant policies, laws and regulations to remove some of the barriers to the implementation of climate change strategies.

5.6. *Initiatives of the private sector*

The private sector plays critical role in implementing adaptation response for reducing vulnerability in developing countries to climate risks by, *inter alia*, including addressing underlying drivers of vulnerability through poverty-reduction strategies and economic diversification, buffering against specific climate change impacts, etc. To further encourage private sector's responses,

guidelines for business to integrate climate change concerns into their routine risk assessment and strategic decision-making are needed. While "climate proofing" of private sector investments is important, the role of the private sector is not limited to managing its own climate exposure as there are also emerging business opportunities in helping others to reduce their climate risks. The private sector could take on various roles that contribute to the scaling up, optimization, and shifting of adaptation finance. The sector can provide financial resources for adaptation through investments, financial risk management, the commercial provision of capital and the philanthropic provision of resources through private foundations.[51] It is necessary to raise awareness among the investor community and finance institutions, bridge the gaps between funders and potential adaptation projects, and use public finance to help spread private finance more evenly.[7]

5.7. *Technology for adaptation*

Technology is a critical component in reducing vulnerability of human and natural systems to climatic hazards. Despite its important role in climate change policy, a technology roadmap is yet available to drive innovation and access to adaptation technology. Compared to mitigation, the scope of technologies for adaptation to climate change is larger. Negative impacts of climate change endanger the way in which many sectors function, and adaptation therefore needs to be integrated in all sectors as a more fundamental planning paradigm rather than "simply" as a technological switch. Adaptation responses are mainly site-specific and take place at local level. Indigenous knowledge and technologies may exist in some areas, particularly for reducing vulnerability to weather-related hazards. Such indigenous components should be considered and effectively harnessed when promoting the development and diffusion of technologies, know-how, and practices for adaptation to climate change.

Climate change is expected to impinge on multiple sectors underpinning economic growth and social well-being. Public interventions are usually the strongest and most direct incentives to adapt to these impacts through catalysing the use and transfer of technologies for adaptation, which are later taken up by the private sector. In this context, governments are generally considered the dominant stakeholders in technology transfer for adaptation.[47,50] The process of transfer also necessitates the role of other stakeholders, including between private partners, between private partners and governments and between governments, which are influenced by the social, economic, legal, technological and political circumstances in each country.[50]

Developing innovative financing options for adaptation projects are generally more challenging relatively to mitigation projects. Such constraints are attributable to a number of reasons as discussed in Table 3. Clearly extra effort is required to access additional and fit-for-purpose financing for adaptation projects. Instruments and mechanisms that can be considered to improve access to financing for

adaptation projects include creating linkages to sectors with a regular cash flow, or involving international corporations as stakeholders in a technology transfer project.[47]

5.8. *Roles of information and communication technologies*

Information and Communication Technologies (ICTs) are undoubtedly part of the cause to climate change due to the emissions of greenhouse gases globally. Although relatively low in total global emissions presently, it is likely that this share will increase over time as the ICTs industry is expected to grow faster than the rest of the economy. The major contribution of ICTs to climate change comes from the proliferation of user devices, all of which need power and radiate heat.

ICTs can also be part of a solution to climate change because of the role they play in monitoring and adapting to it. They are transformative technologies because they put intelligence at the edges of networks and enable this creativity to be widely shared at every level from local to global, thereby maximizing users' capacity to create and adapt. It is, therefore, better to capitalize on ICTs to realizing beneficial opportunities and moderating potential harm.

The role ICTs can play in supporting topdown and bottomup approaches to adaptation, as well as the development of new arrangements for governing global, national, and local responses to climate change could be characterized in three categories.[22,31] These categories include first order or direct effects (the use of ICTs as a tool for monitoring and measuring climate change, assessing its effects, and controlling interactions with the environment); second order or indirect effects (the use of ICTs as a medium for increasing awareness and facilitating dialog about the effects of climate change); and third order or systemic effects (the use of ICTs as an enabler for "networked governance"). The activities that ICTs could contribute to climate change adaptation are summarized in Table 6.[22,31]

5.9. *Ensuring successful adaptation*

While emphasis on adaptation is increasing, due mainly to the argument that mitigation alone is insufficient to addressing climate change, the need to ensure successful adaptation responses is also recognized. Given the uncertainties surrounding climate change, and variability, it is necessary to design, implement and monitor adaptation in avoidance of under-adaptation (where individuals and organizations have failed to respond adequately to a change in their environment) and over-adaptation (where they have over-reacted and magnified a problem out of proportion to its true significance). The endeavor in measuring adaptation to climate change will be vital to driving the identification of the most promising adaptation options during research and planning, prioritization of sectors, regions and locations for adaptation action, and monitoring and evaluation of progress in avoiding and/or reducing adverse impacts of climate change.

Table 6 Role of ICTs in adaptation of climate change.

Activity	Examples
Climate change monitoring	• Use of ICTs (including radio and telecommunication technologies, standards, and equipment) for weather and climate change monitoring, for instance in predicting, detecting, and mitigating the effects of typhoons, thunderstorms, earthquakes, tsunamis; • Remote monitoring and data collection using ICT-equipped sensors is essential for research at the typical but inhospitable locations for climate research (e.g., polar ice caps, glaciers, volcanoes, the ocean bed, or the upper layers of the atmosphere); and • Development of aerial photography, satellite imagery, grid technology and in particular the use of global positioning by satellite (GPS) for tracking slow, long-term movement, for instance of glaciers or ice flows.
Climate modeling	• ICTs are invaluable in computer modeling of the Earth's atmosphere. Meteorological services are among the most demanding users of the world's fastest supercomputers, and produce progressively more sophisticated general circulation models (GCMs) of climate.
Climate change adaptation and disaster risk reduction	• Tool for monitoring and measuring climate change, assessing its effects, and controlling interactions with the environment; • Medium for increasing awareness and facilitating dialog about the effects of climate change; and • Enabler for "networked governance"–the new forms of economic and social organization and decision-making that will likely be needed not only to adapt to climate change, but to achieve sustainable development.

Unlike mitigation that has more distinctive boundary and globally accepted metric, there is no universally accepted ways for measuring adaptation. Successful adaptation may be judged based on such criteria as effectiveness, efficiency, equity and legitimacy, which are contested and context specific that vary spatially and temporally.[2] The indicators to be used should be policy relevant, simple, transparent, comparable, and practical. Fundamentally, it is necessary to determine what constitutes an adaptation action, whose actions and capacity would count, and whether the metrics should be based on outputs (policies and programs) or outcomes (reduced losses).[19] $IGES_{19}$ gathered several approaches for pursuing such measurement:

- The extent of an adaptation option reduces vulnerability over time with indicators on responsiveness, measurability, cost effectiveness, simplicity, policy relevance, comparability, and communicability;
- "Effective choice" framing, which requires linking an adaptation action to an outcome that would then be evaluated with selected indicators;

- "Social learning" framework, which helps to identify generic properties of institutions that are conducive to adaptation by determining the way institutions evolve and identifying factors hindering and supporting adaptation in different contexts.

Tracking adaptation is, however, not easy to institutionalize. Indicators selection is challenging as it should result in measurement technique that does not constrain institutional creativity and flexibility. It is vital to determine appropriate baseline as relative success of an adaptation action would depend upon initial conditions being used to assess the action; to determine the beneficiaries of adaptation actions; and to identify trade-offs in which some stakeholders may benefit at the expense of others. Such assessments should be designed more operational, transferable and comparable through close consultation with policymakers and other stakeholders. Such participatory approach may serve as tools for promoting communication, and ensuring legitimacy of adaptation among various stakeholders.

6. The Way Forward

Adaptation spans from scientific assessment (climate change projections, impact assessment, and vulnerability analysis) to policy facilitation (capacity-building, policy formulation, and planning) and response implementation (piloting, demonstrating, and full-scale implementation of adaptation actions). It is a knowledge-intensive undertaking, which requires provision of access to relevant and usable knowledge to ensure effective implementation and outcome. Knowledge is needed to address uncertainties associated with climate change and its impacts, and the societal responses to render adaptation. Thus, it is important to manage and share the scientific, technological, and socioeconomic insights of adaptation process. The goal of knowledge management and sharing is to meet the knowledge needs for adaptation policy setting, planning, and implementation; contribute to improving the understanding and assessment of impacts, vulnerability and adaptation; and in making informed decisions on practical adaptation actions, with credible scientific, technical, and socioeconomic knowledge.

Building an informed understanding of the capacity to adapt to the effects of climate change, while seemingly a straight forward task, is actually one that is affected by various challenges. Knowledge, information, and data are needed with respect to social and economic changes that might manifest in the future, such as population growth and development and the depreciation and aging of existing infrastructure.[40] Scenario planning is one methodology that can support enhancement of adaptive capacity to uncertain future. The approach is usually useful for development of long-term strategies in an uncertain future, but also a suitable methodology in developing scenarios for the short term (see Ref. 25 for example, on the mitigation case).

Table 7 Priority response areas to advance climate change adaptation in the Asia Pacific.

Theme	Priority areas
Data collection, management, and dissemination	• Establishment and maintenance of observation facilities; • Collection and compilation of climatic, social, and biophysical data; • Improvement of information and data management, sharing and networking.
Biophysical impact studies	Basic physiological and ecological studies on the effects of changes in atmospheric conditions.
Socioeconomic aspects	• Social vulnerability to multiple stressors due to climate change and environmental change; • Identification and characterization of vulnerable communities and groups; • Capability to diversify local economies, livelihoods, and coping strategies beyond tackling the natural systems; • Migration as adaptation strategy and the support systems and social networks; • Institutions and mechanisms supporting social security; • Economic analysis of climate change impacts and adaptation interventions.
Sectoral and cross-sectoral assessments	• More proactive, systematic, and integrated approaches to adaptation in key sectors (agro-technology, water resources management, integrated coastal zone management, pathology and diseases monitoring and control; etc.) • Sectoral interaction such as between irrigation and water resources, agricultural land use and natural ecosystem, water resources and cropping, water resources and livestock farming, water resources and aquaculture, water resource and hydropower, sea-level rise and land use, sea-water invasion and land degradation.
Extreme event and critical threshold, and disaster risk reduction	• Impacts of extreme weather events such as disasters from flood, storm surges, sea-level rise, heatwaves, plant diseases and insect pests; • Critical climate thresholds for various regions and sectors; • Linkage and integration of responses on climate change adaptation and disaster risk reduction.
Policy responses, implementation and integration	• Mainstreaming science of climate change impacts, adaptation, and vulnerability in policy formulation; • Governance across scales and stakeholder groups; • Raising public awareness of climate change and its impact; • Communication of research findings to different stakeholder groups; • Private sector involvement; • Integrated and balanced responses of adaptation and mitigation.

The IPCC, through its Fourth Assessment Report, pointed out several key specific research-related priorities for advancing the understanding of adverse impacts of climate change in Asia.[13] Similar needs apply in Southeast Asian region, which will require strengthening the academic and research institutions to conduct innovative research on the response of human and natural systems to multiple stresses at various levels and scales. Several subsequent regional studies further identified knowledge gaps, priority research aspects and critical policy responses on climate change adaptation.[4–6,15,39] Key priorities for the Southeast Asia in moving forward on adaptation responses are summarized in Table 7.

Acknowledgement

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References

1. N. Adger, Social capital, collective action, and adaptation to climate change, *Journal of Economic Geography* **79**: 387–404 (2003).
2. W. N. Adger, N. W. Arnell, and E. L. Tompkins, Successful adaptation to climate change across scales, *Global Environmental Change* **15**: 77–86 (2005).
3. S. Ancha, The economics of climate change in Southeast Asia: A regional review, Presented in *SEA-EU-NET Conference on Climate Change*, 11–12 November (Bogor, Indonesia, 2009).
4. Asian Development Bank (ADB), *Building Climate Resilience in the Agriculture Sector of the Asia and the Pacific* (ADB, Manila, 2009).
5. ADB, *The Economics of Climate Change in Southeast Asia: A Regional Review* (ADB, Manila, 2009).
6. ADB, *Under the Weather and the Rising Tide: Adapting to a Changing Climate in Asia and the Pacific* (ADB, Manila, 2009).
7. A. Atteridge, Private Sector Finance and Climate Change Adaptation: How Can Voluntary Private Finance Support Adaptation in Developing Countries? Policy Brief (Stockholm Environment Institute, 2009) (http://www.preventionweb.net/files/12379_policybriefprivatesectorfinanceadap.pdf), (Accessed on 17 June 2010).
8. N. Brooks, *Vulnerability, Risk and Adaptation: A Conceptual Framework*, Working Paper 38 (Tyndall Centre for Climate Change Research, Norwich, UK, 2003).
9. I. Burton, S. Huq, B. Lim, O. Pilifosova, and E. L. Schipper, From impacts assessment to adaptation priorities: The shaping of adaptation policy, *Climate Policy* **2**: 145–159 (2002).
10. T. R. Carter, M. L. Parry, H. Harasawa, and S. Nishioka, *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*, Working Group II of the Intergovernmental Panel on Climate Change (University College, London, 1994).
11. A. Challinor, T. Wheeler, J. Sling, and D. Hemming, Quantification of physical and biological uncertainty in the simulation of the yield of a tropical crop using present

day and doubled CO2 climates, *Philosophical Transactions of the Royal Society of London* **360**: 2085–2094 (2005).

12. J. H. Christensen, B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magana Rueda, L. Mearns, C. G. Menendez, J. Raisanen, A. Rinke, A. Sarr, and P. Whetton, Regional climate projections, in *Climate Change 2007: The Physical Science Basis,* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (Cambridge University Press, United Kingdom and USA, 2007).
13. R. V. Cruz, H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li, and N. Huu Ninh, Asia, in *Climate Change 2007: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Cambridge University Press, UK, 2007), pp. 469–506.
14. N. Cuong, Viet Nam country report – a regional review on the economics of climate change in Southeast Asia, Report submitted for RETA 6427: *A Regional Review of the Economics of Climate Change in Southeast Asia* (Asian Development Bank, Manila, 2008).
15. H. A. Francisco, Climate change: Impacts, adaptation, policy responses in South East Asia, Synthesis of proceeding to the *EEPSEA Climate Change Adaptation Conference,* Bali, 13–15 February 2008.
16. H.-M. Fusel and R. J. T. Klein, Climate change vulnerability assessments: An evolution of conceptual thinking, *Climatic Change* **75**: 301–329 (2006).
17. M. H. Glantz (ed.), *Once Burned, Twice Shy? Lessons Learned from the 1997-98 El Niño* (United Nations University, Tokya, 2001).
18. J. Ho, Singapore country report – a regional review on the economics of climate change in Southeast Asia, Report submitted for RETA 6427: *A Regional Review of the Economics of Climate Change in Southeast Asia* (Asian Development Bank, Manila, 2008).
19. Institute for Global Environmental Strategies (IGES), *Expert Consultation on Adaptation Metrics,* 17–18 April 2008 (Tokyo, Japan, 2008).
20. Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Impacts, Adaptation and Vulnerability. Summary for Policy Makers* (World Meteorological Organisation, Geneva, 2001).
21. Intergovernmental Panel on Climate Change (IPCC), *Further Work of the IPCC on Emission Scenarios: Recommendations by the IPCC Task Group on New Emission Scenarios (TGNES),* IPCC Twenty-Fifth Session, 26–28 April 2006 (Mauritius, 2006).
22. International Telecommunication Union (ITU), ICTs and climate change, *ITU Background Report to ITU/MIC Japan Symposium on ICTs and Climate Change,* 15–16 April 2008 (Kyoto, 2008).
23. S. Jesdapipat, Thailand country report – a regional review on the economics of climate change in Southeast Asia. Report submitted for RETA 6427: *A Regional Review of the Economics of Climate Change in Southeast Asia* (Asian Development Bank, Manila, 2008).
24. T. Y. Jung, S. Ancha, K. Tamura, T. Sudo, R. Watanabe, K. Shimada, and H. Kimura, *Asian Perspectives on Climate Regime Beyond 2012: Concerns, Interests and Priorities* (Institute for Global Environmental Strategies, Japan, 2005).
25. Y. Kameyama, K. Tamura, M. Amano, N. Goto, N. Kanie, H. Kimura, K. Kohyama, I. Kubota, M. Nakai, Y. Ninomiya, H. Niizawa, T. Ohkura, K. Shimada, S. Ancha, Y. Takamura, and R. Watanabe, *The Future Climate Regime: Using the Scenario Planning Approach to Develop Options,* NIES/IGES Research Project Final Report (Institute for Global Environmental Strategies, Japan, 2005).

26. P. M. Kelly and W. N. Adger, Theory and practice in assessing vulnerability to climate change and facilitating adaptation, *Climatic Change* **47**: 325–352 (2000).
27. R. J. T. Klein, M. Alam, I. Burton, W. W. Dougherty, K. L. Ebi, M. Fernandes, A. Huber-Lee, A. A. Rahman, and C. Swartz, *Application of Environmentally Sound Technologies for Adaptation to Climate Change*, Technical paper, FCCC/TP/2006/2 (United Nations Framework Convention on Climate Change, 2006).
28. R. J. T. Klein, R. J. Nicholls, and N. Mimura, Coastal adaptation to climate change: Can the IPCC technical guidelines be applied? *Mitigation and Adaptation Strategies for Global Change* **4**: 51–64 (1999).
29. R. S. Kovats, M. J. Bouma, S. Hajat, E. Worrall, and A. Haines, El Niño and health, *Lancet* **362**: 1481–1489 (2003).
30. B. Lim, E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq (eds), *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures* (Cambridge University Press, United Kingdom).
31. D. MacLean, *ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges: An IISD Commentary* (International Institute for Sustainable Development, Canada, 2008).
32. E. L. Malone and E. L. La Rovere, Assessing current and changing socioeconomic conditions, in *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, eds. B. Lim, E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq (Cambridge University Press, UK, 2005), pp. 145–63
33. Ministry of Science, Technology and Environment (MOSTE), *Malaysia Initial National Communication* (2000).
34. R. Moss, M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgizouli, S. Emori, L. Erda, K. Hibbard, R. Jones, M. Kainuma, J. Kelleher, J. F. Lamarque, M. Manning, B. Matthews, J. Meehl, L. Meyer, J. Mitchell, N. Nakicenovic, B. O'Neill, R. Pichs, K. Riahi, S. Rose, P. Runci, R. Stouffer, D. van Vuuren, J. Weyant, T. Wilbanks, J. P. van Ypersele, and M. Zurek, *Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies* (Intergovernmental Panel on Climate Change, Geneva, 2008).
35. N. Nakicenovic, J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T. Y. Jung, T. Kram, E. L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H.-H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, and Z. Dadi, *IPCC Special Report on Emissions Scenarios* (Cambridge University Press, United Kingdom and New York, 2000).
36. W. Pepper, J. Leggett, R. Swart, J. Wasson, J. Edmonds, and I. Mintzer, Emission scenarios for the IPCC: An update, Supplementary document to *Climate change 1992* (Cambridge University Press, Cambridge, 1992).
37. B. L. Preston, R. Suppiah, I. Macadam, J. Bathols, Climate change in the Asia/Pacific region, Report prepared for the *Climate Change and Development Roundtable, Commonwealth Scientific and Industrial Research Organisation* (: CSIRO Publishing, Victoria, 2006).
38. M. A. Ratag, Climate variability and climate change scenario in Indonesia, Paper presented at the *Workshop on Issues on Climate Change and Its Connection with National Development and Planning*, 1 October 2007 (Jakarta, 2007).
39. B. P. Resurreccion, E. E. Sajor, and E. Fajber, *Climate Adaptation in Asia: Knowledge Gaps and Research Issues in South East Asia* (Format Printing Press, Nepal, 2008).
40. T. F. Smith, C. Brooke, T. G. Measham, B. Preston, R. Gorddard, G. Withycombe, B. Beveridge, and Morrison, *Case Study of Adaptive Capacity: Systems Approach to Regional Climate Change Adaptation Strategies* (CSIRO and the Sydney Coastal Councils Group, Australia, 2008).

41. N. S. Sodhi, L. P. Koh, B. W. Brook, and P. K. L. Ng, Southeast Asian biodiversity: An impending disaster, *Trends in Ecology and Evolution* **19**: 654–660 (2004).
42. Subsidiary Body for Implementation (SBI), United Nations Framework Convention on Climate Change, *Climate Change Impacts, Adaptation Measures and Response Strategies*, Addendum in the sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention, FCCC/SBI/2005/18/Add.5 (2005).
43. Subsidiary Body for Implementation (SBI), United Nations Framework Convention on Climate Change, *Education, Training and Public Awareness*, Addendum in the sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention, FCCC/SBI/2005/18/Add.6 (2005).
44. Subsidiary Body for Implementation (SBI), United Nations Framework Convention on Climate Change, *Research and Systematic Observation*, Addendum in the sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention, FCCC/SBI/2005/18/Add.4 (2005).
45. Subsidiary Body for Implementation (SBI), United Nations Framework Convention on Climate Change, *Sustainable Development and the Integration of Climate Change Concerns into Medium- and Long-term Planning*, Addendum in the sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention, FCCC/SBI/2005/18/Add.1 (2005).
46. R. S. J. Tol, Socio-economic scenarios, in *UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Studies*, eds. J. F. Feenstra, I. Burton, J. B. Smith, and R. S. J. Tol (United Nations Environment Programme and Vrije Universiteit, 1998).
47. P. van Aalst, *Innovative Options for Financing the Development and Transfer of Technologies*, Technical paper, FCCC/TP/2006/1 (United Nations Framework Convention on Climate Change, 2006).
48. K. Vincent, Uncertainty in adaptive capacity and the importance of scale, *Global Environmental Change* **17**: 12–24 (2007).
49. United Nations (UN), *United Nations Framework Convention on Climate Change* (1992).
50. United Nations Framework Convention on Climate Change (UNFCCC), *Technical Paper on Terms of Transfer of and Know-how: Barriers and Opportunities Related to Transfer of Technology*, FCCC/TP/1998/1 (United Nations Framework Convention on Climate Change, 2006).
51. UNFCCC, *Investment and Financial Flows to Address Climate Change: An Update* (United Nations Framework Convention on Climate Change, 2009).

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Climate Change Adaptation Research in South Asia: An Overview

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South Asia with its population of about 1.3 billion is one of the regions in the world highly exposed to a variety of natural as well as human-induced hazards. Climate change is already taking place, and the South Asian countries, particularly the poorest people, are most at risk. The impacts of higher temperatures, more variable precipitation, more extreme weather events, and sea level rise are felt in South Asia and will continue to intensify. In South Asia, disasters have 16% stake in South Asia, which contribute to 47% of death and 41% affected people due to disasters. Increasing trends of natural disasters and their threatening impacts on lives and livelihood have resulted in a paradigm shift in disaster management in all the countries of South Asia—from one post-disaster relief and rehabilitation to holistic management of disasters covering all phases of disasters. The significance of CCA (climate change adaptation) DRR (disaster risk reduction) synergy cannot be felt more by vulnerable communities who do not feel the impact of climate change or natural disaster sectorally, but it hits them as a combined whole with devastating effects.

The South Asian Association of Regional Cooperation (SAARC) initiated a "Regional Study on the Causes and Consequences of Natural Disasters and the Protection and Preservation of Environment" in 1991 and another study on "Greenhouse Effect and its Impact on the Region" in 1992, which recommended regional measures in sharing experiences, scientific capabilities and information on climate change, sea level rise, technology transfer, etc. Through a series of studies and research, SAARC region has a high political will and governance framework for both CCA and DRR. There are several initiatives by the regional bodies (including SAARC), national governments, and research organizations.

Recent review reports on research and practice on CCA of the region (including that of UNFCCC) suggest a strong need to conduct implementation-oriented research in different sectors affected by climate change. To conduct future comprehensive research, GET (Governance–Education–Technology) framework is suggested, with specific connotation to different types of technologies (Implementation-Oriented Technology (IOT), Process Technology (PT), and Transferable Indigenous Knowledge (TIK)). This framework looks 11 different sectors, including urban risk reduction, coastal zone management, mountain ecosystem, arid area management, water resource management, river management, forest management, agriculture risk management, health risk management, housing, and economics of CCA. It is found from the analysis that while there is strong emphasis on IOT, PT and TIK need additional inputs and resources. In the GET matrix, education-related research has less emphasis, in contrast to technology or governance. A balanced approach of engineering and social research is suggested in due course.

1. Climate Change Adaptation and Disaster Risk Reduction

United Nations Development Program (UNDP) defines climate change adaptation as: "Changing existing policies and practices and adopting new policies and practices so as to secure Millennium Development Goals in the face of climate change and its associated impacts."[15] Adaptive capacity is defined as the property of a system to adjust its characteristics or behavior in order to expand its coping range under existing climate variability or future change conditions. The expression of adaptive capacity as actions that lead to adaptation can serve to enhance a system's coping capacity and increase its coping range. Adaptive capacity represents the set of resources available for adaptation as well as the ability of the system to use these resources effectively in the pursuit of adaptation.[1]

IPCC[4] defined adaptation as: adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous, and planned adaptation:

Anticipatory adaptation: Adaptation that takes place before impacts of climate changes are observed. This is also referred to as proactive adaptation.
Autonomous adaptation: Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. This is also referred to as spontaneous adaptation.
Planned adaptation: Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptation to climate change became the central issue at COP 10 (2004) in Buenos Aires, Argentina where parties, taking into account the outcomes of the activities under decision 5/CP.7, adopted decision 1/CP.10: the Buenos Aires program of work on adaptation and response measures.[7] Under decision 1/CP.10, parties also agreed to develop a structured five-year program of work on the scientific, technical, and socioeconomic aspects of impacts, vulnerability and adaptation to climate change, to address the issues of methodologies, data and modeling; vulnerability assessments; adaptation planning, measures and actions; and the integration into sustainable development.[16] The initial sets of activities were agreed at COP 12 (2006) in Nairobi, Kenya where it was renamed the "Nairobi work program on impacts, vulnerability and adaptation to climate change."

In its Fourth Assessment Report, the IPCC concluded that the evidence for climate change is unequivocal and that disasters linked to climate-related risks and extreme events will be exacerbated by climate change.[14] As the awareness of the urgent need for adaptation grew, parties recognized the increasing demand for policy-relevant information to increase the effectiveness of impacts, vulnerability, and adaptation assessments. This has promoted methods, tools, and approaches

that have been developed in related fields, including disaster risk management, to be utilized in the context of adaptation.[18]

Adaptation to climate change is a broad concept that addresses a wide range of events with different time horizons. Many of slow-onset events risks, and negative consequences, such as incremental sea-level rise and salinization, loss of water resources, gradual changes in ecosystems, and habitat loss, species extinction, loss of agricultural production, and health thread triggered by variations in temperature, are not associated with disasters, while many negative impacts of extreme evens, such as intensified hurricanes and floods are associated with climate-related disasters. Frequent occurrence of climate-related disasters has repeatedly threatened to derail efforts of sustainable development and long-term achievement of the United Nations Millennium Development Goals.[19] Figure 1 shows the increasing trend of hydrometeorological disasters worldwide. Accordingly, parties have become increasingly aware of the linkages between work on adaptation and DRR, and acknowledged the value in the wealth of knowledge from proven practices in climate-related disaster risk reduction that has been accumulated in the DRR domain. Taking into consideration that climate change will exacerbate climate-related disasters, the capacity and lessons learned from DRR institutions, policies, and practices are an important basis to a future climate change adaptation strategy. The Bali Action Plan, clearly reflecting the need to harness existing knowledge and capacities for coping with extreme weather events and climate variability, mandated the following components to be included in the consideration of enhanced action on adaptation in a future climate change regime:

- Risk management and risk reduction strategies, including risk sharing and transfer mechanisms such as insurance; and

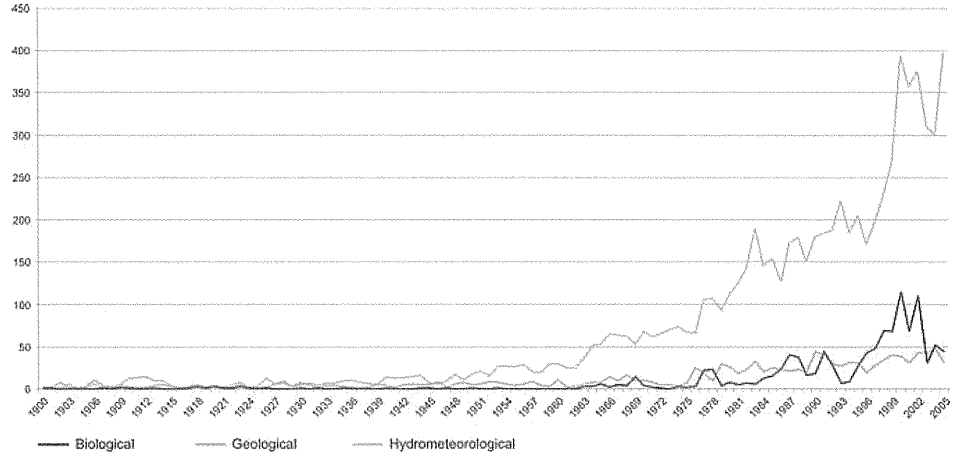

Figure 1 Trends of natural disasters. (*Source*: UN ISDR Prevention Website: http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm).

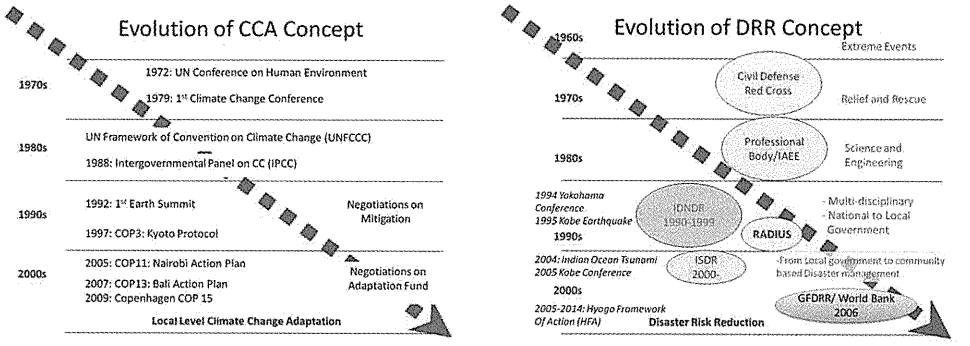

Figure 2 Evolution of CCA and DRR concept. (*Source*: Ref. 13).

- Disaster reduction strategies and means to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change.[17]

These provisions will provide a unique opportunity to address adaptation to climate change in a coherent manner.

Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR), though broadly understood to be linked in some ways, have not yet been taken as a holistically linked complementary set of actions that require collaborative and coordinated action by all concerned stakeholders. The significance of CCA–DRR synergy cannot be felt more by vulnerable communities who do not feel the impact of climate change or natural disaster sectorally, but it hits them as a combined whole with devastating effects. It needs to be appreciated that a piecemeal, sectorally split approach to this complex set of problems will not bear fruit. Recent work by some of the AUEDM university partners has thrown light on the intricate linkages between cross-sectoral development activities, their impact on the environment, subsequent detrimental impacts of a deteriorating environment on human life, and the integrated approach needed to address this combined threat of climate change and disasters.[2] Such an understanding can be very meaningfully deployed at various levels: from governance to voluntary action to education, and can go a long way in developing community-based and environment-based resilience to climate change as well as disasters.

2. Regional Context of South Asia

South Asia with its population of about 1.3 billion is one of the regions in the world highly exposed to a variety of natural as well as human-induced hazards. Countries in the South Asian Association of Regional Cooperation (SAARC) region experienced a number of major disasters in the last one and a half decades,

which took lives of about half a million people and caused huge economic losses and massive destruction in the countries' economy. Among others the major reasons in increasing vulnerability of people in the region are largely related to the demographic conditions, rapid technological and socioeconomic changes, fast expanding urbanization, and development within high-risk environment.[11]

Climate change is already taking place, and the South Asian countries, particularly the poorest people, are at most risk. The impacts of higher temperatures, more variable precipitation, more extreme weather events, and sea level rise are felt in South Asia and will continue to intensify. These changes already have major impacts on the economic performance of South Asian countries and on the lives and livelihoods of millions of poor people. The impacts result not only from gradual changes in temperature and sea level, but also in particular, from increased climate variability and extremes, including more intense floods, droughts, and storms.[20]

The IPCC[4] provides specific information for South Asia region concerning the nature of future impacts. Some of the future impacts include:

- Glacier melting in the Himalayas is projected to increase flooding and will affect water resources within the next two to three decades.
- Climate change will compound the pressures on natural resources and the environment due to rapid urbanization, industrialization, and economic development.
- Crop yields could decrease up to 30% in South Asia by the mid-21st century.
- Mortality due to diarrhea primarily associated with floods and droughts will rise in South Asia.
- Sea level rise will exacerbate inundation, storm surge, erosion, and other coastal hazards.

The consequences of such environmental changes include:

- Decreased water availability and water quality in many arid and semiarid regions, an increased risk of floods, and droughts in many regions
- Reduction in water regulation in mountain habitats
- Decreases in reliability of hydropower and biomass production
- Increased incidence of waterborne diseases such as malaria, dengue, and cholera
- Increased damages and deaths caused by extreme weather events
- Decreased agricultural productivity
- Adverse impacts on fisheries
- Adverse effects on many ecological systems

As a result of these changes, climate change could hamper the achievement of many of the Millennium Development Goals (MDGs), including those on poverty eradication, child mortality, malaria and other diseases, and environmental

sustainability. Much of this damage would come in the form of severe economic shocks. In addition, the impacts of climate change will exacerbate existing social and environmental problems and lead to migration within and across national borders. In sum, climate change is clearly not just an environmental issue but one with severe socioeconomic implications in South Asia.[20]

Figure 3 shows the disaster statistics of South Asia, compared to rest of the world. It shows that the world disasters have 16% stake in South Asia, which contribute to 47% of death and 41% affected people due to disasters. Increasing trends of natural disasters and their threatening impacts on lives and livelihood have resulted in a paradigm shift in disaster management in all the countries of South Asia—from one post-disaster relief and rehabilitation to holistic management of management of disasters covering all phases of disasters. The focus is clearly on Disaster Risk Reduction (DRR)—preparedness, mitigation, and prevention. Many

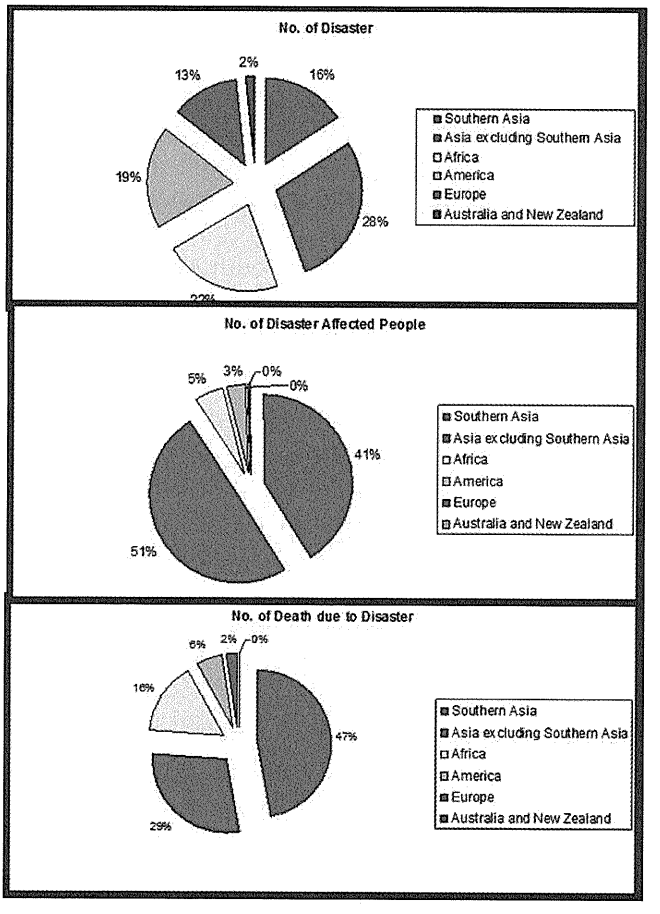

Figure 3 South Asia compared to other regional on number of disasters, deaths, and affected people due to disasters. (*Source*: EMDAT Database).

of the risk reduction measures particularly those related to hydrometeorological disasters, such as drought proofing, flood protection, saline embankment and bioshields, alternative livelihood development, etc., have similarities with Climate Change Adaptation (CCA) programs. Therefore, synergies between DRR and CCA would be necessary not only to avoid duplicities and derive optimal benefits from scarce resources but also to add value to the projects through lessons learnt from the respective perspectives. Factoring climate change issues in disaster risk mitigation projects would enrich the projects and make them more relevant to the emerging concerns just as risk management tools would assess climate change from the perspectives of risks and vulnerabilities over time and the cost–benefit of alternative strategies of adaptation.

3. Key Stakeholders and Actors

Figure 4 shows the key stakeholders at regional, national, and local level. At the regional level, regional bodies like SAARC, its different centers, bilateral and multilateral agencies, international NGOs, universities inside and outside the region, and regional networks of universities, and NGOs play important roles.

At the national level, the key stakeholders are related ministries, centers at the national level, key universities, and NGOs. At certain level, bilateral donors also play important roles in the national levels. At the local level, the keys are the local government, local university or research organization, local NGO, and community-based organizations. With this general structure of the stakeholders, Table 1 shows selected key organizations in different countries, who are directly related to the research and actions related to climate change adaptation. Please note that this is not the exhaustive list, but only outlines some of the key relevant agencies.

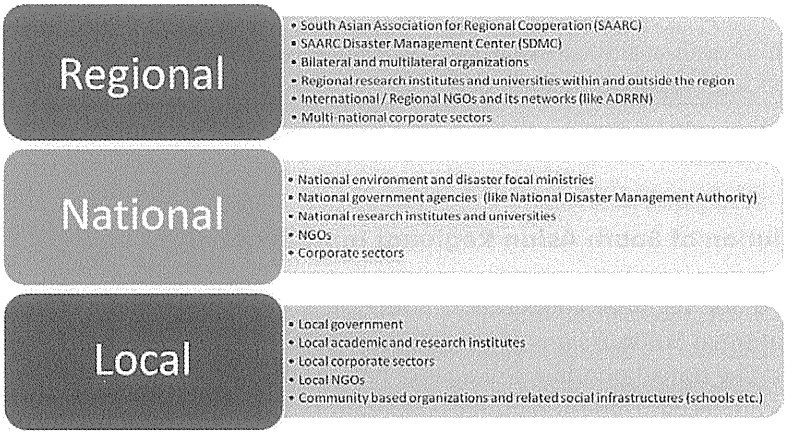

Figure 4 Stakeholder at different levels.

Table 1 List of key organizations in South Asian countries for CCA research.

Country	Research Institutions/NGOs/Universities
Afghanistan	**University:** Kabul University **NGO:** COAR, Church World Services
Bhutan	**Research Organization:** Royal University off Bhutan, Royal Society for Protection of Nature
Bangladesh	**University:** Dhaka University, BRAC University, Bangladesh University of Engineering and Technology (BUET) **Research centers/NGOs:** Bangladesh Center for Advanced Studies (BCAS), Bangladesh Institute of Development Studies, Bangladesh Disaster Preparedness Center (BDPC)
India[a]	**University:** University of Madras, Tata Institute of Social Science, Jawaharlal Nehru University, Annamalai University, Indian Institute of Technology (Kanpur, Delhi, Madras, Bombay), Indian Institute of Management (Ahmedabad) **Research centers/NGOs:** Center for Society and Environment, Center of Environmental Education, The Energy Resource Institute, SEEDS, MS Swaminathan Research Foundation, Indira Gandhi Institute of Development Research, Research Center for Desert Ecology
Maldives	Several research institutes in India are working in Maldives (no university in Maldives)
Nepal	**University:** Tribhuvan University, Kathmandu University **Research centers/NGOs:** Institute of Social and Environmental Transition (ISET)
Pakistan	**University:** Peshawar University **Research centers/NGOs:** Pakistan Institute for Development Economics, Pakistan Poverty Alleviation Fund, FOCUS Humanitarian Agency, Aga Khan Development Network
Srilanka	**University:** University of Colombo, Peradeniya University, Moratuwa University **Research centers/NGOs:** Sarvodaya, Sevalanka, International Water Management Institutes
Cross-cutting (regional)	SAARC Disaster Management Center (SDMC), ICIMOD, Asian Disaster Reduction Center (ADRC), Asian Disaster Preparedness Center (ADPC), Asian University Network of Environment and Disaster Management (AUEDM), Asian Disaster Reduction and Response Network (ADRRN).

[a]Due to large number of institutes, NGOs and universities, only a selected are listed which are directly related to the topic.

4. Evolution of South Asian Regional Initiatives[3]

The need for regional cooperation addressing the concerns for environmental degradation in South Asia was voiced way back in 1987 during the Third SAARC Summit. The trans-boundary linkages of natural disasters with environment in the region were recognized for regional cooperation. The SAARC initiated a "Regional Study on the Causes and Consequences of Natural Disasters and the Protection and Preservation of Environment" in 1991 and another study on "Greenhouse Ef-

fect and its Impact on the Region" in 1992, which recommended regional measures in sharing experiences, scientific capabilities and information on climate change, sea level rise, technology transfer, etc. As a follow-up to these studies, SAARC Plan of Action on Environment was adopted in 1997. The Action Plan provided for the establishment of Regional Centers of Excellence. The SAARC Meteorology Research Centre (SMRC) was established in Dhaka in 1995; the SAARC Coastal Zone Management Centre (SCZMC) was set up in Male in 2004; SAARC Disaster Management Centre (SDMC) came up in New Delhi in 2007, and the SAARC Forestry Center has come into existence in Bhutan recently. All these SAARC Regional Centres can provide credible institutional support for taking up climate change and disaster risk reduction issues in the region.

SAARC Declaration on Climate Change.

We, the Foreign Ministers of member states of SAARC, are deeply concerned that the adverse effects of climate change threaten human lives and livelihoods, sustainable development, and the very existence of many developing countries, particularly in South Asia. We believe that climate change is a phenomenon that impacts on the right to development and human security.

The low-lying regions and long coastlines of SAARC face serious threats from sea-level rise. Our peoples are being adversely impacted, including massive displacement as a consequence of sea-level rise, river bank erosion, drought, severe storms and cyclones, and permanent inundation. The Himalayan regions also face the catastrophic consequences of accelerated glacier melt, including Glacial Lake Outburst Floods (GLOF).

The SAARC member states are determined to contribute to this global effort, in line with the principle of common but differentiated responsibilities. Given our vulnerabilities, inadequate means and limited capacities, we need to ensure rapid social and economic development in our region to make SAARC climate change resilient.

The Fourteenth SAARC Summit held in New Delhi in 2007 expressed "deep concern" over the global climate change and called for pursuing a climate resilient development in South Asia. The member countries pledged for immediate collective action and stronger regional cooperation for the conservation and utilization of SAARC shared resources toward addressing the negatives of climate change. Further, the SAARC Council of Ministers, at their Twenty-ninth Session held in New Delhi in December 2007, adopted the SAARC Declaration on Climate Change which reflects the collective vision of South Asia. On behalf of the SAARC H.E. the president of Maldives presented the declaration in the UNFCC meeting at Bali in December 2007.

The SAARC Ministerial Meeting on Climate Change held on 3 July, 2008 in Dhaka adopted the SAARC Action Plan on Climate Change. Dr. H. E. Sheel Kant Sharma, the SAARC Secretary General, in his inaugural speech laid emphasis on intensifying the regional cooperation on climate change adaptation. He also

highlighted that the emphasis of SAARC is to move from a declaratory to implementation phase and highlighted the roles that SAARC Regional Centres could play therein. He called upon the SAARC Meteorological Research Centre, the SAARC Coastal Zone Management Centre, SAARC Disaster Management Centre, and SAARC Forestry Centre to contribute synergistically with their respective mandates in enhancing the SAARC climate change resilience by pursuing SAARC Action Plan on Climate Change.

SAARC Disaster Management Centre (SDMC) attaches a very high priority on implementing the SAARC Action Plan on Climate Change. In fact, SDMC, in its strategy to evolve the roadmaps on various themes, has taken into account the integration of disaster risk reduction into climate change adaptation as one of its priority areas of action.

5. National Initiatives[3]

Climate change is high on the agenda of every national government of South Asia region. Figure 5 shows the countries include in south Asian region.

5.1. *Afghanistan*

Afghanistan, a mountainous and landlocked country, has been experiencing climate-related disasters like floods, drought, landslide, sandstorms, avalanches,

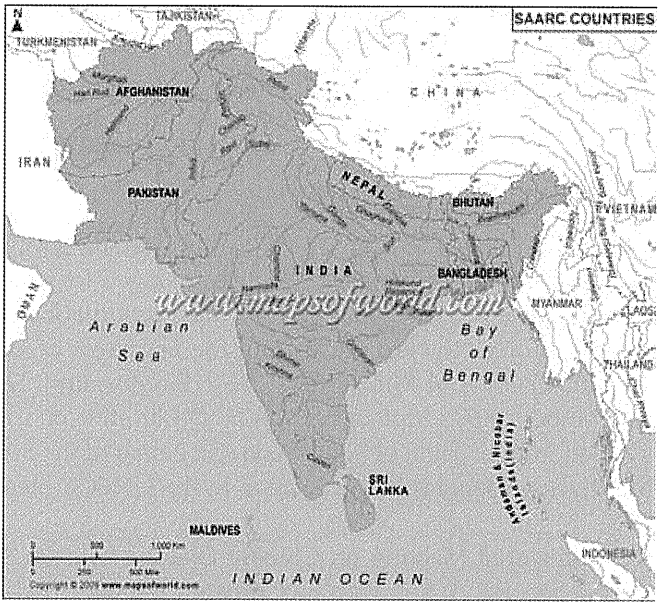

Figure 5 Map of South Asia.

and extreme winter events, which cause considerable loss to life and property and damage an already fragile environment. The National Environment Protection Act (NEPA) of Afghanistan provides the legal and institutional framework for management of natural resource, conservation, biodiversity, drinking water, pollution control, and environmental education.

The Afghanistan National Development Strategy 2004 has set the goal for a five-year plan for institutional reform and sustainable development strategies, which include disaster and climate risk management as a priority. The Afghanistan National Disaster Management Authority (ANDMA) is the nodal agency for formulation and implementation of disaster management policies and plan of action in association with the concerned line ministries and the provincial governments.

5.2. *Bangladesh*

IPCC reports suggest that Bangladesh might lose as much as one third of its land mass due to the potential sea level rise, storm surges, and anomalies in monsoon circulations. Bangladesh has attached a high priority on addressing climate change and disaster management issues in synergy. The Bangladesh Environment Conservation Act, 1995 provides a framework for climate change adaptations with provisions for conservation of environment, improvement of environmental standards, and mitigation of environmental pollution. Water Management Plan of Bangladesh takes into account climate change as a critical factor for future supply and demand. Climate change has been factored in cyclone mitigation and coastal zone management plan. The National Adaptation Programme of Action (NAPA), prepared by six intersectoral groups of core development sectors with Ministry of Environment and Forest in the lead, has envisaged integration of climate change adaptation within the development process. The strategic goals and objectives, as outlined in NAPA, are to reduce adverse effects of climate change including variability and extreme events and promote sustainable development.

The Ministry of Food and Disaster Management (MoFDM) is mandated to coordinate all disaster management activities within the country. The MoFDM has designed a comprehensive disaster management program which has taken a holistic approach to disaster risk including the risks of climate change.

5.3. *Bhutan*

Taking note of the fourth IPCC assessment report that the Himalayan glaciers are receding Bhutan has identified 26 glacial lakes that are extremely vulnerable to GLOFs and has put in place risk mitigation as well as climate change adaptation strategies. The NAPA of Bhutan has spelt out both short-term as well as long-term strategies for climate change adaptation, vulnerability to the fragile mountain ecosystems, farming and livestock rearing, health, etc. Bhutan has a national forest policy, which emphasizes a minimum of 60% forest cover in order to prevent soil

erosion and maintain climate equilibrium. The National Environment Protection Act 2000 takes into account climate change mitigation measures by establishment of an effective system to conserve and protect environment independently by a high-powered National Environment Commission.

Glaciers lake outburst floods (GLOFs), floods, landslides, and forest fires are some of the major climate-related disasters confronting Bhutan. The royal government of Bhutan has endorsed the National Disaster Management Framework under the National Committee on Disaster Management and there is a separate Disaster Management Division within the Ministry of Home and Cultural Affairs as the nodal agency to coordinate disaster risk reduction measures in the country.

5.4. *India*

The Government of India has been an active participant in the climate charge negotiations since the inception of UNFCC in 1992. The Ministry of Environment and Forests is the nodal ministry for all environment-related activities in the country including climate change policy. The National Environment Policy 2006 has laid emphasis on mitigation of climate change. Recently, India unveiled its National Action Plan on Climate Change, which lays down priorities and future actions on addressing climate change. Eight national missions, viz., solar mission, energy efficiency, sustainable habitat, water, Himalayan ecosystem, green-India, eco-green agriculture, and knowledge have been outlined focusing on both GHG mitigation as well as adaptation. The National Action Plan forms the basis for related sectoral developmental planning efforts to harmonize activities in the respective sectors.

Recognizing that India's disaster vulnerability is closely linked to climate change, there are several ongoing centrally funded schemes under implementation for mitigation of weather-related risks, viz., flood control and drought proofing, cyclone warning and shelters, malaria eradication, developing crop varieties resistant to weather-related risks, integrated coastal zone management, etc. Cyclone mitigation guidelines, released recently, takes into account the potential sea level rise besides the historical trends of storm surge. National Food Security Mission and National Rainfed Areas Development Authority taken up by two separate ministries of government, on a mission mode, have strong climate adaptation elements. Similarly, there are ongoing efforts on conservation of Himalayan glaciers taking into account the climate change issues. In fact, Government of India is spending over 2% of GDP in development measures with strong adaptation content including those related to disaster preparedness and mitigation. These programs, in coming days, are likely to be extended and enhanced to cover additional risks of climate change through provision of financial resources and introduction of innovative technologies. Further, India has taken up several initiatives at the national level, inherently supportive of sustainability and clean development. Use of CNG for public transport, metro rail in many

cities, and biodiesel program including mandatory blending of ethanol in petrol are some of the initiatives related to mitigation as well as adaptation. Further, India has launched the Green India project, the world's largest afforestation project covering six million hectares of degraded forest land. Overall, the efforts have been targeted to enhance natural endowments, ensure environment protection, and ecological fragility, while addressing the fundamental issues such as food security and poverty alleviation.

5.5. *Maldives*

With the IPCC report on sea level rise and the December 2004 tsunami which exposed the vulnerability, Maldives, by virtue of having its unique geography and topography, is truly a hotspot island in the region. Low elevation above sea level, perennial beach erosion, dispersal of population across very small islands, remoteness and inaccessibility of islands, concentration of economic activities on tourism, high dependence on imports, and high diseconomies of scale have added layers of coastal vulnerability in the country. Increasing island erosion has become a major threat to nearly half of 194 populated islands of Maldives.

Maldives has developed "Safe Islands" program focusing on the development of larger islands with better economic opportunities, high environmental resilience, and incentives for voluntary migration to these islands. To mitigate future risk from disasters, land use plans of the safer islands have been developed incorporating features of high resilience with a wider environmental protection zone, elevated areas for vertical evacuation in case of floods, establishment of alternative modes of communication and energy, and detailed disaster management plans. Currently five islands have been identified for the program and development plans prepared in consultation with people. Challenges for the program include geographical population dispersion, difficulties of access to islands, high unit cost of delivery of construction material, inadequate human resource to manage projects, and above all unpredictable weather and rough seas.

5.6. *Nepal*

Recognizing that rise in temperature would cause increased melting of Himalayan glaciers creating negative impact downstream in almost all the sectors of development—water, energy, food, etc.—Nepal has launched risk reduction program for the glacier lakes. The Nepal Government, in its five yearly plans, has been putting into the context the climate change adaptation issues by laying emphasis on integrated agriculture and forestry development with focus on poverty alleviation. High priority has been given to natural resources management through community participation. National Action Program (NAP) places focus on reclamation of degraded land to prevent expansion of desert-like areas due to accelerated land degradation, soil erosion, landslide, alkalinity, and salinity in

the agricultural land. A number of legislations have been implemented for the conservation and sustainable use of natural resources, particularly the forest, land, and water. Nepal has put in place a system for the development of Clean Development Mechanism (CDM) projects and formed the Climate Change Network to coordinate climate change activities at the national level.

Nepal has adopted the National Policy Framework for Tenth Plan (2003–2008) and identified disaster management as the core need of sustainable and broad-based economic growth. The plan focuses on disaster risk reduction by enhancing preparedness activities at the national and community levels, by engaging local bodies, NGOs, community organizations, and the private sectors. Nepal has further developed a Water-Induced Disaster Management Policy, 2006 which seeks to

- Mitigate the loss of lives and property arising from water-induced disasters like flood and landslides;
- Preserve rivers, river basins and water-related environment for the sustainable use of natural resources;
- Reclaim riverbanks and flood affected areas for the rehabilitation of landless people and conduct socioeconomic activities; and
- Develop institutions for the control of water-induced disasters and management of flood affected areas.

5.7. *Pakistan*

The National Environment Policy of Pakistan 2005 provides an overarching framework for addressing the environmental issues, particularly pollution of freshwater bodies and coastal waters, air pollution, lack of proper waste management, deforestation, loss of biodiversity, desertification, natural disasters, and climate change. It also gives directions for addressing the cross-sectoral issues as well as the underlying causes of environmental degradation and meeting international obligations. Toward climate change mitigation and minimizing ozone layer depletion the Policy has prescribed the following:

- Establish National Clean Development Mechanism Authority.
- Develop and implement policy and operational framework for effective management of CDM process.
- Promote the use of ozone-friendly technologies.
- Phase out the use of ozone-depleting substances in line with the provisions of the Montreal Protocol.

A Prime Minister's Committee on Climate Change has been reconstituted as a policy review forum, while a Global Change Impact Studies Centre has been established for pursuing related R&D efforts. The country's effort on coastal zone management is yet another initiative to reduce the coastal and marine risks taking into account climate change impacts on these sectors.

5.8. *Srilanka*

With its vulnerability to the coastal hazards, Srilanka has been at the forefront to implement coastal zone conservation. The first Coastal Zone Management Plan (CZMP) was developed and accepted in 1990. The policy that evolved over the next few years has led greater community participation, particularly through the introduction of Special Area Management (SAM). The Policy aims at addressing not only the causes of coastal erosion but also habitat degradation and the wider issue of sustainable coastal livelihoods. The approach includes efforts to decentralize, strengthen local institutions, and encourage working with coastal communities toward sustainable resources management. The Government of Srilanka has recently adopted a National Charter on Environmental Protection, which envisages binding citizens to a set of guidelines toward protecting and conserving the environment through individual actions. The country has also put in place effective mechanisms to incorporate climate change concerns into development program with the Ministry of Environment and Natural Resources as the nodal coordinating agency. Srilanka has been experiencing natural disasters caused by isolated incidents of flood, cyclone, coastal erosion, and landslides until the 2004 tsunami devastated two thirds of Srilanka's coastline. A National Council for Disaster Management and a separate Ministry for Disaster Management and Human Rights have been set up under the Srilanka Disaster Management Act No. 13 of 2005 which has provided a holistic framework for disaster risk management in the country, including the climate-related risks.

6. Integrating DRR with CCA in South Asia

Integration of Disaster Risk Reduction (DRR) into Climate Change Adaptation (CCA) would be one of the challenges of risk management in South Asia. SAARC Disaster Management Center (SDMC) has a strong emphasis of integrating the climate change adaptation (CCA) and disaster risk reduction (DRR), which is outlined in Figure 6.[3] The task can be addressed by identifying those areas which create divergence between DRR and CCA processes, as also those which create convergence between the two. The forces that create divergence are the following:

(a) **Diverse Institutional Structure:** The institutional arrangements that exist in South Asian countries are such that DRR and CCA experts and functionaries are usually different, respond to different needs and to the different constituencies, and do not have authority to implement policy decisions in the areas other than their specific responsibilities. In fact, such structural barriers also exist at the international and regional levels.

(b) **Disconnected Policies, Planning, and Programs:** DRR and CAA policies, planning, and programs often take place in isolation without sharing the respective goals, methodologies, and objectives.

(c) **Lack of Relevant Information:** Information concerned with DRR and CCA are inherently complex which cannot be packaged easily for integration into respective concerns. DRR-related info, for example, often does not describe environmental and socioeconomic information of underlying risk factors which are required in support of pursuing CCA.
(d) **Ad-hoc Short-term Approaches:** For most of DRR projects, risks to investments are not considered for the full lifetime of the project and thus ignore climate change risks, impacts and adaptation factors.

The convergence between DRR and CCA processes has been observed in certain types of projects which need to be recognized for scaling up and replications in the region, especially through regional cooperation. These are

(a) Integrated Coastal Zone Management
(b) Participatory Watershed Development Program
(c) Land Use Planning in areas sensitive to climate and disaster risks
(d) River-basin Floodplain Management
(e) Integrated Drought Mitigation

The tools and techniques used for DRR such as early warning systems, hazard, risk and vulnerability analysis, risk assessment and monitoring, risk mitigation as well as response strategies need to be integrated with CCA strategies in the critical sectors like human health, food, water and environmental security, agriculture, forestry, tourism, etc. There are success stories and good practices demonstrating such integration, which should be replicated and further scaled up.

There are enabling mechanisms for integrating DRR and CCA through integration of appropriate technologies like ICTs, Space, Automatic Weather Stations (AWS), Doppler Weather Radars (DWR), etc. Similarly, networking of DRR and CCA institutions at national, regional, and global levels coupled with multi-stakeholder communication and dialogs as well as exchange of information and expertise may catalyze such integration.

The model for DRR–CCA integration as discussed is presented in Figure 6. From the "conceptual framework" as outlined above to "actionable strategies," the following steps are suggested:

Step I: Targeting Climate-Related Disaster Risks: Most of the Hazard, Vulnerability and Risk (HVR) Assessment efforts are based on the frequency of occurrence of disasters in spatial and temporal domains. Climate risks are not captured well and also the simulated climate change scenarios are not factorized to target the climate-related disaster risks especially in the "hotspots" of South Asian region. While the strategy calls for recasting HVR mapping efforts, such efforts enable closer integration of DRR and CCA in the operational domain of end-to-end project implementation.

Step II: Designing Risk Reduction Strategies: Designing risk reduction strategies for hydrometeorological risks must essentially be based on using the knowledge

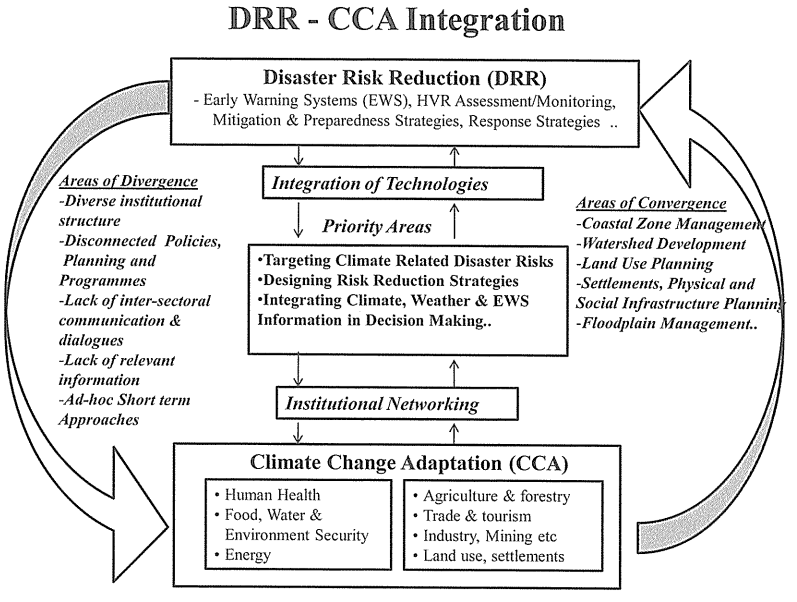

Figure 6 Framework of DRR–CCA integration (*Source:* Ref. 3).

of climate risks. For instance, if it is to develop an effective and people's centered EWS to provide "actionable" information about a climate hazard to a vulnerable population, the assessment of climate risk should form the key inputs. Further, the strategies must be dynamic and in tune with the changing practices and conditions such as depletion of the ecological foundation of the natural resources such as coral reefs and mangrove forests may aggravate risks; further effective insurance and microfinance initiatives to transfer risks and provide additional resources may reduce risks.

Step III: Integrating Climate, Weather, and EWS Information in Decision-Making: Besides implanting DRR in CCA projects, it is important to utilize advanced climate forecast information in managing risks from the existing climate variability and also utilize results from climate change models especially where known climate change impacts lead to a certain direction, viz., glaciers retreat and GLOF in Himalayan region.

As climate hazards are growing in number, more and more people in the region are turning vulnerable because of poverty, powerlessness, population growth, and the movement of people to marginal areas. Climate change has the potential to derail the poverty alleviation efforts in the region, punishing first and most, the very people least responsible for greenhouse-gas emissions—and increasing their vulnerability to the natural disasters further. Concerted national efforts are necessary in support of climate change adaptation and disaster risk reduction.

Uniquely, with the inherited traditional knowledge, South Asia has got the civilization heritage in terms of indigenous coping and community resilience. These heritages need further empowerment in terms of technology and knowledge to withstand the potential climatic shocks and their extremes. Further, with the growing climate risk, the adaptive capacity in South Asia is to be enhanced by providing the necessary financial resources, access to technology and knowledge, and by enhancing the institutional capacity. For example, the capital-intensive agricultural systems are less sensitive to climate, perhaps because they can control many more inputs. Agriculture, water management, land use practices, etc., in South Asia are therefore to harmonize with changing climate regimes.

While there are efforts in South Asian countries to directly address climate change adaptation issues through the development of National Adaptation Plans of Action (NAPAs), their integration to disaster risk reduction needs specific priority. To address adaptation concerns as part of their national development plans, the explicit focus on disaster risk is seen only in few cases. For example, the Safe Island program of Maldives is an integrated effort on addressing vulnerability through strategic planning for climate change adaptation. Similarly, coastal zone management efforts in India, Pakistan, and Srilanka are yet another example in this direction.

Except few cases in the arena of coastal zone management and also in case of integrated watershed development programs, there is a clear disconnect between the institutional and legislative systems developed to address disaster risk and those developed to address climate change. The emphasis is to be laid on climate-related development outcomes—in areas such as agriculture, water resources, food security, health, the environment and livelihoods—that are sensitive to both climate variability, and change.

In South Asia where both climate-related hazard and vulnerability levels are likely to be drastically affected by climate change, it is necessary, based on the regional cooperation among South Asian countries, to establish systematic integration between the institutional frameworks, policies, and strategies to address disaster risk with those related to adaptation to climate change. A key challenge, in this context, is to strengthen regional capacities to manage and reduce risks associated with existing climate variability. To achieve this, closer linkages need to be forged between the policy arenas of climate change and disaster risk reduction at national, regional, and international levels.

Further, at the global level, the implementation of the Hyogo Framework needs to be more clearly recognized as a primary tool to achieve the adaptation goals of the UN Framework Convention on Climate Change (UNFCCC). The reflection of such integration assumes greater importance and urgency in the climate risk hotspot of South Asia through regional cooperation under the SAARC Framework of Disaster Management.

7. Research Focus of CCA in South Asia

7.1. *Regional research review*

UNFCCC made a recent review of the Nairobi Work Program,[8] which is directly linked to the CCA activities, including research, policy dialog, and implementation. Table 2 shows the NWP partners and its activities under seven specific items: improving the provision of climate data and information, developing and disseminating methods and tools, assessing impacts of vulnerability and adaptation to climate change, communicating climate risks, scaling up community-based adaptation actions, reducing risks of extreme events and climate-related disasters, and promoting knowledge sharing and learning. A few findings include:

- Ongoing actions are already delivering concrete results on the ground.
- Good practices and lessons learned are being documented and shared within the adaptation community.
- Challenges as well as opportunities exist for further building adaptive capacity and delivering adaptation actions.
- The NWP has the potential to assist in realizing these opportunities and to facilitate the implementation of adaptation to future climate regime.

The study also clearly states that a comprehensive framework for adaptation under the post-2012 climate regime, including enhanced actions on adaptation, with required financial technological support, institutional structure, and capacity development. Kyoto University International Environment, and Disaster Management Laboratory (IEDM), Asian Development Bank, Christian Aid, International Union of Conservation of Nature (IUCN), Global Change System for Analysis, Research, Training (START), Institute for Social and Environmental Transition (ISET), Practical Action, Satkhira Unnnayan Sangstha (SUS), and Stockholm Environment Institute (SEI) are some of the key organizations mentioned in the list, who have conducted innovative research and practice in the field of CCA in South Asia.

Rockefeller Foundation[10] made a summary report of research centers of excellence in Asia, which includes several of south Asian centers. Out of 59 centers in Asia, 17 are listed from South Asia. The review identified that while there are examples of stellar pieces of research from some of the stronger institutions, there is an inconsistency in quality of outputs, even from these institutions. It also concluded that strong institutions are few in numbers, and often based in capital cities. There is a gap in strong, high-quality institutions that are subnational, especially in larger countries, such as India. The above-mentioned status can be explained by the combination of a few positive or negative factors: increase in capacity in last 10 years, demand outstripping supply, staff turnover, contract-driven agenda, overload of strong researchers, link to government, and challenging nature of regional work. Apart from Rockefeller Foundation, the report acknowledges the regional initiatives of the Asian Development Bank, AUSAID (Australian Agency

Table 2 Nairobi Work Program partners in synthesis report.[8]
Nairobl work programme partners that contributed to this publication.

Thematic Chapter	Compiled by	With Contribution from
Improving the provision of climate data and information	World Meteorological organization (WMO)	– Ibero-American Network of climate change offices (RIOCC) – office of Agricultural Risk (Argentina) (DRA) – Unite Nations Development Programme (UNDP) – Water Center for the Humid tropics of Latin America and the Caribbean (CATHALAC) – WWO
Developing and disseminating methods and tools	Food and Agriculture Organization of the United Nation (FAO)	– Asian Development Bank (ADB) – Christian Aid – FAO – International Union for Conservation of Nature (IUCN)
Assessing impacts of, vulnerability and adaptation to climate change	Global Change System for Analysis, Research and Training (START)	– Center for International Forestry Research (CIFOR) – Christian Aid – Food and Agriculture Organization of the United Nations (FAO) – International Union of Forestry Research Organizations (IUFRO) – START – World Federation of Engineering Organization (WFEO) – world Food Programme (WFP)
Communication climate risks	Environmental Development Action (ENDA)	– ENDA – Global Change System for Analysis, Research and Training (START) – Practical Action

Table 2 Continued.

Scaling up community-based adaptation actions	Practical Action	– Christian Aid – Environmental Development Action (ENDA) – Institute for Social and Environmental Transition (SET) – Kyoto University Graduate School of Global Environmental Studies – Practical Action – Satkhira Unnayan Sangstha (SUS) – United Nations Development Programme (UNDP) – World Food Programme (WFP)
Reducing risks of extreme events and climate-related disasters	United Nations International Strategy for Disaster Reduction (UNISDR)	– Christian Aid – Ibero-American Network of climate change offices (RIOCC) – Institute for Social and Environmental Transition (SET) – Kyoto University Graduate School of Global Environmental Studies – Munich Climate Insurance Initiative (MCII) – UNISDR – World Food Programme (WFP)
Promoting Knowledge sharing and learning	United Nations Environment Programme (UNEP)	– Environmental Development Action (ENDA) – Ibero-American Network of climate change offices (RIOCC) – Institute of Development Studies (IDS) – Kyoto University Graduate School of Global Environmental Studies – Stockholm Environment Institute (SEI) – United Nations Development Programme (UNSP) – UNEP

Table 3 Selection of technologies for CCA and DRR.[9]

Category	Thechnologies for adapatation
Category	Technologies for adapdation
Coastal zones	Restoration of coastal forests and reefs,monitoring coastal and coral erosion, sand dune restoration and construction, dykes, dams, levees,nets and dredging, community-based conservation programs and aquaculture sea walls, revetments saltwater intrusion barriers, tidal barriers
Early warning and forecasting	Agriculture and food security management system, natural diaster response systems, improved weather forecasting , early warning systems for floods and droughts, improved data gathering, improved hydrometeorological networks, improved communication systems, early warning system for desertification, etc.
Infrastructure	Improved technical design and construction, changes in roofing material, improved levee construction, establishment of building codes, windmills, improved planing, use of local nonmetalic construction material, construction of water gates, rehabilitation of multiple use reservoirs, implementation of communications infrastructure, and rehabilitation and reconstruction of meteorological/climate stations.
Terrestrial ecosystems	Afforestation, replanting and improved silviculture, watershed restoration and management, flood zone restoration and creation, protection and rehabilitation of degraded soil and lands, forest and brush fire prevention methods, promotion of agofarming and forestry in semi-arid landscapes, lake training and eradication of invasive flora species.
Water resources	Water harvesting, spate irrigation, control of sand encroachment, small-scale irrigation and harvesting for arid areas, gravity irrigation systems ,maintenance and construction of reservoirs and wells, capture of water run-off, drip irrigation, installation and maintenance of water pumps groundwater recharge of wells, wastewater treatment, etc.
Agrigulture, livestock and fisheris	Soil conservation, and land improvement, coastal zone protection, changing cultivars and crop varieties, improved water distribution networks, improving cultivation practices, crop rotation, bench terracing and contour cropping, construction of windbreaks, integrated pest management, dry farming, diversity and improve aquaculture, food processing and preservation, development, use and promotion of drought and heatresistant crops improved quality of fishery related data, installation of Device for Fish Concentration (DFC) on coastal zones, new navigation technologies for fishing , networks of early warning systems, promotion of new rice varieties and agricultural forecast modeling, etc.

for International Development), DFID (The Department for International Development), the Ford Foundation, IDRC (The International Development Research Center), and Sandee (South Asia Network for Development and Environmental Economics).

Practical Action[9] also made a summary report on south Asian context of climate change and disaster risks. Table 3 points out six key issues of the climate change adaptation in south Asia: coastal zones, early warning and forecasting, infrastructures, terrestrial ecosystem, water resources and agriculture, and livestocks and fisheries. It also identifies key technologies required for each of the sectors; however, the review fails to classify the technology based on its level of implementation.

In another attempt, Asian University Network of Environment and Disaster Management[2] made the comprehensive list of key focus areas related to CCA. It argues that while there is very popular recent focus on carbon footprints, the concept of ecological footprints has existed for a long time in the academic domain. The fact that the environment has a limited carrying capacity beyond which it cannot support consumption and emission levels has been a well-known fact for very long, and has been articulated in scientific terms for many decades. Yet, ecological footprints have gone on increasing exponentially with increasing consumption patterns that have accompanied development and economic growth. The study identified the following sectors as the key entry points of CCA–DRR research and higher education: coastal zone management, mountain ecosystem, forest management, urban risk reduction, education, and learning approaches, and local governance system.

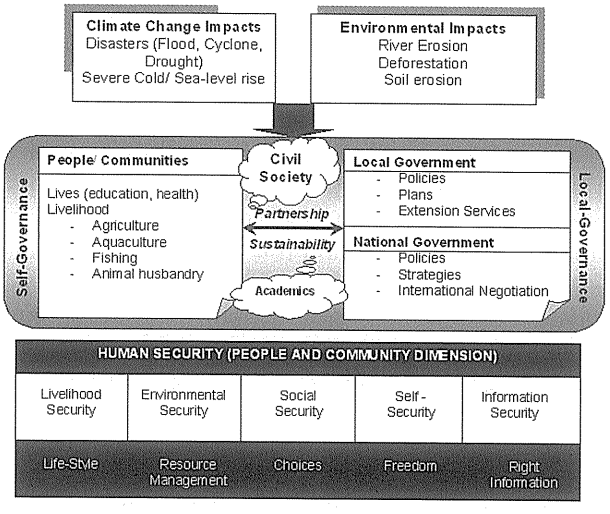

Figure 7 Climate Change Adaptation Model focusing on people and community dimension of human security.[12]

7.2. CCA and Human Security at Local Level

Shaw[12] emphasized that the research and implementation activities related to CCA should be done more on local level. CCA should be looked upon as community development process, through multistakeholder partnership. Shaw (2006) focused on linking CCA with human security and looking at the larger dimension of the environmental changes. This can be considered as people and community dimension of human security, which should include livelihood security, environmental security, social security, self-security, and information security (Figure 7). Livelihood security is the first and the foremost priority, where improvement of lifestyle is desired through income generation in different options: agriculture, aquaculture, fishing, animal husbandry, etc. Environmental security is the second dimension, and is found to be important in many rural areas, where natural resource management by the community is the key issue. Social security is the third dimension, which ensures different social benefits to the people, and enhances people's choice for social services like health, education, etc. Self-security is the fourth dimension in which people and communities are engaged in self-help and cooperation, therefore increasing their degree of freedom. Social security and self-security are closely related to each other. The fifth dimension is the information security, in which right to information to people and community is of extreme importance to take the right decision and action. Needless to say, there are other dimensions of human security; however, these five dimensions are strongly related to the CCA approach.

To enhance human security at the people and community level, the government–people linkage is of utmost importance. People's activities are more related to their lives and livelihoods, which get affected by climate change impacts. For local government, it is more on policy, plans, and extension services, the effectiveness of which can reduce the climate change impacts. For central government, it is more on policy, strategy, and international negotiation. Thus, where climate change adaptation is concerned, the activities in the field (demonstration projects, training activities, awareness raising activities) need to be reflected in the local government policies and programs to make it more sustainable. Thus, a strong partnership between people and government is extremely important. Civil society and academic play an important role in strengthening this partnership and ensuring its long-term sustainability through policy integration. Self-governance and local governance are the key factors in ensuring policy integration.

7.3. Gap analysis and potential of future research of CCA in South Asia

The gap analysis is done using two specific concepts: the first one is the GET (Governance–Education–Technology) matrix, where the future research of CCA can be aligned to this matrix. The second one is the type of technology. This framework is used for the identified research topics, which are considered important to the context of South Asia.

Governance research is focusing more on the policy issue. Simply putting, governance is the art/science of decision-making. The concept of governance refers to the complex set of values, norms, processes, and institutions by which society manages its development and resolves conflict, formally and informally. It involves not only the state, but also the civil society at the local, national, regional, and global levels. Four pillars of governance are: accountability, accessibility, transparency, and efficiency. The governance-related research do not necessarily be linked to the national level, it can go to local governance or even to the community level. Governance research needs to emphasize how the harmonious partnerships are essential between Governments and NGOs, however in many situations there is a lack of cooperation and a spirit of competition. Often governmental, and NGO officials accentuate what divides them rather than recognize their shared values.

Education is a cultural issue. Education research needs to focus on the contents and process of education on CCA. The contents part needs to be culturally calibrated based on the local context of South Asia. The region has different socioeconomic and political diversity, and the contents need to be very much customized to the local context. Customization process itself can be an important research theme of the CCA. The process of education is equally important. There is a saying "tell me, I will forget; show me, I may remember; involve me, I will understand." The involvement of different stakeholders in the education process is an important research issue of the CCA. The delivery mechanism of the education should be strengthened, and needs to be customized as per the local issues.

Technology has different meanings to definition. Kameda[5] defines technology as "a set of rational means and knowledge pertinent to realizing specific objectives that have solid logical bases and stability." In a conventional recognition, technology meant just engineering products. But when we consider implementation strategies, technologies should involve not only products but processes as well. This requires innovation of research community to reform from "product focused research" to "process oriented research," or "product-process linked research." Kameda[6] classified technology as:

- **Implementation Oriented Technology (IOT):** Products from modern research and development that are practiced under clear implementation strategies
- **Process Technology (PT):** Know-how for implementation and practice, capacity building, and social development for knowledge ownership
- **Transferable Indigenous Knowledge (TIK):** Traditional art of disaster reduction that is indigenous to specific region(s) but having potential to be applied to other regions and having time-tested reliability

Criteria for each of these types are as follows:

Criteria for Implementation-Oriented Technology (IOT)

- Technically or scientifically acceptable
- Problem identification and methodology development practiced in direct communication with stakeholders and end-users to create incentive for their participation and ownership

- Regional characteristics properly incorporated in terms of local context including available materials, cost, and workmanship
- Most advanced research methodologies mobilized to generate high-quality products and meet the actual demands of the region

Criteria for Process Technology (PT)

- With emphasis on "practical use" of research
- A tested methodology with social, cultural, economic, ecological, and technical feasibilities, developed through an implementation/testing process ensuring results in disaster reduction
- Demonstrated stakeholders' participation and enhanced ownership
  - of the process
  - of results and lessons
- Amenable/adaptable to local context, and with institutionalization potential
- In-depth knowledge and insight gained through experience with disasters and mitigation

Criteria for Transferable Indigenous Knowledge (TIK)

- Originated within communities, based on local needs, and specific to culture and context (environment and economy)
- Provides core knowledge with flexibility for local adaptation for implementation
- Uses local knowledge and skills, and materials based on local ecology
- Has been proven to be time-tested and useful in disasters
- Is applied or applicable in other communities or generations

Elevan specific research areas related to CCA are identified based on the earlier analysis:

- Urban risk reduction
- Coastal zone management
- Mountain ecosystem
- Arid area management
- Water resource management
- River management
- Forest management
- Agriculture risk management
- Health risk management
- Housing
- Economics of CCA

Among these issues, some of the burning problems of South Asia are: urban risk reduction,[14] which points out the following as the emerging issues of future research: urban rural linkages, neighborhood level approach in urban context,

focusing on daily environmental problems as the entry to CCA/DRR, risk communication strategy, and synergy of international and local knowledge. A related research area is the LECZ (Low Elevation Coastal Zone) in South Asia. Data[9] shows that India, Bangladesh, Pakistan, and Srilanka have significant population exposed to the LECZ (31, 15, 2, and 1 million, respectively). Comparing the fractions of urban population in LECZ in cities exceeding 5 million, Pakistan seems to have the highest exposure (92%), followed by India (58%) and Bangladesh (33%). Thus, research focusing on the urban LECZ can be an important target area of research in future.

The other important, yet low focused, area of research is water management or drought risk management in the monsoon areas. Parts of South Asia like Afghanistan, Pakistan, India, and Srilanka are prone to drought due to conventional low rainfall in the arid climate. However, it is increasingly observed that the monsoon regions are gradually becoming vulnerable to drought, which affects the local livelihoods, like agriculture and/or aquaculture. Some parts of northwest Bangladesh, eastern India, south-central Srilanka are experiencing this. The key contributing issue is water management through participation of different stakeholders, and this can be another important research issue in the region.

Coastal zone and mangrove management have been a long-term issue in the region; however, the integration of social, physical, and ecological dimensions of mangrove is yet to be done, and there are lots of scopes of future research. Figure 8 shows the four-level evaluation of the identified 11 sectors. The evaluation is qualitative, and based mainly on author's experiences in the South Asian region, combining with the current trend of CCA/DRR. A quick look at the figure states that there is strong focus on the IOT in different sectors; however, the PT or TIK needs significant improvement in most of the sectors. In some sectors, governance research is done, however, the research related to education (both contents and process) needs significant attention.

7.4. Way ahead

It has been observed that in most cases of adaptation research, there is significant focus on the technological or engineering solutions. Figure 9 shows that while most part of the problem is social problem, the solution or resource allocation for solving social problem is significantly less. In contrast, while the engineering problems constitute a small component of the problem, the resource allocation is the most. This is one of the key issue that needs to be solved for the scientific and technical research in CCA for South Asia. To solve this dilemma, a holistic research process and framework are required, which will be a balanced approach of both engineering and social research.

Figure 10 shows the idealized process for evolution of the CCA research, and to integrate these to the national development pathway. Considering the CCA research as a vehicle to reach the development goals, it needs appropriate

Thematic Focus on CCA Research	Governance	Education	Technology		
			Implementation Oriented Technology (IOT)	Process Technology (PT)	Transferable Indigenous Knowledge (TIK)
Urban risk reduction	◎	○	◎	○	✕
Coastal zone management	△	○	◎	○	○
Mountain ecosystem	△	△	○	△	○
Arid area management	○	△	○	△	◎
Water resource management	◎	△	◎	✕	△
River management	○	○	◎	△	△
Forest Management	△	△	◎	○	△
Agriculture risk management	◎	△	◎	✕	△
Health risk management	○	△	○	✕	△
Housing	○	✕	◎	○	△
Economics of CCA	○	✕	○	○	△

LEGEND ◎ High emphasis ○ Relatively less emphasis △ Neglected ✕ Not yet done

Figure 8 Current status and analysis of potential future research focus areas in CCA.

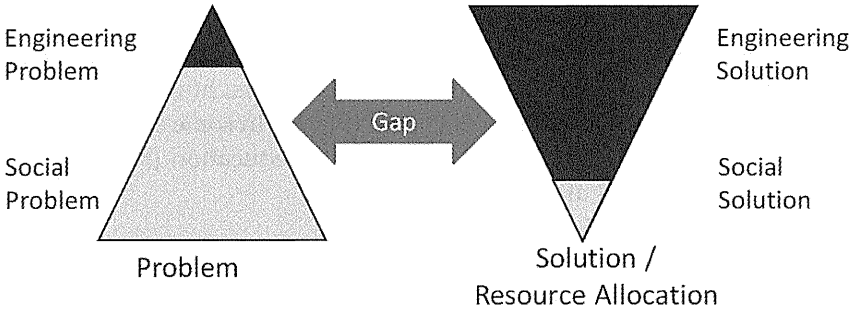

Figure 9 Gap between problem and solution/resource allocation in adaptation research.

technologies, which can be classified as IOT, PT, and TIK, as explained in the earlier section. However, we need to remember that technology can be a driver for the whole process. To enhance the inter-linkage with the development process, the research results need to be integrated, and for that significant resources, institutionalization, and political commitment are required. This part can be regarded as the governance structure in the Get matrix, described in the earlier section. Last, but not the least, is the awareness of the people, communities, and decision making-process, which are linked to the educational components of Figure 8.

Needless to say, this analysis does not cover the whole spectrum of CCA research of South Asia. However, this provides a comprehensive overview of the

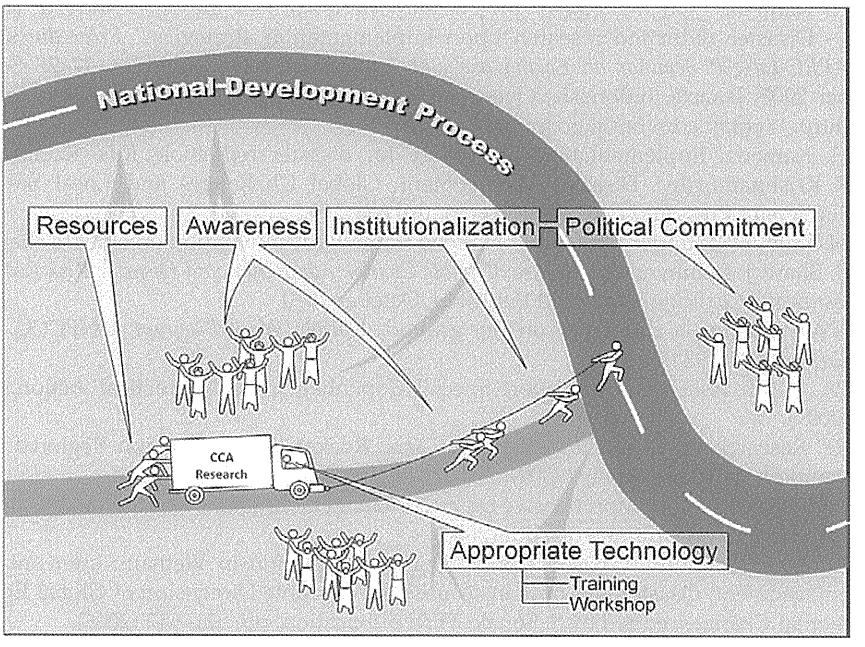

Figure 10 Linking CCA research to development process. (Adapted from the original figure by NSET-Nepal).

gaps and the challenges of CCA research, and has identified the key point of focusing more implementation-oriented research.

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References

1. APF, Adaptation Policy Framework, by UNDP, available at http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/undp_adaptation_policy_framework_apf_.pdf (2005).
2. AUEDM, Education-Research Interface of Climate Change Adaptation and Disaster Risk Reduction, AUEDM Report (Kyoto, Japan, 2010, pp. 33).
3. P. Dhar Chakrabarti, Integrating DRR with CCA: Recent initiatives in South Asia, in R. Shaw, J. Pulhin and J. Pereira, *Climate Change Adaptation and Disaster Risk Reduction: Issues and Challenges*, (Emerald Publisher, 2010).
4. IPCC , *IPCC Fourth Assessment Report* (Intergovernmental Panel on Climate Change, Geneva, 2007).

5. H. Kameda, "On the EqTAP project and framework of the APEC-EqTAP seminar — Disaster reduction research upon implementation strategies," *Proceedings of the APEC-EqTAP Seminar on Earthquake and Tsunami Disaster Reduction*, 27–28 September 2005, Jakarta, Indonesia, Overview Paper, Website EqTAP Digital City/Tool Box (http://eqtap.edm.bosai.go.jp/index.html).
6. H. Kameda, Implementation technology for disaster reduction, Eds. R. Shaw and R. Krishnamurthy, Disaster Management: Global Challenges and Local Solutions: University Press and CRC Press (2009), pp. 206–219.
7. M. Kato, DRR under the United Nations framework convention on climate change, in R. Shaw, J. Pulhin and J. Pereira, *Climate Change Adaptation and Disaster Risk Reduction: Issues and Challenges*, Emerald Publisher, October 2010.
8. NWP, Making a difference on the ground, *Nairobi Work Program*, UNFCCC, Bonn, Germany, PP 93 (2009).
9. PA, South Asia Disaster Report Special Copenhagen issue, Practical Action, pp 19 (2009).
10. RF, Research Centers of Excellence in Asia, Rockefeller Foundation Regional Office, Bangkok, Thailand, pp 49 (2009).
11. SAARC, SAARC Comprehensive Disaster Management Framework, available at: saarc-sdmc.nic.in/pdf/framework.pdf (2006).
12. R. Shaw, Community based climate change adaptation in Vietnam: inter-linkage of environment, disaster and human security, In: Multiple Dimension of Global Environmental Changes, edited by S. Sonak, TERI publication, pp. 521–547 (2006).
13. R. Shaw, Climate change adaptation and disaster risk reduction: evolution and concept, Unpublished report, IEDM, Kyoto University, Kyoto, Japan (2008a).
14. R. Shaw, An overview of urban risk in South Asia: issues, approaches and thoughts, In Journal of South Asia Disaster Studies, **1**(1), pp. 69–84 (2008b).
15. UNDP, United Nations Development Program unpublished report on Climate change adaptation. Available from: http://www.undp.org/climatechange/adapt/role.html (2006).
16. UNFCCC, Report of the Conference of the Parties on its tenth session, held at Buenos Aires from 6 to 18 December 2004 Addendum Part Two: Action taken by the Conference of the Parties at its tenth session. Geneva: United Nations Office at Geneva pp. 2–6. Available at <http: //unfccc.int/resource/docs/cop10/10a01.pdf#page=2> (2004).
17. UNFCCC, Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007. Addendum. Part Two: Action taken by the Conference of the Parties at its thirteenth session. Geneva: United Nations office at Geneva. pp. 4. Available at http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=3> (2007c).
18. UNFCCC, Report on the expert meeting on methods and tools and on data and observations. Geneva: United Nations Office at Geneva. Available at http://unfccc.int/resource/docs/2008/sbsta/eng/03.pdf (2008a).
19. UNFCCC, Technical Paper on physical and socio-economic trends in climate-related risks and extreme events, and their implications for sustainable developments. Geneva: United Nations Office at Geneva. Available at http://unfccc.int/resource/docs/2008/tp/03.pdf (2008b).
20. World Bank, Managing climate risk: integrating adaptation into World Bank group operation, available at: http://web.worldbank.org/WBSITE/EXTERNAL/ COUNTRIES/SOUTHASIAEXT/0,contentMDK:21469804 menuPK:2246552 pagePK:2865106 piPK:2865128 theSitePK:223547,00.html (2010).

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Financing Adaptation in Agriculture and Water Sectors in Asia: An Overview

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Adaptation financing is a major challenge for developing countries, including emerging economies in Asia. No single mechanism can bridge the adaptation funding mechanism. Focusing on climate change, many reports recently published intensifying potential climate change impacts on agriculture and suggests where investments are needed to better climate-proof agriculture. There are many researches, which indicate that diversification of rural livelihoods through agricultural micro-enterprise development can reduce exposure to climate risks; farmer access to credit and information are important for adaptation to climate change; and increased flooding poses the greatest potential risk from climate change. It is well obvious that these mechanisms need enormous funding and instruments especially for the agricultural and water sectors in LDCs. Together with funding there is a need to pay solemn attention to use indigenous knowledge for adaptation, local initiatives for natural resource conservation and is necessary to support reducing vulnerability. Therefore this paper raised the issued related to financing adaptation in agriculture and water sectors in Asia and discussed some financial initiatives for climate change related issues, problems, and challenges.

Keywords: Adaptation, Finance, Climate change, Asia.

1. Introduction

The World Bank published a report intensifying potential climate change impacts on agriculture in the developing world, which discusses the causes of vulnerability, and suggests where investments are needed to better climate-proof agriculture.[9] The conclusions of the report are as follows; diversification of rural livelihoods through agricultural micro-enterprise development can reduce exposure to climate risks; farmer access to credit and information are important for adaptation to climate change; and increased flooding poses the greatest potential risk from

*Disclaimer: The views expressed in this presentation are those of the author and do not necessarily reflect the views and polices of the Asian Development Bank (ADB). The paper was prepared for the Inception Workshop on "Mainstreaming to Climate Change in Agriculture and Water Sectors," held on 10 August 2009 in Kuala Lumpur, Malaysia.

climate change. Why is funding for adaptation in agriculture and water sectors crucial? There are several reasons: (a) continued reliance of Asian economies in terms of livelihoods particularly in the agriculture sector (even if proportion of GDP is declining), (b) high sensitivity of sectors to climate change, (c) looming food and water insecurity, (c) declining resource flows to both sectors, and d) interrelatedness of food and water security with the energy and social security.

A review of the different existing financing mechanisms showed that there are opportunities for enhancing the ability of financing mechanisms to reach poor countries and communities in developing countries, by broadening their scope to be more inclusive of agriculture and water sectors, and that can be easily possible simplifying their procedures and making them more flexible. However the financing on adaptation should be based on (a) rationale, (b) guiding principles for adaptation finance, (c) financing requests, (d) mechanisms in the current regime, and (e) proposed mechanisms for the future regime. Recently Asia is looking for climate change action but current problems with adaptation financing are insufficient, unpredictable, unreliable and duplication of activities such as overlap (of objectives) among PPCR (Pilot Project for Climate Resilience), AF (adaptation fund), and GEF (Global Environment Facility) funds.[6–8] Some fundings are overlapped among bilateral initiatives, level of harmonization, and finally limited absorption (disbursement) capacity of the recipient governments. Consequently, adaptation financing is a major challenge for developing countries, including emerging economies in Asia. No single mechanism can bridge the adaptation funding mechanism. New adaptation funding instruments are needed especially for the agricultural and water sectors and need to pay serious attention to use indigenous knowledge for adaptation; finance local initiatives for natural resource conservation and use; encourage local financial institutions to provide credit on timely and at low interest rate; and sectoral budgets may be necessary to support reducing vulnerability. Therefore, this paper raised the issues related to financing on agriculture and water sectors for adaptation in Asia together with financial initiatives for climate change related issues, problems, and challenges.

2. Issues

Within the framework of international climate policy and its associated mechanisms, under the United Nations Framework Convention on Climate Change (UNFCCC), a key challenge is how to enable agriculture and water sector to contribute to climate change adaptation. As the climate change is well evidenced,[3] water security links together the web of food, energy, climate, economic growth, and human security challenges that simply cannot manage in the future as we have in the past, or the economic web will collapse.[2] Water resource issues have not been adequately addressed in climate change analysis and climate

policy formulations. Likewise, climate change problems have not been dealt within water resource analysis, management, and policy formulation.[1] Consequently to support the climate change initiatives—which adaptations do need funding? Some adaptations may have major financial implications: policy-driven, institutional reform, behavioral changes. Some costs are borne by agricultural or water sector users and they "finance" their own adaptation.

Some investment is of the "soft" type, e.g., information, research, policy—Asia desperately needs! But "hard infrastructure" is also required, with major financial implications e.g., multipurpose storage schemes, irrigated, and rainfed agriculture. Now the key issue arises again: do we need hard infrastructure for adaptation measures? That means, upgrading existing infrastructure such as protective infrastructure: strengthening dams, ensuring coastal defenses are workable, or we need other mechanisms such as nonprotective infrastructure such as reinforcing roads, improving water management to cope with flood risks and water shortages; designing new infrastructure such as heat resistant and permeable roads (rainwater can percolate easily, smaller risk of inundation); hydropower infrastructure, water supply and demand infrastructure. All these issues need enormous financing.

3. Some Initiatives

There is a clear need for funding for climate change adaptation programs in developing countries hard hit by climate change effects, such as droughts, floods, unpredictable weather, spread of diseases, and other impacts. One piece of good news is that arguments for funding adaptation projects do not suffer from the statistical uncertainties that climate change mitigation suffers from. There is a potential problem, however, in that climate change adaptation is still a very nebulous concept. At the multinational level, currently there are several funds and financing mechanisms for climate change adaptation, but most of these are not fully funded or operational. Less than 5% of funds available for climate change issues are available for adaptation.[9,10] Table 1 shares some climeate change initiatives by the world research groups funding mechanism in the current regime.

There is a need for approximately US$2 billion right now.[6–8,10] There should be continuing discussions about funding mechanisms for longer term. The total GEF funds for adaptation since 1991 was $330 million, total allocations were $172 million, and the total disbursements were $78 million. Table 2 indicates the country-specific adaptation funding status and states detailed adaptation initiatives by the Asian region.

Now we share some climate change initiatives should be taken by the world research groups to finance for adaptation in agriculture and water sectors as (a) Agriculture—$14 billion/year, (b) Water sector—$23 billion/year (USD 531

Table 1 World research groups funding mechanism in the current regime.

Sources	Cooperation
UNFCCC Funds	• GEF Trust Fund • Least Developed Countries Fund • Special Climate Change Fund
Adaptation Fund (Kyoto Protocol)	• Under the Kyoto Protocol Compensation and Development Fund
Other UN Conventions	• Convention on Biological Diversity • Convention on Wetlands • Convention to Combat Desertification
Adaptation Funds	• World Bank: Strategic Climate Fund • (SCF) with a Pilot Program for Climate Resilience (PPCR) • ADB: Climate Change Fund, • SGA, Water Financing Partnership Facility
Bilateral Funds	• Japan—Cool Earth Partnership • Korea—East Asia Climate Partnership • Australia—MRC Climate Change Adaptation Initiative • European Commission—Global Climate Change Alliance (GCCA) • United Kingdom—International Window of the Environmental Transformation Fund (ETF-IW) • Spain—Millennium Development Goals (MDG) Fund • Germany—International Climate Protection Initiative • Norway—Agency for Development Cooperation (NORAD) Rainforest Initiative

Source: Authors' compilation from Refs. 6–8 and 10.

billion *from now to 2030*), (c) Water supply/conservation—$11 billion/year, and (d) Coastal zones—$11 billion/year. However, in LDCs the funding allocation is (a) (38 NAPAs): Agriculture—$270 million, (b) Water—$141 million, and (c) Coastal—$96 million.[4–8]

4. Proposed Funding

The estimated costs of climate change adaptation and mitigation in the agriculture and water sectors by researchers are well estimated recently, which exceed public and private resources currently available in the world economy. Proposed funding mechanisms for adaptation in the future climate regime beyond 2012 recently published by World Bank[9,10] are shown in two categories namely global market-based

Table 2 Country-specific adaptation funding status (M = million dollars).

Country	Status of projects and funding sources
China	• Mainstreaming Adaptation to Climate Change Into Water Resources Management and Rural Development (World Bank)—$5.8 M; Co-financing—$50 M
India	• Climate-resilient Development and Adaptation (UNDP)–$5.7 M (in the pipeline)
The Philippines	• Climate Change Adaptation Project (World Bank)–$5.8 M: Co-financing–$25.4 M
Vietnam	• Climate-resilient Infrastructure Planning and Coastal Zone Development in Vietnam (ADB/UNDP)—$3.4: Co-financing—$180 M
Regional: Pacific Islands	• Adaptation to Climate Change Project (PACC) UNDP—14.8 M

Source: Authors' compilation from Ref. 6–8 and 10.

levies and regional and national market-based levies which are mentioned below:

I. Global Market-based Levies

- Increasing levy on CDM (e.g., from 2% to 5%)—$0.3%—$1.7 billion/year in 2020 (Bangladesh and Pakistan); 5% levy = $200—$750 million (2008–2012)
- Extending levy to other market mechanisms (IET and JI)—10–50 million (2008–2012); 300 million–2.25 billion/year after 2012
- Currency transaction development levy (Tobin tax)—15–20 billion/year
- Air travel and shipping levies
- International air travel levy at $7–$10/ticket ($8–$14 billion/year) (LDCs)
- Solidarity tax on air travel (France)
- Levy on marine bunker fuels ($4–$15 billion/year) (LDCs)
- Auctioning of allowances for international maritime and aviation emissions ($22–$40 billion/year) (Tuvalu)
- Levy on REDD funds (5% ~ $600 million)
- Agricultural carbon storage payments similar to REDD

II. Regional and National Market-based Levies (in Developed Countries)

- Auctioning a portion of Annex I emission allowances—$15–$25 billion with 2% of AAUs (Norway)
- Levy on fossil fuel sales in Annex I (Tuvalu, 2005)
- Portion of income from border tax adjustment measures (based on carbon intensity) by Annex I
- Auctioning a portion of EU-ETS allowances ($2.3 billion/year by 2020)
- Business adaptation (e.g., EU wine industry—CLAWINE)
- US Congress–Boxer–Lieberman–Warner bill $3–$25 billion/year (proposed but failed)

5. Conclusions

The arguments state that adaptation funding is critical for the survival of millions of climate change affected people especially in the developing Asian countries. It is also critical for development strategies and as a matter of climate justice, since many affected communities (i.e., south Asian LDCs) did not cause the climate problem, but suffer the most. A number of voices from developing countries assert that this is a make or break issue for the success or failure after the COP15 conference. The unconstrained deal between developed and developing nations in the COP15 and the provision of funding by industrialized countries to the developing world can deal with climate change adaptation. However, financial leveraging is to generate US$20–$100 billion a year in 2030 through large-scale mitigation. However that requires mobilization of both public and private resources, including linkages with existing investment and financial flows to rural development. These flows—comprising international debt, FDI, and ODA—are small compared with the expected costs of adaptation and mitigation in agriculture and water sectors. New adaptation funding instruments are needed especially for these sectors. Now the time has come to pay attention to use indigenous knowledge for adaptation, financing on local initiatives for natural resource conservation and use encouraging local financial institutions to provide credit on timely and at low interest rate, and sectoral budgets may be necessary to support locally. If we utilized new and additional resources for climate change, positive synergies could be obtained in future and the next generation will get a new clean future.

References

1. B. C. Bates, Z. W. Kundzewicz, S. Wu, and J. P. Palutikof (eds), *Climate Change and Water*, Technical Paper of the Intergovernmental Panel on Climate Change (IPCC Secretariat, Geneva, 2008).
2. Davos, World Economic Forum Water Initiative paper (2009).
3. IPCC, in *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. S. D. Solomon, M. Qin, Z. Manning, M. Chen, K. B. Marquis, M. Averyt, and H.L.M. Tignor (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007).
4. SEI, Sei funding calls (2008) www.sei.ie/Grants/EU_Programmes/FP7/FP7_ Funding_Calls/
5. UNFCCC, *Investment and Financial Flows to Address Climate Change* (UNFCCC Secretariat, Bonn, 2007).
6. UNFCCC, *Identifying, Analyzing and Assessing Existing and Potential New Financing Resources and Relevant Vehicles to Support the Development, Deployment, Diffusion and Transfer of Environmentally Sound Technologies*, Interim report by the Chair of the Expert Group on Technology Transfer, FCCC/SB/2008/INF.7, November (Poznan, 2008).
7. UNFCCC, *Investment and Financial Flows to Address Climate Change: An update*, FCCC/TP/2008/7, November (Poznan, 2008).

8. UNFCCC, Syntheis report on submissions from Parties on the review of the financial mechanisms: Note by the secretariat, FCCC/SBI/2008/INF.4, May 30 (2008).
9. World Bank, *Agricultural Development Under a Changing Climate: Opportunities and Challenges for Adaptation* (World Bank Publication, 2009).
10. World Bank, *The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates*, The global report of the economics of adaptation to climate change study (2009).

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Monitoring Progress of Adaptation to Climate Change: The Use of Adaptation Metrics

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Adaptation to climate change is critical to minimize the impacts of changing climate. However, owing to the lack of appropriate metrics for adaptatation, the progress in adaption has been rather slow compared with the mitigation actions that have clear metrics for greenhouse gas emissions. To develop adaptation metrics, it is critical to consider the fact that adaptation happens at regional, national, and local scales so that the metrics has to be applicable to these levels. In addition, adaptation actions are also often seamlessly integrated with various other developmental actions that make it difficult to identify their impact. Once standardized metrics are established, it has potentials to be utilized to evaluate adaptation projects or to prioritize policies and measures technologies.

Keywords: Adaptation metrics, Determinants of adaptative capacity, Prioritizing adaptation actions.

1. Introduction

At the global negotiation under the United Nations Framework Convention on Climate Change (UNFCCC), mitigation and adaptation have been identified as equally important measures to deal with climate change. However, the progress on adaptation is much slower than mitigation, partly owing to the lack of the appropriate metrics. For mitigation, a major advance was made with clear targets for the Kyoto Protocol in 1997, which was possible because there was a clear metric of the actions, "the greenhouse gas (GHG) emissions." In addition to the lack of the metrics, adaptation is more complicated than mitigation for the following reasons. First, it is locally oriented so that necessary local actions can substantially vary, which makes difficult to generate standard actions. Second, it is the complex interaction of biophysical and socioeconomic elements, which necessitates for adaptation to be made at a system level. This creates a condition that an adaptation option can have different impacts and outcomes at different times and geographic scales.

This paper makes a case on the need for adaptation metrics through elaborating on aspects such as criteria for selecting adaptation metrics, and the types of metrics available thus far, particularly relevant for the agriculture sector are discussed. The main purpose is to highlight the challenges involved in developing an adaptation metrics.

2. Need for adaptation metrics

The need for metrics for adaptation has been emphasized in the global negotiation under the UNFCCC process. The Bali Action Plan, which was agreed at the Conference of the Parties 13 (COP13) in Bali in 2007 states "Enhanced action on adaptation with consideration of ... prioritization of actions... and support adaptation in a coherent and integrated manner," and "Positive incentives for developing countries for enhanced mitigation and adaptation actions".[12] To make these provisions in the Plan feasible, it is critical for adaptation actions to be measureable, reportable, and verifiable with appropriate "metrics." Once the metrics are established, it becomes feasible to prioritize and incentivize appropriate adaptation actions, and also the metrics allow for clear targets to be set with a certain time frame and steps. Finally, the standardized measurement system (adaptation metrics) can help set a base line of adaptation to compare the progress and effectiveness.

Determinants of adaptive capacity (e.g., economic resources, technology, information etc., Figure 1) are variable at a local scale as well as at national scale.[14] Hence, metrics have to be flexible enough to be applicable to various conditions

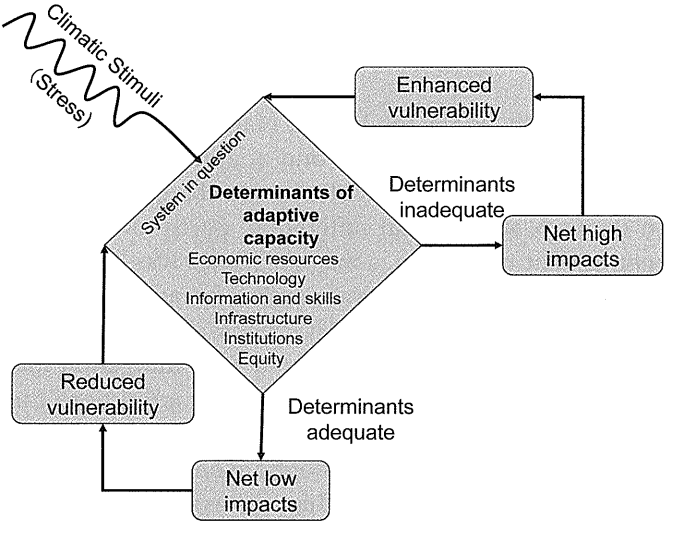

Figure 1 The determinants of adaptation and their link with the system vulnerability.[6]

and location-related aspects. In addition, the adaptation metrics need to be able to measure adaption at any given scale and sectors so that it can provide a means to compare the level of adaptation reached in different locations, regions, societies, and nations. The establishment of the adaptation metrics can help decision-makers to identify and prioritize appropriate adaption actions, to fund these actions, and minimize the risk of maladaption.

3. Criteria to Select Appropriate Adaptation Metrics

There are a few criteria for adaptation metrics to be effective. The metrics have to be measurable and cost effective. As adaptation can vary with time and space, adaptation metrics have to be scalable spatially and temporally.[6] And, it should be comparable in a wide range of opportunities. Reflecting the context-specific nature of adaptation, the adaptation metrics should be specific to the system being measured, and they have it has to be sensitive to the degree of change in adaptatation. Table 1 lists several methodologies for choosing adaptation metrics in the agriculture sector. As adaptation metrics are a relatively new concept, it is necessary to develop new methodologies that are simple and be able to be used at the operational level.

4. Types of Adaptation Metrics

Many options can be considered for effective adaptation metrics. It can be qualitative and quantitative depending on costs and time resources. In some cases, it has to be indirect metrics using proxies when direct measures are not possible.[4] The metrics can be utilized to prioritize adaptation policy and measure options before adaptation actions are taken, or the metrics can be applied to evaluate the effectiveness of the implemented adaption actions. Although various adaptation

Table 1 Methods for choosing adaptation metrics in agriculture.

Methodology	Geographical scope	Sources
Benefit–cost analysis	L, N, R[a]	Tubiello and Rosenzweing[11]
Cost–effectiveness analysis	L, N, R	Rosenqweig and Tubiello[7]
Multi–criteria analysis	L, N, R	Dolan *et al.*[3]
Expert consultation (workshops)	L, N, R	Rosenzweig and Tubiello[8]
Dynamic crop models	L, N, R	Tubiello and Rosenzweig[11]
Modeling relationship between stressor and outcome variables	L	Luers *et al.*[5]
GIS-based index based on normalization and aggregation of determinants	Subnational	Swanson *et al.*[9]
Historical trend analysis and constructing conceptual models	Subnational	Allison and Hobbs[1]

[a] L, N, and R represent local, national, and regional levels, respectively.

metrics have been proposed as listed in Table 2, some difficulties to form appropriate adaptation metrics have been noticed. First, many of those metrics are single metric because policy-makers usually prefer single composite index representing the entire sector with a single number. However, that approach often fails to provide an overall picture of adaption in agriculture sector. Secondly, although composite indices (e.g., Gross Domestic Product and Human Development Index) have been suggested as possible metrics for adaptation metrics, the composite indices can grossly average out and even nullify the impacts at the sectoral and subnational level. In addition, the use of the composite indices as adaptation metrics is criticized as either primitive or too unattainable as in the case of HDI. Therefore, some researchers have tried to come up with new composite indices for adaptation metrics such as "Index of usefulness of practices for adaptation to climate change (IUPA)" developed by Claudio Szlafsztein, Federal University of Para, Brazil.[10] The index is calculated by integrating both qualitative and quantitative parameters into a single number. However, it is found to be rather difficult to choose appropriate weighting coefficients for individual parameters.

Table 2 Adaptation metrics from existing studies.

Metric/s	Description on availability and limitation	**Sources**
Mean and variability of yield and production, income, aggregate of value added	Measured and computed metrics. Available at local, national, regional, and international levels in many countries. The aggregate of value added may need to be computed at the local level as such statistics will not be readily available.	Tubiello and Rosenzweig[11]
Nutrition index	Computed metric (sum of local production and net imports divided by total food demand). Can be computed at national regional level.	Tubiello and Rosenzweig[11]
Yield estimates (remotely sensed), yield variability, highest relative yield/yield percentile	Estimates could help in filling the gaps in the existing yield data, validating the measured yield data, etc. Accuracy could be an issue when resolution of remote sensing is low.	Luers *et al.*[5]
Agricultural export, farm income, out-migration from farming, emergency payments	Agricultural exports and outmigration of farming are mostly applicable at the macro-economic level, while data on rest of the metrics could be sparingly available.	Venema[13]
Sources of income, livestock number, source of fertilizer	It was not clear on how many sources of income is considered as optimal, and also the number of cattle. However, it is suggested that the higher the sources of income, with more diversification into nonfarm sources, the higher the adaptive capacity.	Brooks and Adger[2]

5. Discussion and Conclusions

First, it has been found that adaptive capacity of people and policies is an important element for identifying metrics.[4] Second, the linkages between causes, effects, and responses are critical for the stress on community-based adaptatation. In these cases, metrics need to be based on qualitative indicators. Third, the challenges to initiate adaptation actions are often related to the long–term nature of climate change, difficulties to find cause-effect relations, lack of attribution of climate change on the impacts of social change, lack of baseline data, and inadequate understanding of the complex social problems. Fourth, it is found that reliability, cost effectiveness, measurability, comparability, and local applicability are important criteria for adaptation metrics. Fifth, societies especially in developing countries are exposed to climate change and globalization, which has increased vulnerabilities of the societies. Sixth, adaptive capacity indicators should include biophysical, socioeconomic, and technological aspects. Seventh, the metrics need to be applicable at various scales to reflect impacts on various sectors. Finally, the metrics need to be simple enough for making it possible for regular monitoring.

Some consensuses are possible on adaptation metrics. First, it is found that metrics are essential for prioritizing adaptatation. Second, to establish adaptation metrics, purpose (such as screening of adaptation projects in multilateral development banks) and context (such as to set global adaptation targets) should be as clear as possible. Third, adaptation metrics have to be scalable, transferable, independent, comparable, and cost-effective, and it has to be flexible enough to accommodate changes as experiences accumulate. Fourth, adaptation metrics may need to have two different sets to be used before and after adaptation interventions. Fifth, it is critical to have involvements of policy-makers and local communities in deciding metrics. Sixth, adaptive learning and management must be reflected while developing adaptation metrics as the process of developing indicators itself is important for communities to learn adaptation. Seventh, it will be necessary to consider linkages between mitigation and adaptation when developing adaptation metrics as some of the mitigation measures (such as carbon offsets and supports on land use change) have relevance to adaption. Eighth, it is still debated how emphasis on "quantitative versus qualitative metrics" or "direct versus proxy indicators" should be placed. Ninth, methods for evaluation of the metrics need to be established. Tenth, over-reliance on adaptation metrics should be avoided as it may end up with managing metrics than managing adaptatation. Eleventh, it needs to be clarified how important the metrics is for decision-making, as compared with other information such as climate risks at local level and long-term climate information.

6. Future Work

We plan to establish a theoretical framework that governs adaptation metrics, which is based on the current understanding of the risk management principles. Then, a set of metrics (or a single adaptation index) that can capture the multiple dimensions of adaptation will be identified by investigating ongoing adaptation projects. Identified adaptation metrics will be prioritized using multicriteria approaches. The metrics will be then validated and refined further to enhance its applicability different conditions.

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References

1. H. E. Allison and R. J. Hobbs, Resilience, adaptive capacity and the lock-in trap of the Western Australian agricultural region, *Ecology and Society* **9**(1): 3 (2004) [online] http://ecologyandsociety.org/vol9/iss1/art3/ (Accessed 26 June 2008).
2. N. Brooks, and N. Adger, Assessing and enhancing adaptive capacity, in *Adaptive Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, eds. B. Lim and E. Spanger-Siegfried (United Nations Development Program and Cambridge University Press, Cambridge, 2005), pp. 165–181.
3. A. H. Dolan, B. Smit, W. M. Skinner, B. Bradshaw, and C. R. Bryant, *Adaptation to Climate Change in Agriculture: Evaluation of Options*, Occasional Paper No. 26 (Department of Geography, University of Guelph, Canada, 2001).
4. A. Srinivasan, and S. V. R. K. Prabhakar, *Measures of Adaptation to Climatic Change and Variability (Adaptation Metrics)* (The World Bank and Institute for Global Environmental Strategies, Hayama, Japan, 2009).
5. A. L. Luers, D. B. Lobell, L. S. Sklar, C. L. Addams, and P. A. Matson, A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico, *Global Environmental Change* **13**: 255–267 (2003).
6. S. V. R. K. Prabhakar and A. Srinivasan, Metrics for mainstreaming adaptation in agriculture sector, in *Climate Change and Food Security in South Asia*, eds. R. Lal, M. V. K. Sivakumar, S. M. A. Faiz, A. H. M. Rahman, and K. R. Islam (Springer, Netherlands, 2011), pp. 551–568.
7. C. Rosenzweig and F. N. Tubiello, Developing climate change impacts and adaptation metrics for agriculture, Presented at the *Global Forum on Sustainable Development on the Economic Benefits of Climate Change Policies*, 6–7 July 2006, Paris, France.
8. C. Rosenzweig and F. Tubiello, *Metrics for Assessing the Economic Benefits of Climate Change Policies in Agriculture*, 20 December 2007 (Working Party on Global and Structural Policies, Organization for Economic Cooperation and Development, Paris, France, 2007).

9. D. Swanson, J. Hiley and H. D. Venema, Indicators of adaptive capacity to climate change for agriculture in the prairie region of agriculture: An analysis based on Statistics Canada's Census of Agriculture, IISD Draft Working Paper for Adaptation as Resilience Building, April 2007 (International Institute for Sustainable Development, Canada, 2007).
10. C. Szlafsztein, Adaptation to climate change and vulnerability metrics: The Index of Usefulness of Practices for Adaptation (IUPA), Presented at the *Expert Consultation on Adaptation Metrics*, 17–18 April 2008 (Institute for Global Environmental Strategies, Toshi Center Hotel, Tokyo, Japan, 2008).
11. F. N. Tubiello and C. Rosenzweig, Agricultural impact metrics to assess the benefits of climate policies, *Journal of Integrated Assessment* **8**(1): 165–184 (2008).
12. UNFCCC, *Bali Action Plan*, Report of the Conference of the Parties on its thirteenth session, 3–15 December 2007 (United Nations Framework Convention on Climate Change, Bonn Germany, 2007).
13. H. D. Venema, The Canadian prairies: Biophysical and socioeconomic context, in *Designing Policies in a World of Uncertainty, Change, and Surprise: Adaptive Policy Making for Agriculture and Water Resources in the Face of Climate Change* (TERI, New Delhi and IISD, Canada, 2006).
14. G. Yohe and S. J. Tol, Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity, *Global Environmental Change* **12**: 25–40 (2002).

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Mainstreaming Adaptation to Climate Change in Agriculture and Water Sectors in India: Current Status, Issues and Barriers

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This paper presents available evidence for climate change impacts in India and discusses issues and barriers that make mainstreaming adaptation difficult in agriculture and water sectors in India. Evidence suggests a wide range of climate change impacts in Indian agriculture and water sectors. Most important ones being severe reduction in crop production due to a combination of factors such as warming, incidence of pests and diseases, changes in rainfall patterns, and reduction in freshwater sources for irrigation. Information that is useful for initiating action by various stakeholders involved in agriculture and water sectors is very poor. Lack of vulnerability assessment tools, awareness at the extension level, focused research, financial and human resources, political and institutional rigidity, inaccessible data, and absence of proper knowledge management systems are some of the key barriers. Overcoming these barriers requires a set of policies, institutional reforms and investments in capacity building, and deploying tools for vulnerability and risk assessments and for monitoring and evaluating adaptation interventions.

Keywords: Agriculture, Water, National action plan on climate change, Mainstreaming, No-regret adaptation.

1. Introduction

There is a compelling evidence of climate change and its impacts.[11] The potential impacts of climate change are very broad including widespread droughts, floods, change in the behavior of tropical cyclones, spread of insect pests, and sea level rise. Given the projected extent of climate change impacts, governments, institutions, and individuals need to prepare mechanisms that will help the society to adapt. There have already been several initiatives to mitigate climate change through reducing greenhouse gas (GHG) emissions. However, the GHG mitigation alone will not suffice and there is a need to complement adaptation measures which address the vulnerability to current and future climatic changes and associated impacts.

Developing countries like India are considered particularly vulnerable to climatic changes due to their dependency on climate-sensitive sectors, such as agriculture, fisheries, forestry, water and other natural resources and limited capacities to anticipate and respond to climatic changes.[27] Most of the Indian rural population live in harsh climate regions of mountains, desert, and river delta, which make them more susceptible to changing climate.

The Ministry of Environment and Forests, Government of India, in its initial national communication to the UN Framework Convention on Climate Change stated that the livelihoods of the majority of the Indian population are threatened due to the impacts of climate change.[20] Adverse impacts on water availability due to changes in glaciers, rainfall patterns, and flooding may threaten food security, degrade ecosystems, and impacts on the coastal system due to sea level rise were projected.[19] Because of the above-stated reasons, adaptation becomes paramount for India. However, the progress in mainstreaming adaptation in some of the vulnerable sectors in India is still negligible making a case for objective evaluation of reasons behind the limited progress in mainstreaming climate change adaptation. Keeping this in view, this paper reviews climate change impacts in India and identifies issues and barriers for mainstreaming adaptation in agriculture and water sectors in India.

2. Climate Change Trends and Impacts in Agriculture and Water Sectors

2.1. *Climate change trends in India*

Preliminary assessments of the historical climatic records available in the literature reveal that the mean annual surface air temperature has risen by an average of 0.4°C in the last 50 years (1948–1998).[28] However, temperature change has not been uniform across the country with warming observed along the west coast, central, interior peninsula, and over Northeast India, and cooling patterns were observed in North West and some parts of southern India.[6] No clear trend in monsoon rainfall was observed during the past 100 years. However, some regional patterns and random variations were observed including increase in the intensity of rainfall and reduction in number of rainy days.[6] The intensity of rainfall has gone up and the number of rainy days has come down in certain areas.

The climate projections available from HADCM2 model for India indicated different trends for different parts of India. An increase in annual temperature in the range of 2°C and increase in rainfall to the tune of 30% in the northeast region were projected for the duration of 2041–2060.[20] Projected trends for the rest of the country were severe with warming to an extent of 3°C and decrease in precipitation to the magnitude of 30% when compared to the long-term historical averages. A raise in sea level (40–80 mm) was predicted in the next 3 decades which

would have a profound impact on human lives, economic assets, and a variety of coastal livelihood systems spread over a vast stretch of 7500 km of India's coastline.

In addition to the above observed trends, India is already very vulnerable to gradual aridification process. According to the estimates available, about 32.7% of the total land area is affected by aridification and related land degradation processes.[12] With climate change, the process of land degradation could further be accelerated leading to widespread impact on local livelihoods and environment.

2.2. *Impacts on agriculture and water sectors*

Much of Indian agriculture has been historically dependent on the rainfall as a source of water and hence has been severely impacted by any changes in the rainfall patterns in the past.[15] The impacts of vagaries of rainfall and other weather patterns on the crop production have been significant (with significant negative impacts in some northern states such as Uttar Pradesh, Haryana, and Punjab) and hence are termed as highly climate-sensitive. Such high climate sensitivity is detrimental to the development of the country in general and for the agrarian sector in particular. Similar sensitivity could be observed from the available data on food grains and pertinent rainfall patterns too.

Potential impacts of climate change on agricultural production will depend on two factors: the degree of climate change and the intrinsic capacity of the agriculture system to overcome those impacts, including ability to adapt.[7] In the Indian context, few research analyses have shown the correlation between raise in temperature and yield reduction. An estimated yield reduction of 0.71 ton/hectare with one degree increase in the minimum temperature was reported.[23] Slightly deviating from the above study,[25] (as cited by Kumar[17]) reported that a 2°C increase in mean air temperature could decrease rice yield by about 0.75 ton/hectare in the high-yield areas and by about 0.06 ton/hectare in the low-yield coastal regions. The studies also revealed a substantial yield reduction of wheat due to global warming[25] (as cited by Kumar[17]). According to Kumar and Parikh,[14] a temperature rise of 2°C to 3.5°C would result in 9% to 25% loss in farm-level net revenue after accounting for farm-level adaptation. They confirmed that even with adaptation of cropping patterns by farmers, the losses would remain significant. Recent IPCC report[11] and Parry *et al.*[22] indicated a probability of 10%–40% loss in crop production in India with increases in temperature by 2080–2100 (as cited by Boomiraj *et al.*[4]).

Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance.[26] A preliminary estimate indicates that global warming is likely to lead to a loss of 1.6 million tons in milk production in India by 2020 (Upadhyay, National Dairy Research Institute, 2008; personal communication by Aggarwal[2]). Increasing sea and river water temperature is likely to affect fish breeding, migration, and harvests.[3] A rise in temperature as small as 1°C could have important and rapid effects on the mortality of fish and their geographical distributions.[30]

India has 20% of the world population yet dependent on less than 4% of the world water resources. Water resources are already scarce in many parts of India and the future water availability in India is highly vulnerable to climate change. Literature suggests that there will be significant changes in water runoff systems. For example, Sharma and Bharat[24] suggest that under a changed climatic regime for any given region the combined water effect of lower rainfall and more evaporation would have dire consequences. According to these authors, these would lead to runoff and substantially change the availability of freshwater in the watersheds.

The vulnerability of water in a given region could be understood in terms of land use and management (as storage of water depends on land morphology, cover, and soil), state of groundwater (changes in watertable in terms of overdraft and recharge), stream flow (precipitation and potential evaporation) and seasonal and yearly variation in regional supplies of water to streams and soils, and the frequency of extreme events like droughts and floods.

Apart from the decreasing quantity of water, water quality is fast emerging as a major concern in both urban and rural areas of India. Some of the rapidly declining water sources, including deep aquifers, face the risk of increasing concentration of existing minerals like arsenic, fluoride, etc., having profound implications for western regions of India. In addition, growing incidence of floods across the country amplifies the risk of biological contamination of water sources. Thus, in India where large population is dependent on single source of water, water quality deterioration further exacerbates the problem of water security. It is against this backdrop of climate change that guaranteeing water availability for food security in India is critical. Therefore, there is a strong need to accelerate research activities and knowledge dissemination on the impact of and vulnerability to climate change.

3. Issues and Barriers to Mainstreaming Adaptation

There are already several developmental initiatives taken up at state and national level in both project and program modes. These are largely relating to development objectives paying little deliberate attention to adaptation as a viable option though few adaptation-only initiatives could be found in project mode in several parts of the country. As an overarching initiative to promote climate actions at the national level, the Indian government unveiled the National Action Plan on Climate Change (NAPCC) in July 2008, which lays emphasis on the need to be proactive and recognizes "development and poverty eradication" as the best form of adaptation to climate change.[10] The NAPCC addresses climate change through eight core national missions, which include special missions on water and sustainable agriculture. The national strategy emphasizes both climate change mitigation and adaptation and synergies between the two.

3.1. *Agriculture sector*

Over the time, agricultural systems and practices have adapted to changing climatic, physical, social, and economic conditions. Consequently, adaptation in the agricultural context could be examined at different levels especially at the farm level, technological, and institutional levels. A wide variety of adaptive actions may be taken to lessen or overcome adverse effects of climate change on agriculture.[17] While some of the adaptations are natural consequences (autonomous adaptation), some are planned and deliberate. Planned adaptation strategies could include strategic selection of crops and varieties that can take advantage of changes in the growing season,[5] new market opportunities, and innovative agrotechnologies that leapfrog from the existing technologies.

Some of the well-established adaptations in agriculture would include changing varieties/crops, altering agronomic practices, avoiding water shortages through water harvesting and improving irrigation efficiency, conserving soil moisture by crop residue retention, altering the timing or location of cropping activities, diversifying income including livestock raising,[1] promoting conservation farming practices that sequester carbon for improving soil organic matter and physicochemical conditions, and promotion of risk-coping practices such as crop rotations, agroforestry, crop–livestock associations, etc.[8]

3.2. *Water sector*

In India, water management for irrigation purposes is decentralized and it is for the state governments to institute policies and programs for effective use of water at the state level. However, all the state governments and water management authorities are not at the same level of understanding the issue of climate change and in implementing proactive water management practices. One of the ways to adapt is to develop more flexible institutions in the water sector. Water-management organizations should use the best available information in their planning in order to adapt to climate change. For this, it is imperative for the water management institutions at all levels to understand the challenges associated with water security, specifically in terms of the sensitivity, vulnerability, and key response measures. An adequate regulatory mechanism to generate incentives to enhance water use efficiency is very critical in this context.

In some parts of India, water user associations were created by state level legislation (for example, watershed level water user associations were formed in many parts of the state of Andhra Pradesh, and at the canal level in the state of Maharashtra.[21] Such water user associations are yet to spread across the country to make any significant change in the way the water resources are governed. Sharma and Bharat[24] have indicated that lack of risk assessment framework for water sector in India is a major bottleneck for adaptation in the sector. Water rationing and allocation systems are also very poorly developed. Making available weather

projections and translating that information in a way useful for water users and managers is at most priority for efficient use of water resources.

3.3. *Overarching barriers*

There are several barriers that make mainstreaming adaptation difficult in India though they may not be very specific to the country. They arise from the fact that India is a very diverse country, both in terms of physical and cultural endowments, having different agroclimatic zones, and partially due to the complex organizational and hierarchical systems that render institutions slow to respond to changing circumstances and external pressures. Agriculture and water are two critical sectors for the Indian economy. As a result, these sectors have been part and parcel of national developmental agenda for the past several decades because of which the country has witnessed considerable investments and interventions in these sectors. However, these investments continue to decline over the years due to several reasons among which noteworthy to mention in the context of adaptation is poor composition of public expenditure and inadequate allocations to agriculture and irrigation development.[29]

Lack of information, vulnerability assessment tools, awareness at the extension level, focused research, resources, political and institutional rigidity, inadequate capacities, inaccessible data, and absence of proper knowledge management systems are some of the key barriers. One of the main challenges in the climate change context is the uncertainty. Use of macromodels with long timeframes has an element of uncertainty.[16] In addition, uncertainty in economic projections was found to be a main barrier in strategic planning for improving the resilience in India.[18] Also, there are different levels of certainty (projections, risk extremes, major events) which do not help in effective planning. Research information on managing climate variability is very poor.

4. Conclusion

In this paper, an effort was made to review the climate change trends, impacts, adaptation interventions, and existing barriers. A range of climate change impacts is reported in the literature. However, the existing uncertainty in this impact literature makes it far from being useful for initiating interventions at the local level. Nevertheless broad evidence does support initiating overarching programs and policies with reasonable success on a regional basis in the country. This also necessitates the need to search for no-regret adaptation options that could be applicable in a range of climate change projection and impact scenarios available. Investments, both public and private, in agriculture and water sectors are to be boosted with proper allocation depending on the socioeconomic status of the administrative units in the country. Prioritization of these investments should

consider the use of adaptation metrics in areas such as identification and dissemination of best practices across the states and overcoming distortive farm policies including water management and river management regulations. Dissemination of customized weather and climatic information to related stakeholders, especially to farmer and water user groups, along with capacity building to enable proper understanding and use of this information is needed. Risk-resilient farming practices identified in this paper in combination with weather-linked crop insurance programs need to be promoted. In addition, it is important to ensure that the provisions of the NAPCC are utilized to assist in the integration of adaptation into existing policies. NAPCC should address issues such as institutional reforms providing local level players needing flexibility to strategize and act on issues such as climate change.

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References

1. P. K. Aggarwal, Climate change and Indian agriculture: Current focus and future priorities, in *Proceedings of the International Workshop on Vulnerability and Adaptation to Climate Change: From Practice to Policy*, 11–12 May 2006 (Winrock International India, India, 2006).
2. P. K. Aggarwal, Global climate change and India agriculture: Impacts, adaptation and mitigation, *Indian Journal of Agricultural Sciences* **78**(10): 911–919 (2008).
3. P. K. Aggarwal, *Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project* (Indian Council of Agricultural Research, New Delhi, India, 2009).
4. K. Boomiraj, B. Chakrabarti, P. K. Aggarwal, R. Choudhary, and S. Chander, Impact of climate change on Indian Mustard (*Brassica juncea*) in contrasting agro-environments of the tropics, in *ISPRS Ahmadabad Workshop on Impacts of Climate Change on Agriculture*, eds. S. Panigrahy, S. S. Ray, and J. S. Parihar (ISPRS, Ahmadabad, India, 2009).
5. Brunswick, *New Brunswick and Climate Change*, Discussion Paper (Brunswick, Canada, 2003), p. 48.
6. Department of Science and Technology, *Climate Change Monitored by IMD*, Response of the Minister for Science and Technology and Earth Sciences to the Rajya Sabha, 5 March 2008 (Press Information Bureau, 2008).
7. FAO, *Climate Variability and Change: A Challenge for Sustainable Agricultural Production*, Report of the Committee on Agriculture, Sixteenth Session, 26–30 March 2001 (FAO, Rome, 2001).

8. FAO, *Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework, and Priorities* (Food and Agriculture Organization of the United Nations, Rome, 2007).
9. G. Fischer, M. Shah, and H. V. Velthuizen, *Climate Change and Agricultural Vulnerability,* World Summit on Sustainable Development, Johannesburg (International Institute for Applied Systems Analysis, Laxenburg, Austria, 2002).
10. Government of India, *National Action Plan on Climate Change* (Prime Minister's Office, Government of India, New Delhi, India, 2008).
11. IPCC, *Climate Change 2007: Synthesis Report,* Working Group Contributions to the Fourth Assessment Report (Intergovernmental Panel on Climate Change, Genera, Switzerland, 2007).
12. A. Kar, B. K. Garg, M. P. Singh, and S. Kathju, *Trends in Arid Zone Research in India* (Central Arid Zone Research Institute, Jodhpur, India, 2009).
13. A. Kulkarni, R. H. Kripalani, and S. S. Sabade, *Examining Indian Monsoon Variability in Coupled Climate Model Simulations and Projections* (Indian Institute of Tropical Meteorology, India, 2010).
14. K. Kumar and J. Parikh, Climate change impacts on Indian agriculture: The Ricardian approach, in *Measuring the Impact of Climate Change on Indian Agriculture,* eds. A. Dinar, R. Mendelsohn, Everson, J. Parika, A. Sanghi, K. Kumar, J. Mckinsey, and S. Lonergan (The World Bank, Washington, DC, 1998).
15. K. S. Kumar and J. Parikh, Indian agriculture and climate sensitivity, *Global Environmental Change* **11**(2): 147–154 (2001).
16. R. K. Kumar, A. K. Sahai, K. K. Kumar, S. K. Patwardhan, P. K. Mishra, J. V. Revadekar, K. Kamala, and G. B. Pant, High-resolution climate change scenarios for India for the 21st century, *Current Science* **90**(3): 334–345 (2006).
17. S. M. Kumar, Socio-economics of climate change: Impact on agriculture land use changes in India, PhD Dissertation (Szent István University, Gödöllõ, 2010).
18. E. L. Malone and A. L. Brenkert, Uncertainty in resilience to climate change in India and Indian states, *Climatic Change* **91**: 451–476 (2008).
19. H. P. I. K. Meister, R. Martina, R. Wilson, and L. Chad, *Floating Houses and Mosquito Nets: Emerging Climate Change Adaptation Strategies Around the World* (Meister Consultants Group, Boston, 2009), pp. 71–73.
20. Ministry of Environment and Forests, *India's Initial National Communication to the United Nations Framework Convention on Climate Change* (Ministry of Environment and Forests, Government of India, New Delhi, India, 2004).
21. G. Naik and A. H. Kalro, Two case studies on the role of water users' associations in irrigation management in Maharashtra, India, *Sustainable Rural Development Information System: An Online Library of Internet Resources* (CESIN and The World Bank, 1998).
22. M. L. Parry, C. Rosenzweig, A. M. L. Iglesias, and G. Fischer, Effects of climate change on global food production under SRES emission and socioeconomic scenarios, *Global Environmental Change* **14**: 53–67 (2004).
23. U. Patnaik and K. Narayanan, Vulnerability and climate change: An analysis of the eastern coastal districts of India, in *An International Workshop on Human Security and Climate Change,* 21–23 June 2005, Asker, Oslo (Global Environmental Change and Human Security Program, Oslo, 2005).
24. D. Sharma and A. Bharat, Conceptualizing risk assessment framework for impacts of climate change on water resources, *Current Science* **96**(8): 1044–1052 (2009).
25. S. K. Sinha and M. S. Swaminathan, Deforestation, climate change and sustainable nutrition security: A case study of India, *Climatic Change* **19**: 201–209 (1991).

26. S. Sirohi and A. Michaelowa, Sufferer and cause: Indian livestock and climate change, *Climatic Change* **85**(3–4): 285–298 (2007).
27. The Energy and Resources Institute, *India's First National Communication to UNFCCC* (The Energy Resources Institute, New Delhi, India, 2001).
28. The World Bank, *Climate Change Impacts in Drought and Flood Affected Areas: Case Studies in India* New Delhi, India: South Asia Region India Country Management Unit, Sustainable Development Department, Social, Environment and Water Resources Management Unit (The World Bank, 2008).
29. The World Bank, *India: Priorities for Agriculture and Rural Development* (The World Bank, Washington D.C., 2011), Web. 13 January 2011. http://go.worldbank.org/8EFXZBL3Y0.
30. E. Vivekanandan, N. G. K. Pillai, and M. Rajagopalan, Adaptation of the oil sardine (*Sardinella longiceps*) to sea water warming along the Indian coast, *Glimpse of Indian Biodiversity*, Rajiv Gandhi Chair Special Publication **7**: 111–119 (2008).

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Adaptive Capacity to Climate Change: Concept and Approaches for the Water Sector in Malaysia

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Building adaptive capacity against climate change is one of the central targets in adaptation responses. The ability to cope with the change in climate can be enhanced for the projected future climate change (end-point approach) or improved in the present systems to respond to stressors (starting-point approach). This paper reviews the understanding of and approach for assessing adaptive capacity in adaptation policy and the water sector in Malaysia. The findings of two national studies, which were carried out in the 1990s to address the potential impacts of climate change, were examined on the approaches of the adaptation measures for the water sector. There was limited consideration on the capacity of the sector, both its current and future ability, to cope with future climate change as the proposed adaptation responses may not have been driven directly toward enhancing adaptive capacity to climate change. They would, however, if implemented, improve the ability to either moderate the potential damages or cope with the probable consequences of the projected change in future climate. The paper concludes with several critical factors that should be addressed in future research on adaptive capacity of the water sector in Malaysia.

1. Introduction

Climate change exaggerates stresses on natural and human social systems, prompting response for necessary adjustment. The changes in climate cannot be totally avoided, and is likely to be continuous for many decades and could be more rapid and pronounced than expected.[6] Countries, irrespective of their material standards of living and social and economic development, are potentially vulnerable to climate change biophysically and socioeconomically.[27] This paper reviews the conceptual basis and approaches of adaptation in the water sector in Malaysia. The findings of two national studies carried out in the 1990s were examined on their adaptation approaches in order to identify needs for future research that can enhance adaptive capacity in the water sector.

2. Vulnerability and Adaptive Capacity in Climate Change Adaptation

The global surface temperatures have increased by 0.76°C ± 0.19°C over the last 150 years and 11 of the 12 years from 1995 to 2006 rank the warmest years since 1850.[16] This warming is expected to escalate in the future, as scenarios show an increase of global average temperature by 0.2°C per decade for the next two decades.[16] The warming is likely to be accompanied by changes in precipitation amounts and patterns, resulting in more and intensified occurrence of flood and drought. Adaptation measures are therefore necessary to avoid or cope with the potential adverse impacts, particularly the more vulnerable ones in a system. The extent of which a system, human, or nature, is impacted by the change in climate depends greatly on its degree of vulnerability. Vulnerability is a function of the character, magnitude, and rate of climate change and the variation to which a system is exposed, its sensitivity, and its adaptive capacity.[29] With the increasing focus on adaptation in climate change policy,[31] there are more research in dissecting the role of adaptive capacity in formulating adaptation strategies.[37] Building adaptive capacity in the implementation of adaptation is particularly important to developing countries.[17]

3. Definition and Evolution of the Understanding of Adaptive Capacity

As a critical factor in determining the impacts of climate change, adaptive capacity is the potential or ability of a system in moderating the potential damages, taking advantage of the prospective opportunities or coping with the probable consequences.[15,18,33,37] This definition mainly aims to address the end-point vulnerability, where adaptations are designed or carried out in the face of future climate change and the vulnerability in biophysical factors.[8,22,27] This is also consistent with the characteristics of the first generation adaptation research as reviewed by Burton *et al.*[10] However, considering adaptive capacity as an end point is fraught with uncertainties.[2,27,37] Such uncertainties may originate from external factors, including climate scenarios, climatic effects on sectors, and future socioeconomic conditions, or internal drivers of whether the adaptive capacity assets will be drawn upon in time of need as per the projections.[27,37,40] As climate change may alter in a different way than expected over time, the predefined adaptation measures, technological ones in particular, may become inappropriate. Furthermore, with the social and economic factors, in addition to the biophysical factors, being increasingly included in the adaptation assessment,[35,36] enhancing the adaptive capacity of the present systems' ability to deal with and respond to stressors as well as to secure livelihood is gaining greater attention.[10,27] Such approach, sometimes known to as starting-point approach, assesses the way the

conditions or risks due to current and past exposures and sensitivities are dealt with, including the factors and processes that facilitate or constrain the choices.[34] Besides being a practical means of coping with changes and uncertainties in climate,[33] this approach also promotes sustainable development[13,25,32,41–43] and facilitates cheaper adaptation strategies that target the poor and vulnerable groups more effectively than many larger scale, technological or infrastructural adaptation measures.[28]

3.1. *Assessment of adaptive capacity*

The capacity to adapt varies from the level of country down to individual.[9,36,37] Globally some assessments of country-level adaptive capacity have been undertaken with the view to assisting international decision-making around investments in adaptations under the United Nations Framework Convention on Climate Change (UNFCCC) mechanisms.[9,14,24] At the national level, assessing the adaptive capacity of different systems and groups allows greater comprehension of their vulnerability, including the processes that trigger and aggravate it, so that decision-making is grounded on knowledge and information in such a way that the available resources are mobilised to target the most vulnerable areas and groups of people effectively. Adaptive capacity is influenced by a number of factors, including economic wealth; technology; access to resources; institutional capacities and decision-making processes; human and social capitals; accessibility to risk-spreading processes; the public's perceived attribution of the source of stress; and others.[9,14,27,30,39]

3.2. *Adaptive capacity in water sector*

The management of water resources is influenced by hydrological cycle and water use. As one of the many pressures on freshwater systems, anthropogenic climate change affects freshwater quantity and quality (e.g., water availability as well as floods and droughts) as well as impacts the use of water. Significant changes in water use or the hydrological cycle (affecting water supply and floods) require adaptation in the management of water resources.[20] If not properly addressed, the implications of climate change on water, including drought-related stresses, flood events, water quality problems, and growing water demands, could impact across many sectors of the economy, society, and the environment.[5]

Adaptation options in the water sector include supply-side management through increase of capacity (e.g., building reservoirs or structural flood defenses), changing in operating rules for existing structures and systems; and demand-side management by managing demand and changing institutional practices.[5] While changes to meet altered conditions and new ways of managing water are autonomous adaptations which are not deliberately designed to adjust with climate change, there are also planned adaptations that take climate change specifi-

cally into account to evaluate risks and response options.[20] Arnell *et al.*[5] reviewed a range of institutional, technological, regulatory, cultural, financial, and governance factors affecting the adaptive capacity of water sector to climate change.

4. Climate Change Impact and Adaptation Assessment in Malaysia's Water Sector

Several studies had been undertaken in Malaysia in the last two decades with the main focus on potential impacts of climate change and adaptation strategies. Despite the uncertainties of the timing and magnitude of climate change impacts, these studies were either driven by the belief that developing country like Malaysia would be hit greater by the change in climate or in response to the commitment under the UNFCCC. Two such national studies were carried out in the 1990s to address the potential climate change impacts on several key resource and economic sectors, including water. The studies are Climate Change in Asia: Malaysia Country Report in 1994[44] and Malaysia Initial National Communication (INC) that was submitted to the UNFCCC in 2000.[23] Both were undertaken through multilateral funding supports. The former one was initiated in 1992 while the latter was carried out in the second half of the 1990s. They were the earliest national level assessments that took place during the decade, with the main focus on the impacts of and adaptation to climate change, and covered more than one particular sector.

The Malaysia Country Report study projected a 9% increase in flood peaks that would lead to widespread flooding caused by a larger overbank spill and have severe implications on design criteria and costs for future flood mitigation structures as well as raise the need to reassess the safety of existing structures. The present 30-year return period flood would have the same impact as a 50-year return period in future. Floods would increase in occurrence and inundate larger areas. On the contrary, a 30%–35% increase in water deficit during dry season would exacerbate the present shortage of water for irrigation, leading to reduction in cultivable area and water supply would become more costly. Water intake point just upstream from tidal influence will be increasingly threatened by sea level rise and decreased discharge from rivers. Unlike the aquifers in west coast of Peninsular Malaysia that are naturally protected by impermeable clay layer, the rise in sea level may cause intrusion of saline water into aquifers adjacent to the shore along the east coast. The study recommended watershed management to address the imbalance spatial distribution of future rainfalls in order to maximize the harnessing for channelling to the more needed areas. Catchment areas of rainfall at the upper courses of river basins need to be identified through surveys, not necessarily for dam building, but to maximize interception and minimize surface runoff. The flood mitigation program at the lower course of basin should pay attention to the implication of sea level rise.

The sensitivity analysis approach was adopted in the INC study to assess the impacts that climate change may potentially have on water resources due to high uncertainty in climate modeling and the lack of simulation on extreme events. The report discussed the impacts due to excessive (flooding, and erosion and sedimentation) and deficit conditions (water availability). It highlights the importance of improved information of various aspects, especially climatic conditions, for more accurate forecast of water availability. Essentially, the options for reducing climatic and nonclimatic stresses on water resources are similar. The options discussed in the report could be categorized as supply-side and demand-side managements, as summarized in Table 1.

Both studies adopted the impact assessment approach that evaluates the potential effects of projected climate change scenarios on the water sector. The climatic stimuli were developed based on the assumed $2\times CO_2$ case, before being applied on the sector for evaluating its exposure and sensitivity in the assessments of the vulnerability to potential impacts.[12] Limited (if not none at all) consideration, however, was given to the sector's adaptive capacity with regard to its current or future ability to cope with future climate change. The inadequacy in such detailed

Table 1 Adaptive measures and policy response for water sector in the INC.[23]

Suppy-side management	**Demand-side management**
• Enlarge reservoir capacity	• Use of low water-demanding technologies
• Change the operating rules of wate resources systems	• Recycling of water used
• Promote widespread use of groundwater	• Harness rainwater for secondary consumption
• Improve long- and short-range hydrologic forecasting	• Discourage excessive use of resources (water and electricity) through water pricing policy
• Institutional and regulatory approaches in watershed management	• Control of flood volume and pollution at source
– tighter enforcement of present water and land regulations	• Optimum land use planning and management to reduce water pollution and optimize demand pattern spatially and temporally
– implementation of Environmental Impact Assessment (EIA), Environment Management Plan (EMP), River Catchment Management Plan (RCMP) in major water resources and land development projects	• Address erosion and sedimentation problems in agriculture and forestry industries, and during property development
– establishment of the National Water Resources Council and river management authorities	• Education and awareness programs
– national water resource study for a comprehensive long-term plan for all aspects of water resources development	

analysis may be attributable to the projected future scenarios of climate change that remain greatly uncertain and the assessment of adaptive capacity only emerged as a critical focus of attention as observed in the IPCC Third Assessment Report.[3]

The adaptation measures proposed in the studies are mainly related to supply-side management; moreover, the INC emphasizes water resource management development programs that advocate supply management over the demand management approach. Besides the typical engineering or structural measures, there are also planning, institutional, regulatory, and behavioral responses being recommended. The measures generally target physical or natural factors, except those awareness and education, and regulatory and institutional approaches that focus more on human system. Although the suggested responses may not be driven directly toward enhancing adaptive capacity, they would, if implemented, improve the ability to either moderate the potential damages or cope with the probable consequences of the projected change in future climate.

5. Conclusions

This paper reviews the understanding of and approach for assessing adaptive capacity in adaptation policy and the water sector in Malaysia. By examining two national studies funded by multilateral agencies in the 1990s, it is found that vulnerability to the climate change was assessed as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and identification of adaptive options.[19] There was limited consideration on the capacity of the sector, both its current and future abilities, to cope with future climate change as the proposed adaptation responses may not have been driven directly towards enhancing adaptive capacity to climate change.

Pursuant to the recommendation in the INC,[23] a number of studies have been commissioned since 2006 to analyze the implications of climate change on existing and future water resource system on a basinal basis.[26] However, these studies would examine the biophysical sensitivity of the basins under the exposure to projected future climate; hence it may be inadequate to gain insight on their current adaptive capacity and whether such adaptability will transform or facilitate actual adaptation in the future.

While the confidence level of global and localized climate models are increasing progressively, there is a need to begin addressing adaptation through the enhancement of the present adaptive capacity to cope with and respond to stressors and secure livelihoods. Addressing present-day vulnerability will reduce vulnerability under future climate conditions.[10] As more adaptation initiatives will be implemented in future, it is important to ensure that adaptive capacity is drawn upon and translated into action, by identifying and removing barriers, to ensure successful adaptation.[37,45–47] Future research on adaptive capacity of the water sector in Malaysia should examine a range of carefully selected factors, which

is context-specific and could refer to those generic factors as discussed above, to ensure that coping capacity of the present day could adapt to future climatic risks.

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References

1. W. N. Adger, N. Brooks, G. Bentham, M. Agnew, and S. Eriksen, *New Indicators of Vulnerability and Adaptive Capacity* (Tyndall Centre for Climate Change Research Technical Report 7, Norwich, 2004).
2. W. N. Adger and K. Vincent, Uncertainty in adaptive capacity, *C.R. Geoscience* **337**: 399–410 (2005).
3. Q. K. Ahmad, R. A. Warrick, T. E. Downing, S. Nishioka, K. S. Parikh, C. Parmesan, S. H. Schneider, F. Toth, and G. Yohe, Methods and tools, in *Climate Change 2001: Impacts, Adaptation, and Vulnerability,* Contribution of II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, eds. J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (Cambridge University Press, Cambridge, 2001), pp. 105–143.
4. M. Alam, A. Rahman, M. Rashid, G. Rabbani, P. Bhandary, S. Bhadwal, M. Lal, and M. H. Soejachmoen, *Background Paper: Impacts, Vulnerability and Adaptation to Climate Change in Asia* (United Nations Framework Convention on Climate Change, 2007).
5. N. W. Arnell, C. Liu, R. Compagnucci, L. da Cunha, K. Hanaki, C. Howe, G. Mailu, I. Shiklomanov, and E. Stakhiv, Hydrology and water resources, in *Climate Change 2001: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, eds. J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (Cambridge University Press, Cambridge, 2001), pp. 191–234.
6. F. Berkhout, Rationales for adaptation in EU climate change policies, *Climate Policy* **5**: 377–391 (2005).
7. A. L. Brenkert and E. L. Malone, Modeling vulnerability and resilience to climate change: A case study of India and Indian states, *Climatic Change* **72**: 57–102.
8. N. Brooks, *Vulnerability, Risk and Adaptation: A Conceptual Framework,* Working Paper 38 (Tyndall Center for Climate Change Research, Norwich, UK, 2003).
9. N. Brooks, W. N. Adger, and P. M. Kelly, The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation, *Global Environmental Change* **15**: 151–163 (2005).
10. I. Burton, S. Huq, B. Lim, O. Pilifosova, and E. L. Schipper, From impacts assessment to adaptation priorities: The shaping of adaptation policy, *Climate Policy* **2**: 145–159 (2002).

11. A. L. Chong and P. Mathews (eds.), *Malaysia: National Response Strategies to Climate Change* (Ministry of Science, Technology and Environment, Kuala Lumpur, 2001).
12. H.-M. Fusel and R. J. T. Klein, Climate change vulnerability assessments: An evolution of conceptual thinking, *Climatic Change* **75**: 301–329 (2006).
13. I. M. Goklany, Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development, *Mitigation and Adaptation Strategies for Global Change* **12**: 755–786 (2007).
14. B. M. Haddad, Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit, *Global Environmental Change* **15**: 165–176 (2005).
15. Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Impacts, Adaptation and Vulnerability. Summary for Policy Makers* (World Meteorological Organisation, Geneva, 2001).
16. IPCC, Summary for policymakers, in *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007).
17. IPCC, Summary for policymakers, in *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Cambridge University Press, Cambridge, UK, 2007), pp. 7–22.
18. IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Cambridge University Press, Cambridge, UK, 2007), 976 pp.
19. P. M. Kelly and W. N. Adger, Theory and practice in assessing vulnerability to climate change and facilitating adaptation, *Climatic Change* **47**: 325–352 (2000).
20. Z. W. Kundzewicz, L. J. Mata, N. W. Arnell, P. Döll, P. Kabat, B. Jiménez, K. A. Miller, T. Oki, Z. Sen, and I. A. Shiklomanov, Freshwater resources and their management, *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Cambridge University Press, Cambridge, UK, 2007), pp. 173–210.
21. R. M. Leichenko and K. L. O'Brien, The dynamics of rural vulnerability to global change: The case of South Africa, *Mitigation and Adaptation Strategies for Global Change* **7**: 1–18 (2002).
22. D. Liverman, Vulnerability to global environmental change, in *Global Environmental Risk*, eds. J. X. Kasperson and R. E. Kasperson (Earthscan and United Nations University Press, London, 2001).
23. Ministry of Science, Technology and Environment (MOSTE), *Malaysia Initial National Communication* (2000).
24. R. H. Moss, A. L. Brenkert, and E. L. Malone, *Vulnerability to Climate change: A Quantitative Approach* (Department of Energy, US, 2000).
25. M. Munasinghe, Development, equity and sustainabillity (DES) in the context of climate change, in *Climate Change and Its Linkages with Development, Equity and Sustainability: Proceedings of the IPCC Expert Meeting*, Colombo, Srilanka, 27–29 April 1999, eds. M. Munasinghe and R. Swart (LIFE, Colombo, Sri Lanka; RIVM, Bilthoven, The Netherlands; and World Bank, Washington, DC, USA, 2000), pp. 13–66.
26. National Hydraulic Research Institute Malaysia (NAHRIM), *Study of the Impact of*

Climate Change on the Hydrologic Regime and Water Resources of Peninsular Malaysia—Final Report (NAHRIM, Malaysia, 2006).
27. K. O'Brien, S. Eriksen, A. Schjolden, and L. Nygaard, *What's in a Word? Conflicting Interpretations of Vulnerability in Climate Change Research,* CICERO Working Paper 2004: 04 (CICERO, Norway, 2004), 16 pp.
28. V. A. Orindi and S. Eriksen, *Mainstreaming Adaptation to Climate Change in the Development Process in Uganda* (Acts Press, Kenya, 2005).
29. M. L. Parry, O. F. Canziani, J. P. Palutikof, and Co-authors, Technical summary, in *Climate Change 2007: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Cambridge University Press, Cambridge, UK, 2007), pp. 23–78.
30. M. Pelling and C. High, Understanding adaptation: What can social capital offer assessments of adaptive capacity? *Global Environmental Change* **15**: 308–319 (2005).
31. E. L. Schipper, Conceptual history of adaptation in the UNFCCC process, *RECIEL* **15**: 82–92 (2006).
32. B. Smit, I. Burton, R. J. T. Klein, and J. Wandel, An anatomy of adaptation to climate change and variability, *Climatic Change* **45**: 223–251 (2000).
33. B. Smit and O. Pilifosova, Adaptation to climate change in the context of sustainable development and equity, in *Climate Change 2001: Impacts, Adaptation, and Vulnerability,* eds. McCarthy (Cambridge University Press, Cambridge, 2001).
34. B. Smit and J. Wandel, Adaptation, adaptive capacity and vulnerability, *Global Environmental Change* **16**: 282–292 (2006).
35. L. Sygna, S. Eriksen, K. O'Brien, and L. O. Naess, *Climate Change in Norway: Analysis of Economic and Social Impacts and Adaptation,* CICERO Report 2004: 12 (CICERO, Norway, 2004), 39 pp.
36. R. S. J. Tol and S. Fankhauser, On the representation of impact in integrated assessment models of climate change, *Environmental Modeling and Assessment* **3**: 63–74 (1998).
37. K. Vincent, Uncertainty in adaptive capacity and the importance of scale, *Global Environmental Change* **17**: 12–24 (2007).
38. G. W. Yohe, Mitigative capacity—the mirror image of adaptive capacity on the emissions side—An editorial, *Climatic Change* **49**: 247–262 (2001).
39. G. W. Yohe and R. S. J. Tol, Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity, *Global Environmental Change* **12**: 25–40 (2002).
40. T. D. Mitchell and M. Hulme, Predicting regional climate change: living with uncertainty *Progress in hysical Geography* **23**: 57–78 (1999).
41. I. Burton, Vulnerability and adaptive response in the context of climate and climate change. *Climatic Change* **36**: 185–196 (1997).
42. S. Cohen, D. Demeritt, J. Robinson and D. Rothman, Climate change and sustainable development: towards dialogue. *Global Environmental Change* **8**(4): 341–371 (1998).
43. Asian Development Bank (ADB), Climate change in Asia: Malaysia country report. ADB, Manila (1994).
44. N. W. Arnell and D. K. Delaney, Adapting to climate change: public water supply in England and Wales. *Climatic Change* **78**: 227–255 (2006).
45. W. N. Adger and J. Barnett, Four reasons for concern about adaptation to climate change. *Environment and Planning A* **41**: 2800–2805 (2009).
46. M.D.F. Doria, E. Boyd, E. L. Tompkins and W. N. Adger, Using expert elicitation to define successful adaptation to climate change. *Environmental Science & Policy* **12**: 810–819 (2009).

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Climate Change Adaptation Policy Guidelines for Agricultural Sector in Malaysia

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Climate Projection shows the impacts of climate change on agricultural sustainability and relevant livelihood sustainability vulnerable in Malaysia. Here mitigation is necessary but adapting to future risk is more important for immediate and long-term action relating to the larger number of stakeholders in local scale. Generally, adaptation policy has different levels and approaches that relate with different challenges. Several countries have already prepared their adaptation approaches in their own way. Malaysia is on the way to develop its adaptation policy for last couple of years. This paper focuses on few guidelines that need to examine carefully while determining the climatic change adaptation approach for agricultural sector in Malaysia.

1. Introduction

The changing patterns of climate factors adversely affect the social, economical, and environmental agents all over the world. The direct impacts of climate change include loss of life, destruction of resources, and vulnerability of livelihoods. The agricultural sector is fully sensitive toward the changes of climate factors. So, any little changes in climate factors adversely affects agricultural production as well as relevant stakeholders.

According to FAO[3] agriculture accounts for 24% of world output that uses 40% of total land area. Among all agricultural output, rice, wheat, and maize make up 85% of world cereal exports which are the main sensitive crops to climate change. Under current climate change scenario, temperature above 25°C may decline grain mass of 4.4% per 1°C rise,[9] and grain yield may decline as much as 9.6%–10.0% per 1°C rise.[2] But the average temperature of rice-growing areas in Malaysia is about 26°C. Singh *et al.*[7] mentioned that the actual farm yields of rice in Malaysia vary from 3 to 5 tons per hectare, where potential yield is 7.2 tons. They also mentioned a decline of rice yield between 4.6% and 6.1% per 1°C temperature

increase under the present CO_2 level. Alam *et al.*[1] mentioned that total yearly rainfall in Malaysia is increasing but its monthly variation is too high. In Malaysia, the effect of lower rainfall is almost possible to check through proper irrigation system, but the opposite phenomenon of over rainfall for any particular time, especially at the end of the crop cycle or at the maturity period, causes serious damages to crops, which is absolutely uncontrollable now.

Due to high greenhouse gas emissions, the temperature is projected to rise by 0.3°C to 4.5°C in Malaysia. Warmer temperature will cause a rise in sea level about 95 cm over hundred-year period. The changes in rainfall may fluctuate from about −30% to +30%. This change will reduce crop yield and prone to drought in many areas so that cultivation of some crops such as rubber, oil palm, and cocoa will not be possible.[6]

NRS[6] projection shows more than 0.4% changes of rainfall by 2020 and 1% by 2060 will cause a decline to the earning of farmers under a certain level of temperature. Moreover, NAHRIM[5] projection shows maximum monthly precipitation will increase up to 51% over Pahang, Kelantan, and Terengganu, while minimum precipitation decreases between 32% and 61% all over Peninsular Malaysia. At the same time, annual rainfall will increase up to 10% in Kelantan, Terengganu, Pahang, and North West Coast, and decrease up to 5% in Selangor and Johor by 2050. This variation in climate factors will cause the agricultural system vulnerable in Malaysia. As poor people are mostly engaged in agricultural activities, the poverty rate will increase more in the agriculture sector based on the projected variation of rainfall and temperature. Moreover, climate change will be likely to exacerbate inequalities due to the uneven distribution of the burden of damage and remedy actions. Under these circumstances, adaptation policy is very crucial for the agricultural sustainability as well as the livelihood sustainability in Malaysia. This paper is an attempt to provide some essential issues that need to examine carefully while determining the climatic change adaptation approach for agricultural sector in Malaysia.

2. Levels and Approaches of Adaptation for Malaysia

Adaptation is not a substitute of mitigation, but there are arguments for adaptation to consider as a response measure. Mitigation actions never stop a certain degree of climate change due to historical emissions and the inertia of the climate system.[4] Moreover, mitigation effects may take several decades to manifest, where most adaptation activities take immediate effect. Adaptation reduces risks associated with current climate variability as well as addressing the risks associated with future climate changes, where mitigation only focuses on future risks. The measures of adaptation can be applied on a local scale or root level with the involvement of large number of stakeholders, where mitigation works in the decision-making level. In the current world, climate factors are exogenously

variable that are immitigable in a quick manner; as a consequence adaptation is the most appropriate way to cope the system properly.

Different approacheds have been taken by different countries to adapt to climate changes. Nepal takes the approach of community-based adaptation measures to weather-related disasters, microfinance mechanism through special insurance scheme to cope with increasing flash-flood, and adaptation through institutional arrangement. Mongolia takes the approach of policy framework for adaptation strategies for the Mongolian rangelands to climate change at multiple scales, and risk communication at multiple levels to build common awareness. India takes the approach of promoting integration of adaptation strategies into developmental policies by effectively communicating climate risks and adaptation measures. The Philippines takes the approach of mainstreaming climate change adaptation in watershed management and upland farming. Bangladesh takes the approach of participatory climate risk assessment and development of local adaptation action plans, community-based practice to survive in changing ecosystem condition—permanent flood (water logging), and household level adaptation.

Malaysia is in the process of developing its policy for upcoming adverse negative climate impacts. It recognizes adaptation as an important component of policy response to climate change strategy[6] that has been reflected in the basic principles of Second National Communication to the UNFCCC Project (NC2) Malaysia: fit in with the nation's development priorities (poverty alleviation, food security enhancement, action plans under MEAs); to reverse trends that increase maladaptation and raise risks for human populations and natural systems; continuous reassessment of current plans for increasing the robustness of infrastructure designs and long-term investments; improvement of societal awareness and preparedness for future climate change (policy-makers to local communities); increase understanding of factors that enhance or threaten the adaptability of vulnerable populations and natural systems; create a focus toward assessing the flexibility and resilience of social and natural systems; ultimately rely on a thoughtful assessment involving a robust stakeholder process rather than being dependent on the availability of high-quality data and extensive experience on computer-based models.

While developing an approach of adaptation, Malaysia should carefully focus on few issues. IPCC[4] mentioned few issues while refers to adaptation assessment—"practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility". Policy-makers also need to focus on the determinants of adaptation capacity that have been suggested by Yohe and Tol[11]: the range of available technological options for adaptation; the availability of resources and their distribution across the population; the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed; the stock of human capital, including education and personal

security; the stock of social capital, including the definition of property rights; the system's access to risk-spreading processes, e.g., insurance; the ability of decision makers to manage information, the processes by which these decision-makers determine which information is credible and the credibility of the decision-makers, themselves; and the public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

3. Options of Adaptation for Malaysia

The options of adaptation depend on the local socioeconomic–cultural–political perspectives. The adaptation should be taken in different stages—government, farm, and other relevant service providers' level. Smit and Skinner[8] said adaptation approaches need to be followed in the technological level, government level, and farm level. While defining the adaptation policy, Malaysia needs to consider the following issues carefully.

(1) ***Technological developments***: The technological adaptation is being practicing almost all developed countries. In several places it is sponsored by federal and provincial governments and found effective. The technological development needs to adapt in the following different ways:

- *Resource management innovations*: To address the risk of moisture deficiencies, increasing frequency of droughts, and improvement of irrigation, water management innovations need to be developed. Farm-level resource management innovations need to be develop to address the risk associated with changing temperature, moisture and other relevant climatic conditions.
- *Crop development*: To increase the tolerance and suitability of plants under different temperature, moisture and other unfavorable climatic conditions, crop variation, hybrids, new crops, and alternative crops development are very important.
- *Weather and climate information systems*: Weather forecast, early warning system and ensuring delivery of proper information to farm level is also very important.

(2) ***Government programs***: Government as the policy and law-making authority has to play a most influential role to ensure adaptation in all level. Government roles in adaptation approach can proceed in the following ways:

- *Agricultural subsidy and support programs*: Proper policy for financial support—subsidy, incentive, compensation, assistance—need to be set up to influence farm-level production practices, risk-management strategies, financial management, disasters or extreme events challenge, and ensure income stabilization programs.
- *Resource management programs*: Develop and implement policies to ensure proper utilization of the resources—water, land, infrastructure, etc.—time to time in the light of changing climate conditions.

(3) ***Farm production practices***: Farm production adaptations include farm-level decisions with respect to farm production, land use, irrigation, the timing of operations, etc. Details of options are as follows:

- *Farm production*: Farm needs to change the intensification of production and diversify crop types and crop substitution to address the environmental variations and economic risks associated with climate change.
- *Land use*: Farms need to utilize land properly and change the location of crop production to address the environmental variations and economic risks associated with climate change.
- *Irrigation*: Farm needs to develop efficient irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought.
- *Timing of operations*: Farm needs to adapt to the changing duration of growing seasons and associated changes in temperature and moisture.

(4) ***Farm financial management***: Farm financial adaptation options include responses toward farm income and financial management strategies related to the risk of climate change that elaborate following options:

- *Crop shares and futures*: To reduce the risk of climate-related income loss, farm needs to take protection through crop sharing, and financial options such as hedging/future option, insurance, etc.
- *Income stabilization programs*: Farm needs to take income stabilization programs, such as portfolio of investment, saving scheme, minimum income protection by government or insurance, etc., to reduce the risk of income loss due to changing climate conditions and variability.

Among all of these options, it is also important to project more accurate changes in climatic factors and level of effects of the changes. Ultimately, the adaptation will be highly dependnt on technology in the long run and financial protection in the short run. So, the complete adaptation policy should be flexible with respect to options and time. At the same time coordination among all the stakeholders also need to be prioritized.

4. Conclusions

Considering the discussion and the projection, the overall agriculture and relative livelihood in Malaysia will become vulnerable, and their socioeconomic development and sustainability will be hampered due to the climatic changes. In recent years, adaptation has gained prominence as an important response measure, especially for vulnerable countries, as it has become clear that some impacts are now unavoidable in the short- to medium-term. Mitigation is necessary but adapting to future risk is more important for immediate and long-term action for various

actors including government, development partners, research organizations, and community organizations.

Several countries follow their own approaches of adaptation for climatic changes based on the local characteristics as well as general barriers to adaptation, such as ecological, financial, institutional, technological, information, and cognitive hurdles. Malaysia is in the process to develop its adaptation approaches. It should carefully determine its adaptation policy based on climate change relevant to potential socioeconomic vulnerability among different stakeholders at different levels.

Agricultural adaptation options regarding climatic change in Malaysia should be followed in farm or individual farmer level, and policy level. Technological advancement needs to be focused to ensure its most crucial roles to solve the problem in the long run. Government bodies also need to take preferable subsidy policies and ensure financial sustainability to the farmers and farm. Overall, co-operation among different groups, stakeholders, and agencies is very important to better cope with the changing nature of climatic factors.

References

1. M. M. Alam, S. Siwar and M. E. Toriman, Rainfall variability, water and agricultural sustainability: A socioeconomic study of vulnerability and adaptation of climate change, Case of Paddy Farming in North West Selangor, Malaysia, In *Proceedings of the International Conference on Water, Environment, Energy and Society,* 28–30 June 2009 (S. R. K. College, Agra University, India, 2009).
2. J. T. Baker and L. H. Allen, Jr., Contrasting crop species responses to CO_2 and temperature: Rice, soybean and citrus, *Vegetatio* **104/105**: 239–260 (1993).
3. FAO, *World Agriculture Towards 2015/2030: An FAO Perspective* (Food and Agriculture Organisation of the United Nations, Rome, 2003).
4. IPCC, *Climate Change 2001: Impacts, Adaptation and Vulnerability,* IPCC Third Assessment Report (Cambridge University Press, 2001).
5. NAHRIM, *Final Report: Study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Peninsular Malaysia* (National Hydraulic Research Institute of Malaysia (NAHRIM) and California Hydrologic Research Laboratory (CHRL), 2006).
6. NRS, *National Response Strategies to Climate Change* (Ministry of Science, Technology and the Environment, Malaysia, 2001).
7. S. Singh, R. Amartalingam, W. S. Wan Harun and M. T. Islam, Simulated impact of climate change on rice production in Peninsular Malaysia, in *Proceedings of National Conference on Climate Change* (UPM, 1996), pp. 41–49.
8. B. Smit and M. W. Skinner, Adaptation options in agriculture to climate change: A typology, *Mitigation and Adaptation Strategies for Global Change* **7**: 85–114 (2002).

9. T. Tashiro and I. F. Wardlaw, A comparison of the effect of high temperature on grain development in wheat and rice, *Annals of Botany* **64**: 59–65 (1989).
10. UNDP, Adaptation Policy Framework for Climate Change: Developing Policies Strategies and Measures, eds. B. Lim and E. Spanger-Siegfred (Cambridge University Press, 2005).
11. G. Yohe and R. S. J. Tol, Indicators for social and economic coping capacity: Moving toward a working definition of adaptive capacity, *Global Environmental Change* **12**: 25–40 (2001).

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Climate Change Adaptation in Water and Agricultural Sectors in the Philippines: Some Issues and Challenges

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This paper reviews climate change adaptation in water and agricultural sectors in the Philippines. It discusses the current and potential impacts of climate change, particularly the associated climate variability and climate extremes, and presents the adaptation strategies practiced by the local stakeholders. Most adaptation practices for the water and agriculture sectors were found to be reactive in nature. Efforts toward more proactive, systematized, and well-planned adaptation are recommended to be prioritized over the existing, short-span adaptation strategies. The need for long-term sustainability and wide-scale adaptation approaches were emphasized. Local government units and communities should also be strengthened to be prepared to take on the challenge of climate change.

1. The Philippines and Climate Change

The Philippines, covering an area of approximately 30 million hectares (M ha), is home to 88.5 M Filipinos.[17] The country ranked 12th and 15th among the most populous and mega-diverse countries in the world, respectively. With a dense population and its biodiversity in critical condition due to the degradation of natural systems, the country is also extremely vulnerable to climate change.

Historical data in the Philippines have indicated anomalies in climate observations. A 55-year record (1951–2006) of the El Niño Southern Oscillation (ENSO) and La Niña events by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) showed a warming trend in the country (PAGASA, n.d.). The occurrence of ENSO events became more frequent since 1980 (figure 1). The Asian Development Bank (ADB)[1] reported that water stress increased in Southeast Asia, particularly during El Niño years, causing damage to crops, shortage in drinking water, and a drop in electricity production. The 1997–1998 El Niño was recorded as the worst drought ever, reducing the amount of water in Angat reservoir by 10%, and affecting other hydroelectric power plants in the country.

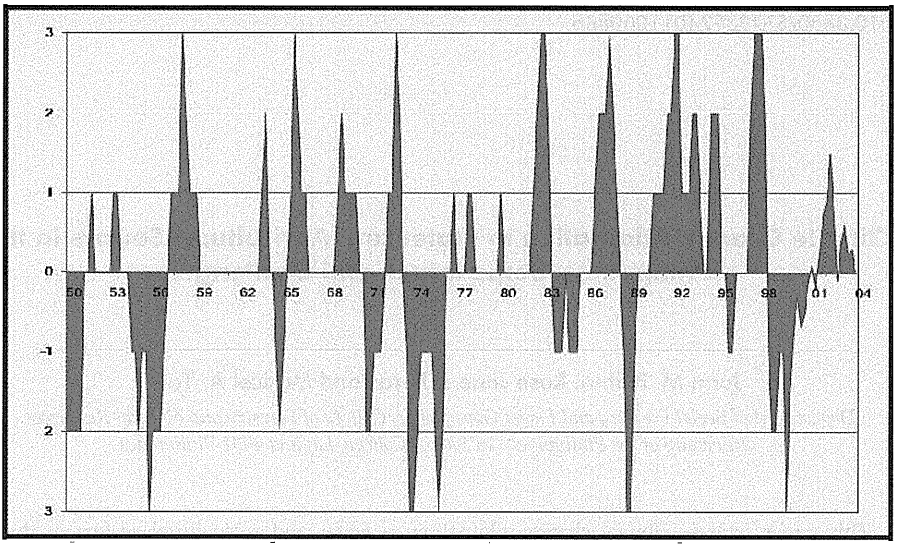

Figure 1 ENSO occurrences from 1950 to 2006 (PAGASA, n.d.).

Between 1990 and 2003, about 20 tropical cyclones visited the country each year, of which 9 would make landfall. Data records also indicated an increase in the number of strong typhoons with more than 185 kilometers per hour (kph) wind speed throughout the years. This could be attributed to the rising sea surface temperature which enhances the strength of tropical cyclones. Meanwhile, almost 80% of disasters occurring in the country were weather-related, which caused landslides and flash floods leading to loss of lives and properties (Amadore 2005 in Ref. 1). Therefore, an increase in the intensity of the tropical cyclones could lead to far greater adverse effects.

Sea level rise was observed in Manila Bay since 1960s, while Cebu, Davao, Jolo, and Legazpi have recorded an increase in sea levels in 1970s. This could lead to increased salinity of groundwater resources, which are sources of drinking and irrigation water (Perez, 2008 in Ref. 1).

Among the climate-related hazards experienced in the country, typhoon is the most damaging of all. Records from 1975 to 2000 showed average annual deaths of 593, damage to property amounting to PhP4.5 B ($83 M), and damage to agriculture at PhP 3B ($55 M). In 2006 alone, around 2.38 M families were affected by typhoons and 0.678 M families were displaced. Deaths reached 1158; damaged houses amounted to 0.82 M; and agriculture and infrastructure losses summed up to about PhP 19 B (NDCC, 2006 in Ref. 20). A strong typhoon coupled with excessive rains also proved more damaging, usually resulting in landslides and flash floods.

On top of this, recent climate projections revealed more frequent ENSO events and a shift in seasonal cycle.[8] It is expected that these would lead to heightened

chances of summer droughts and increase in the intensity and frequency of tropical cyclones. All sectors particularly agriculture and water would be highly affected by the future impacts of climate change.

This paper, therefore, reviews the current impacts of climate change, particularly the associated climate variability and climate extremes, to the agriculture and water sectors. It assesses the adaptation strategies practiced by the local stakeholders, and identified the issues and challenges facing the two sectors. The paper highlights the need for a more proactive, systematized, and well-planned adaptation strategies, instead of band-aid approaches to the impacts of climate change.

2. Impacts of Climate Change in Agriculture and Water Sectors

Water and agriculture are most vulnerable sectors to erratic weather occurrences and a changing climate. Productivity for both water and agriculture depends on the weather and climate situation.[1]

2.1. *Agriculture*

Studies on the economics of agricultural production as influenced by climate change suggested a negative outlook in the future (Bruinsma, 2003 and IPCC, 2007 in Ref. 1). For instance, Cline (2007 in Ref. 24) estimated a 15.9% decline in global agricultural production in 2080 if global warming would remain unabated. The worst projected impacts would be experienced by developing countries with a 19.7% decrease in agricultural production.[1]

Future impacts would affect developing and low-lying countries, such as the Philippines, which have limited capacity to adapt to climate change. As is the case in other Southeast Asian countries, agriculture is one of the major economic activities in the Philippines, with 14% contribution to the Gross Domestic Product (GDP) in 2007 alone. It also employs at least 36% of the country's working population.[17] Thus, the impacts of climate change on agriculture would be critical to many populations and to the country's economy at large.

The Philippines has a total farm area of 9.67 M ha, which is about 68% of the country's total alienable and disposable lands[a] (Table 1). In the past three decades (1980–2002), the average farm area cultivated per family was observed to have decreased by 30%. Nevertheless, the volume and value of production also increased. For instance, the volume of production between 1980 and 2002 increased by 2%–4% primarily due to agricultural advances (46%). Considering the impacts

[a]Presidential Decree 705 of 1975 defines "alienable and disposable lands" as lands of the public domain which have been the subject of the present system of classification and declared as not needed for forest purposes

of future climate change, however, such technological advances may not be able to bring about the same level of productivity.[17]

Table 1 Philippine statistics on water and agricultural sector.[17]

	1980	1991	2002
Number of farms (M)	3.42	4.61	4.82
Farm Area (M ha)	9.73	9.98	9.67
Average farm area (ha)	2.82	2.16	2.00
	2005	2006	2007
Volume of production (Th MT)	73,725.9	77,401.1	78,775.7
Value of production (MP) at current prices	410,303.1	459,585.3	510,266.2
Area harvested (Th Ha)			
Palay	4,070.4	4,159.9	4,272.9
Corn	2,441.8	2,570.7	2,648.3
Yield per hectare (MT)			
Palay	3.60	3.68	3.80
Corn	2.20	2.37	2.54
Total employment in agriculture			
With ATE less than 20	6,072	17,125	20,098
With ATE more than 20	96,430	97,326	103,757
Status of irrigation (in ha)			
Total irrigable area	3,126,340	3,126,340	3,126,340
Total service area	1,413,236	1,427,924	1,434,597
Irrigation development (%)	45.2	45.7	46.0

Climate change threatens crop production. In seasonally dry areas, a 1°C–2°C rise in temperature could lead to increase in irrigation requirement, decrease in freshwater availability, changes in flowering of plants, and decrease the productivity of crops such as rice and corn.[1,4,5,14,23] As demonstrated by vulnerability studies in the Philippines[3,11,19,22,23] increasing temperature not only amplifies evapotranspiration but also creates stress to crops. This is especially the case in water-scarce areas, such as rainfed farms in the uplands. This eventually results in reduction in crop yield, thus also leading to decrease in farmer's income.

The El Niño years of 1983 and 1998 caused losses of approximately 3 million metric tons (MT) of rice and 0.5 million MT of corn.[2] A study of the International Rice Research Institute (IRRI) in 1994 also revealed a 10% decline in rice production with every 1°C increase in growing season minimum temperature (Peng *et al.* 2004 in Ref. 1). The same is true for corn with a 5%–44% decrease in productivity depending on the location of production (ONEP, 2008 in Ref. 1). Meanwhile, findings by Lansigan and Salvacion[14] showed as much as 30% decline in corn production would be experienced in Bukidnon and Laguna with a 2°C increase in air temperature, and 15% decrease in Isabela (Figure 2).

Cline (2007 in Ref. 24) investigated the impacts of climate change in agriculture in 2080 using Ricardian statistical and crop models. Results showed a global

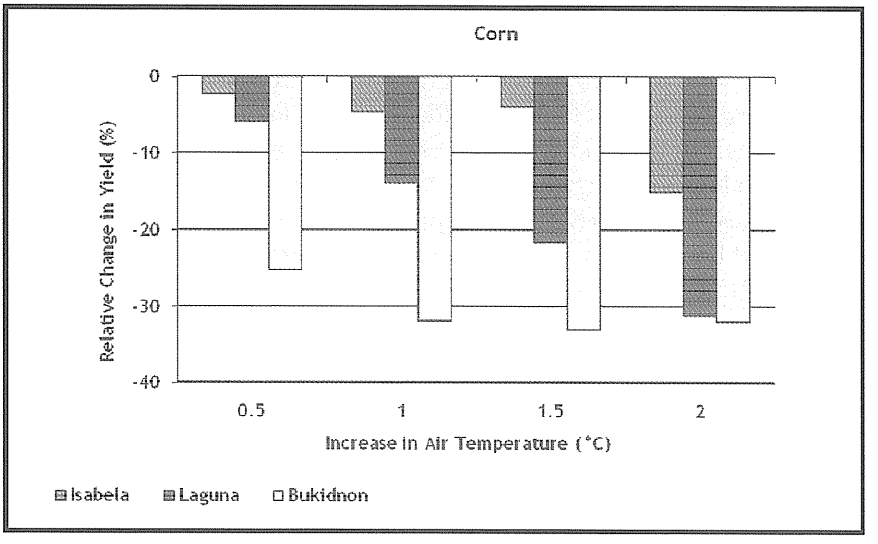

Figure 2 Relative change in corn production with increase in air temperature. (*Source*: Ref. 14).

reduction in agricultural production by 3% with carbon fertilization effect and 16% without carbon fertilization effect. Developing countries were seen to be highly affected by this, particularly South Asia, where a reduction of −9.1% and −21% would be experienced with and without carbon fertilization effect, respectively. For the Philippines, the model indicated a decrease of −11.9% and −23.4%, with and without carbon fertilization effect, respectively. These projections therefore warrant a well-planned adaptation strategy that would counter such impacts.

2.2. *Water*

Water resources in the Philippines include rainfall, surface water and groundwater from 18 major river basins and 421 principal river basins. The groundwater reservoir of the country extends to an aggregate area of 5 M ha. Various rock formations underlie the 10 M ha groundwater basins located in Northeast Luzon, Central Luzon, Laguna Lake basin, Cavite–Batangas–Laguna basin, Southeast Luzon, Mindoro Island, Negros Island, Northeast Leyte, Ormoc–Kananga basin, Agusan-Davao basin, Occidental Misamis basin, and Lanao–Bukidnon–Misamis basin. Rains and seepage from rivers and lakes constantly recharge these groundwater resources (PEM, 2003 and EMB, 2006 in Ref. 6).

The country receives an annual rainfall ranging from 1000 to 4000 mm. About 50% of total rainfall is collected as water runoff in the country's 421 principal river basins, 59 natural lakes and a number of small streams (Kho, 2005 and NWRB, 2003 in Ref. 6). About 145,900 million cubic meters (MCM) freshwater resources are available annually. This estimate is based on 80% probability for surface water

and groundwater recharge of 20,200 MCM/year (NWRB-SPM, 2003; PEM, 2003; and ASEAN, 2005 in Ref. 6). In 1996, the water demand was 48.23% (of 29,944 MCM/year) higher than the available groundwater recharge for domestic, industrial, and agricultural use (PEM, 2003 Ref. 6). The total volume of water resources potential of the country (145,000 MCM) should give an adequate supply of water for said uses. However, current weather and climate-related variations can lead to water shortages, particularly in highly populated areas. This is further supported by the study of Lansigan[15] which projected water scarcity in the Philippines for the years 2010, 2015 and 2025. These projections were based on water withdrawal-to-availability, water consumption-to-availability, and water availability-per-capita.

Impacts of climate change on the water sector could be high streamflow, increased average annual runoff, and increase in water volume in some wet areas by 10%–40%. This higher supply of water could also lead to floods, landslides, and flash floods. On the other extreme end, impacts of climate change could also lead to water scarcity due to 10%–30% decrease in water supply in dry areas which are already water-stressed and water-related extreme events—such as droughts. These are compounded by increasing demand of the population for water.

In Southeast Asia, an increase in evapotranspiration in rivers, dams, and other water reservoirs was already observed leading to decreased water availability for human consumption, agricultural irrigation, and hydropower generation. Other pressures on the water sector that are believed to be caused by the changing climate are decreased river flows and water level in many dams and water reservoirs, particularly during El Niño years; increased populations under water stress; increased stream flow particularly during La Niña years leading to increased water availability in some parts of the region; increased runoff, soil erosion, and flooding, which affect the quality of surface water and groundwater; and advancing saltwater intrusion into aquifer and groundwater resources leading to decreased freshwater availability (Boer and Dewi, 2008; Cuong, 2008; Ho, 2008; Jesdapipat, 2008, and Perez, 2008 in Ref. 1).

3. Key Adaptation Options

Adaptation measures increase the system's resilience to climate risks. Adaptation efforts have been undertaken in many Southeast Asian countries, yet a more holistic approach in building the adaptive capacity of the vulnerable groups and localities is still wanting. Such an approach would enhance policy and planning coordination across different stakeholders (ministries and different levels of government) for climate change adaptation. Most of the adaptations applied or practiced were noted to be reactive not proactive, autonomous not well-planned, and developed to address climate variability and not change.[1]

Drawing from the adaptation options in the Southeast Asian region as highlighted by the Asian Development Bank,[1] the Philippines, key adaptation options

Table 2 Philippines' key adaptation options for agriculture and water sectors.

Practice	Scale	Reactive/ Proactive	Planned/ Autonomous	Prevalence
Adjustment of cropping calendar and pattern	Local	Reactive	Autonomous	Widely used
Changes in management and farming techniques	Local	Reactive	Autonomous	Widely used
Use of heat-resistant varieties	Local/ Subregional	Proactive	Autonomous	Widely used
Diversified farming, intercropping, crop rotation	Local	Proactive	Autonomous	Widely used
Development of early warning systems	Local/Regional	Proactive	Planned	The Philippines, Thailand, Viet Nam
Multipurpose reservoirs, dams, water-impounding system	Regional	Proactive	Planned	Widely used
Metering and pricing to encourage water conservation	Local	Reactive	Autonomous	Widely used

Sources: Boer and Dewi, 2008; Cuong, 2008; Ho, 2008; Jesdapipat, 2008; and Perez, 2008 in Ref. 1.

for the agriculture and water sectors are listed in Table 2. Many of the responses are reactive in nature due to a need for a complete analysis of the past impacts brought about by different climatic phenomena. It is noted that being proactive would entail less cost as compared to being reactive to the impacts. Such an approach could also lead to a planned course of action which will allow mainstreaming/ integration of options suited to a locality/watershed/community. However, most of these adaptation options as observed by IPCC[9] were autonomous in nature.

Adaptations for the agriculture sector based on the initial National Communication on Climate Change in 1999 were divided into three categories: economic, technological, and institutional. This was trimmed down into the most common adaptations for agriculture such as changes in cropping patterns and cropping calendar, and improved farm management.[1,22] Effective farm-level adaptation practices enhanced by institutional and policy support from the government can be helpful in coping with climate variability (OECD, 2008 in Ref. 1). The effectiveness of household level adaptations is dependent on the availability of support systems.

The adaptation strategies above show a need to scale up the responses of the Philippines toward stresses caused by climate change on agriculture and water sectors. The integration of comprehensive water management practices should be applied more widely in the above strategies to capture multiple benefits such as flood prevention, efficient use of water supply, and clean power generation,[1] like the Small Water Impounding Project of the government. Benioff (1996 in Ref. 10) noted the above water adaptation practices as part of the supply adaptation.

Meanwhile, enhancement of irrigation efficiency, introduction of low water use crops and efficient farming practices, recycling (reuse) of water, improvement of monitoring and forecasting systems for floods and droughts, and use of water pricing policies and structures were considered as demand adaptation practices.

Recent findings showed varied practices employed by farmers in response to climate variability and extremes (Table 3). These studies were conducted in different localities and results were compiled for purposes of this review. Those performed by IRRI using yield/production experiments were mostly conducted in the northern part of the country, where the ill effects of El Niño and strong typhoons are highly felt.[4,7] Farmers were able to devise new strategies and improve existing practices to reduce risks from climate-related phenomena. It was observed that when farmers have knowledge on the imminent occurrence of El Niño in the next cropping season, they reduce the size of cultivated farm lands to lessen potential negative impacts in production as well as income. Some also modified the choice of crops and cultivars through a trial and error process or experimentation to check whether any crop would be sensitive or resilient to the drought season. There are those who applied varying amounts of fertilizers to cope with the needed nutrient requirements for crop growth. Furthermore, the use of "pump irrigation" system for those near bodies of water was practiced even if it commands higher cost. This is sometimes thought to be the only feasible strategy so that they could earn a little and not totally lose the investment already made.

On the other hand, wise use of farm wastes by converting them into commercial products and shifting to organic farming are less costly due to the application of time-tested principles of soil replenishment, biodiversity and ecological balance. Cropping sequence and schedule should be planned in such a way that it takes advantage of the available moisture or should be dependent on the sufficiency of accumulated rainfall. Meanwhile, Lansigan *et al.*[12] quantified the risk levels crucial

Table 3 Examples of location-specific adaptation strategies to climate variability and change in agriculture.

Adaptation Strategies	Location	Literature
Reduction in area cultivated	Los Baños, Daet, Iloilo	Lansigan *et al.*[11]
Modification in choice of crops or cultivars	Los Baños, Daet, Iloilo	Lansigan *et al.*[11]
Changes in agronomic practices (fertilizer use, irrigation, and control of pests and diseases)	Los Baños, Daet, Iloilo	Lansigan *et al.*[11]
Using farm wastes wisely	Central Luzon	Tibig and Lansigan[22]
Organic farming	Cordilleras	Tibig and Lansigan[22]
Use of sulfate-containing fertilizers	Central Luzon	Corton *et al.*[3]
Direct seeding crop establishment	Central Luzon	Corton *et al.*[3]
Planned cropping sequence and schedule	Los Banos, Daet, Iloilo	Lansigan *et al.*[11]
Crop insurance	Isabela and South Cotabato	Lansigan[13]

in the formulation of crop insurance coverage policy needed in the processing of loan and insurance application in agricultural banks and insurance companies. The study also saw the necessity to review the uniform policy on crop insurance premiums levied across different locations.

4. Some Issues and Challenges

The current impacts of climate variability and extremes demonstrated the high degree of vulnerability of the agriculture and water sectors. While some adaptation strategies have been implemented by farmers and local communities, key issues and challenges need to be addressed for more effective and efficient responses. Some of these, distilled from available literature and analysis by the authors, include the following:

- *Raising public awareness and appreciation of climate change issues and concerns.*[1] Public awareness is a vital element for any successful endeavor as an informed public can serve as partners toward climate change adaptation. Public awareness can create a big impact in reducing current risks to climate change because their knowledge can make them plan ahead and improve present adaptation strategies.
- *Implementing enabling laws and national adaptation framework to mainstream adaptation in development policies and programs.* Climate Change Act of 2009, signed into law on 23 October 2009, is a concrete policy that integrates/mainstreams adaptation options to all development programs/projects. It is expected that through this Act, the different sectors, especially the local government units, will be guided on the implementation of mitigation and adaptation strategies to future climate risks, highlighting partnerships among them. However, a major challenge to the Climate Change Act and its recently completed national adaptation framework is the political will in the part of the government to allocate sufficient resources and implement what is contained in the provisions of the law. Incidentally, past experience shows that the Philippines is quite good in formulating good laws but very poor in their implementation.
- *Strengthening the capacity of local government units to champion effective adaptation strategies at the local level.* The Province of Albay is the first and pioneering local government unit that has mainstreamed climate change adaptation due to its past experiences of frequent and severe climate hazards. The province has institutionalized Albay Public Safety and Emergency Management Office (APSEMO); established its Community-based Early Warning System, Communication Protocol, and Evacuation Procedures; kept a good working relationship between APSEMO, Warning Agencies and the Local Media; established Disaster Operation Center as the hub of action and the center of emergency coordination and communication; and developed the Cluster Approach on Recovery Program.[16] The Albay experience in mainstreaming climate

adaptation demonstrated the presence of a strong and committed LGU as critical for effective integration of these strategies in the water and agriculture sectors. This is a viable guarantee for a more sustained and effective implementation of adaptation efforts. Along the lines of strengthening the LGUs is the need to capacitate its officials and personnel for a comprehensive and integrative outlook on the issue. It would be a good start to disseminate the importance of collective action to minimize future consequences of climate change.

Strengthening local adaptive capacity through the provision of better climate information, research on and development of resilient crop varieties and other techniques should also be prioritized.[1]

- *Improving the science of climate change projection relevant to national and local levels.* While there are still a lot of uncertainties with regards to future climate change, climate scenarios through the use of computer modeling would be instrumental particularly on planning and preparedness. However, scenario outputs usually cover continents and regions and there is need to downscale the projections to be useful for national and local-level planners. Information on climate change projection is not available for a small locality, and this is where future efforts should be directed in order to be of practical help to the local-level planners.
- *Enhancing capacity of researchers to conduct integrated assessment of climate change impacts, vulnerability and adaptation.* The increasing attention gained by climate change from various sectors and disciplines has stirred interest among many to engage in climate change research and other activities. However, we still have to develop our capacity to effectively conduct climate change assessments, particularly focusing on impacts, vulnerability, and adaptation.[18] This requires an interdisciplinary approach to fully understand the dynamics of risks and impacts brought about by a changing climate. Hence, partnerships among scientists and institutions need to be emphasized.
- *Strengthening the science–policy–local action interface.* Climate change research should not end with the writing of the final report or the publication of its findings in scientific journals. Instead, efforts should be undertaken to communicate the research outputs to policy-makers down to local level, so that these will be integrated in the policies, programs, and local community actions. There is also a need to evaluate through a feedback mechanism whether local communities' capacity was improved.
- *Adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks.* Employing a holistic approach (watershed/landscape approach/ecosystem-based approach) toward reducing shocks/vulnerability of both human and biophysical systems should be taken into consideration, in order to have more integrated and effective projects and programs, thereby also avoiding fragmented approaches and redundancy (Locatelli *et al.*, 2010).

- *Building on the experience of indigenous adaptation strategies to enhance effectiveness of future adaptation*. The sustainability of present adaptation strategies to support agricultural production is a concern by most farmers, especially those who depend on rainfall. A well-analyzed and well-planned adaptation option that caters to the long-term sustainability of water supply and agricultural production should be prioritized. In this regard, building on existing adaptation strategies employed by communities, particularly those indigenous or local practices, could minimize costs and efforts rather than developing new and unpopular ones.[21] This would be more acceptable among the end-users as it would not deviate very much from their current practices, and the applicability of the approaches is also likely to be higher.
- *Developing and using adaptation metrics for planning and monitoring purposes to enhance adaptation effectiveness*. Local communities are faced with the problem of ineffective adaptation strategies to weather-related risks and vulnerability. This is usually brought about by high costs associated with the strategy, complexity, and the presence of barriers.[18] Reliable, adequate and cost-effective adaptation strategies are needed to sustain resilience of both sectors to the impacts of climate change. Appropriate adaptation metrics will serve as a useful guide to assist in determining suitable investments for adaptation as well as to monitor progress of these investments.

5. Conclusions

The sensitivity of water and agriculture sectors to climate change calls for effective and efficient adaptation measures to reduce risks and impacts. However, most of the adaptation options for the above sectors were found to be reactive in nature. Efforts towards more proactive, systematized and well-planned adaptation should be prioritized over the existing, short-span adaptation strategies. The long-term sustainability of adaptation strategies and its application to a wider scale should also be given further attention. Local government units and communities should also be strengthened to be prepared to take on the challenge of climate change.

Adaptation strategies are evolving through time, with more approaches being developed by various research institutions, such as IRRI. Some are found to be complicated while others are user-friendly. Nonetheless, it is important to employ an adaptation measure that is acceptable among the communities, and feasible for their surroundings. In this case, building on current practices would prove very helpful.

References

1. ADB, *The Economics of Climate Change in Southeast Asia: A Regional Review* (Asian Development Bank, Jakarta, 2009), 223 pp.
2. Bureau of Agricultural Statistics, *Volume of Cereals Production 1983–1998*, N.d., www.bas.gov.ph.

3. T. M. Corton, J. B. Bajita, F. S. Grospe, R. R. Pamplona, C. A. Asis Jr., R. Wassmann, R. S. Lantin, and L. V. Buendia, Methane emission from irrigated and intensively managed rice fields in Central Luzon (Philippines), *Nutrient Cycling in Agroecosystems* **58**: 37–53 (2000).
4. D. Dawe, P. Moya, and S. Valencia, Institutional, policy and farmer responses to drought: El Niño events and rice in the Philippines, *Disasters* **33**(2): 291–307 (2009). (IRRI Reprint 2009-3146).
5. W. L. De Los Santos, F. P. Lansigan, and J. Hansen, Linking corn production, climate information and farm-level decision-making: A case study in Isabela, Philippines, in *Climate Prediction and Agriculture, Advances and Challenges*, eds. Sivakumar, V. K. Mnnava, and J. Hansen (Springer, 2007).
6. Greenpeace, *The State of Water Resources in the Philippines* (Greenpeace Southeast Asia, Quezon City, Philippines, 2007).
7. L. C. Guerra, S. I. Bhuiyan, T. P. Tuong, and R. Barker, *Producing More Rice with Less Water from Irrigated Systems* (International Rice Research Institute, Manila (Philippines), 1998).
8. IPCC, *Climate Change 2001: The Scientific Basis*, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, eds. J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2001), 881 pp.
9. IPCC, Adaptation to climate change in the context of sustainable development and equity, Chapter 18, Lead Authors: I. Burton (Canada), B. Challenger (Antigua and Barbuda), S. Huq (Bangladesh), R. J. T. Klein (Germany/The Netherlands), and G. Yohe (USA); Contributing Authors: N. Adger (UK), T. Downing (UK), E. Harvey (Canada), S. Kane (USA), M. Parry (UK), M. Skinner (Canada), J. Smith (USA), and J. Wandel (Canada); Review Editors: A. Patwardhan (India) and J.-F. Soussana (France) (2007).
10. A. M. Jose, N. A. Cruz, Climate change impacts and responses in the Philippines: Water resources *Climate Research* **12**: 77–84 (1999).
11. F. P. Lansigan, W.L. de los Santos, and J. O. Codilla, Agronomic impacts of climate variability on rice production in the Philippines, *Agriculture, Ecosystems and Environment* **82**: 129–137 (2000).
12. F. P. Lansigan, W. L. delos Santos, M. T. Fabellar, and R. G. Perez, Estimating corn yields in selected locations in the Philippines using an ecophysiological process-based crop simulation model, *Proceedings of the National Corn R&D Conference*, 27–29 November 2002 (Calamba City, 2002).
13. F. P. Lansigan, *Assessing Impacts of Climate Variability on Crop Production, and Developing Coping Strategies in Rainfed Agriculture*, UN-ESCAP CGPRT Centre Monograph No. 43, pp. 21–36 (2003).
14. F. P. Lansigan and A. R. Salvacion, Assessing the effect ef climatecChange on rice and corn yields in selected provinces in the Philippines Paper presented at the *10th National Convention on Statistics (NCS)* 1–2 October 2007 (EDSA Shangri-La Hotel, 2007).
15. F. P. Lansigan, Frequency analysis of extreme events and water scarcity in a changing climate in the Philippines *SEARCA Special Seminar* (2008)
16. R. D. Lasco, R. J. Delfino, F. B. Pulhin, and M. Rangasa, The role of local government units in mainstreaming climate change adaptation in the Philippines *AdaptNet Policy Forum 08-09-P-Ad* (2008)
17. National Statistics Office (NSO) *Philippine in Figures* (NSO, Manila, Philippines, 2008)
18. J. M. Pulhin, R. J. Peras and F. B. Pulhin, Farmers' adaptation to climate variability: Assessment of effectiveness and barriers based on local experience Paper presented at

the *Global Environmental Change and Human Security (GECHS) Synthesis Conference on Human Security in an Era of Global Change*, 22–24 June 2009 (University of Oslo, Norway, 2009)

19. J. M. Pulhin, R. J. J. Peras, R. V. O. Cruz, R. D. Lasco, F. B. Pulhin, and M. A. Tapia, Climate variability and extremes in the Pantabangan–Carrangalan watershed of the Philippines: An assessment of vulnerability, in *Climate Change and Vulnerability*, eds. N. Leary, C. Conde, J. Kulkarni, A. Nyong, and J. Pulhin (Earthscan, Sterling, VA, London, 2008), pp. 307–332.
20. G. J. Rabonza, Vulnerability to natural disasters: The Philippine experience [PowerPoint presentation], Paper presented at *XVIII Meeting of International Cooperation Directors of Latin American and Caribbean*, 17–18 September 2007 (Caracas, Venezuela, 2007).
21. R. Shaw, A. Sharma, and Y. Takeuchi (eds.), *Indigenous Knowledge and Disaster Risk Reduction: From Practice to Policy* (Nova Science Publishers, Inc., New York, 2009).
22. L. V. Tibig and F. P. Lansigan, Coping strategies with agrometeorological risks and uncertainties for crop yield, in *Managing Weather and Climate Risks in Agriculture*, eds. M. V. K. SivaKumar and R. P. Motha (World Meteorological Organization, Commission for Agricultural Meteorology, 2007).
23. R. Wassmann, S. V. K. Jagadish, S. Heuer, A. Ismail, E. Redona, R. Serraj, R. K. Singh, G. Howell, H. Pathak, and K. Sumfleth, Climate change affecting rice production: The physiological and agronomic basis for possible adaptation strategies, in *Advances in Agronomy*, Vol. 101, ed. D. L. Sparks (Academic Press, Burlington, 2009), pp. 59–122, ISBN: 978-0-12-374817-1 © Copyright 2009 Elsevier Inc. Academic Press.
24. F. Zhai and J. Zhuang, *Agricultural Impact of Climate Change: A General Equilibrium Analysis with Special Reference to Southeast Asia*, ADBI Working Paper 131 (Asian Development Bank Institute, Tokyo, 2009). Available: http://www.adbi.org/workingpaper/2009/02/23/2887.agricultural.impact.climate.change/

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Climate Change Adaptation in the Agriculture and Water Sectors: Current Status, Issues, and Challenges in Vietnam

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This review explores climate change adaptation in water and agricultural sectors in Vietnam and presents the current status, issues, and constraints in climate change adaptation. So far, the implications of climate change for Vietnam are not well understood and recognized and there is a lack of awareness within government and the general public outside the scientific community. This study presents a number of barriers for implementing climate change adaptation in Vietnam, which include (a) uncertainty in the climate change scenarios; (b) weak planning, institutional setup and coordination for responding to challenges of climate change; (c) limited awareness and poor data to support planning and implementation; and (d) weak capacity to undertake climate change impact analysis and identification of cost effective adaptation measures. In this paper, we argued that there is a need to bring together various stakeholders to bridge these gaps through a comprehensive national framework for climate change adaptation that cuts across different sectors and geographical scales.

1. Introduction

Vietnam's climate, complex topography, and long coastline make the country particularly vulnerable to natural disasters.[1] Most analysis and scenarios[1,6–8,14] suggest that climate change will exacerbate vulnerability, particularly in coastal regions and influence most economic sectors, regions, and communities in Vietnam. The ongoing research by the authors suggest a number of barriers to implementing climate change adaptation exits, including (a) uncertainty in the climate change scenarios; (b) weak planning, institutional setup and coordination for responding to challenges of climate change; (c) limited awareness and poor data to support planning and implementation; and (d) weak capacity to undertake climate change impact analysis and identification of cost-effective adaptation measures.

Taking the above country context and the climate change vulnerabilities, this study aims to explore climate change adaptation in water and agricultural sectors in Vietnam and presents the current status, issues and constraints, and impacts of climate change.

2. Current status of Climate Change in Vietnam

Vietnam is situated in Southeast Asia, stretching from 8°27 to 23°23 N and from 102°08 to 109°30 E. The land area occupies 330,992 km^2. The coastal line of 3,260 km covers the East and the South. Three-fourth Vietnam territory is covered by mountains and hills with the elevation mostly from 100 to 1000 m. The plains concentrate in the downstreams of two big rivers: the Red and Mekong rivers. The river network in Vietnam is rather dense with the average density of 0.6 km/km^2. Based on climatic and topographic conditions, Vietnam is divided into seven regions: (i) Northwest of the North; (ii) Northeast of the North; (iii) The Red River delta; (iv) Northern Central coast; (v) Southern Central coast; (vi) Central highland; and (vii) The South.[10]

Vietnam possesses a monsoon tropical climate with plentiful heat and humidity but due to the lengthy territory stretching on many latitudes and diversified topography, the differentiation of climate between the regions is rather clear. It means that the seven regions can be characterized by their own climate.

Annual mean temperature in different regions ranges from 18°C to 29°C. Monthly mean of the coldest month is about 13°C–20°C in the northern mountainous part and from 20°C to 28°C in the southern parts. Temperature of the summer varies from 25°C to 30°C. Vietnam is located in the area affected by typhoon and tropical cyclones in the Northwest Pacific Ocean. On average, annually, there are five to six typhoons/tropical cyclones affecting Vietnam.[12]

Annual rainfalls are very different in different regions, ranging from 600 to 5,000 mm. About 80%–90% of rainfall concentrates during rainy season; the number of rainy days in the year is also very different between the regions and ranges from 60 to 200. In several regions, floods and inundation occur during rainy season but in dry season, drought is often recorded.

The results of analysis[6,7] of observed data indicated the changes of climate parameters and sea level with the following noticeable features:

- *Temperature*: During the last 50 years (1958–2007), the annual average temperature in Vietnam increased by about 0.5°C to 0.7°C. Winter temperatures increased faster than those of summer and temperatures in Northern climate zones increased faster than those of Southern climate zones (Figure 1(a)). The annual average temperature for the last four decades (1961–2000) was higher than that of the three previous decades (1931–1960). Annual average temperatures for 1991–2000 in Ha Noi, Da Nang and Ho Chi Minh City were all higher than the average for 1931–1940 by 0.8°C, 0.4°C, and 0.6°C respectively. In 2007, the annual average temperatures at these three locations were all higher than the average for 1931–1940 by 0.8°C–1.3°C and similarly higher than the average for 1991–2000 by 0.4°C–0.5°C.[6,7]

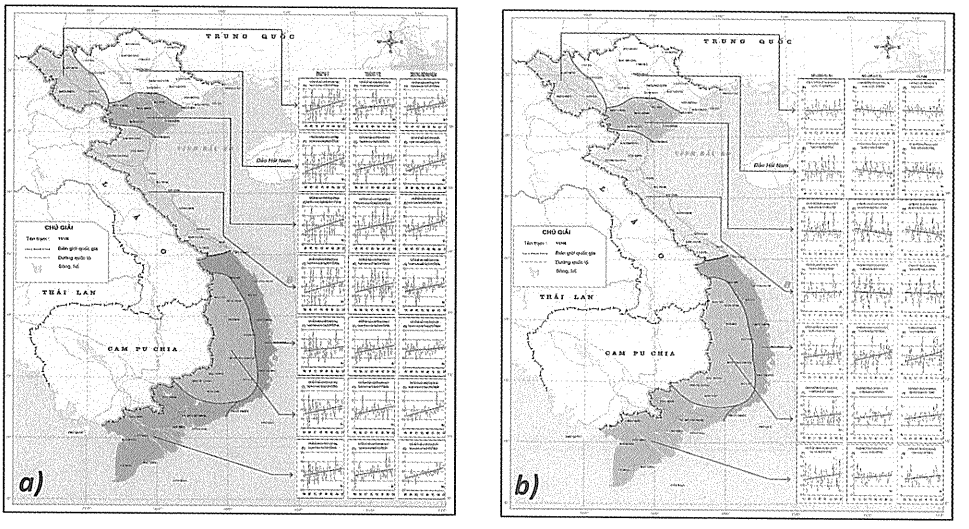

Figure 1 Trend of temperature (a) and rainfall (b) over Vietnam for the last 50 years.

- *Rainfall*: At every location, the change of annual average rainfalls for the last nine decades (1911–2000) was not distinct and not consistent with each other. There were ascending and also descending periods. The annual rainfall decreased over Northern climate zones while increased over Southern ones (Figure 1(b)). On average for the whole country, the rainfall over the past 50 years (1958–2007) decreased by about 2%.[6,7]
- *Cold fronts*: In the last two decades, the number of cold fronts affecting Vietnam was reduced remarkably. Anomalous events, however take place more frequently such as the most recent extremely and damaging cold surge lasting consecutively for 38 days during January and February 2008 in Northern Vietnam.[6]
- *Typhoons*: In recent years, there were more typhoons with higher intensity affecting Vietnam. Typhoon track has a tendency of moving southward and typhoon season tends to end later. There were more typhoons with abnormal movements (Figure 2).[2]
- *Drizzle*: Drizzle is a specific characteristic of climate in North Vietnam in winter with a little rain amount of under 5.0 mm. The average number of drizzle days in Ha Noi gradually decreased since the decade of 1981–1990, and in the last 10 years, the number of drizzle days decreased to half (15 days/year) of the long-term average number (38.7 days/year).[9]
- *Sea level*: Data from tidal gauges along Vietnam coasts show that sea level rise was at the rate of about 3 mm/year during the period 1993–2008 which is comparable with the global trend. In the past 50 years, sea level (Figure 3) at Hon Dau station rose to about 20 cm.[7]

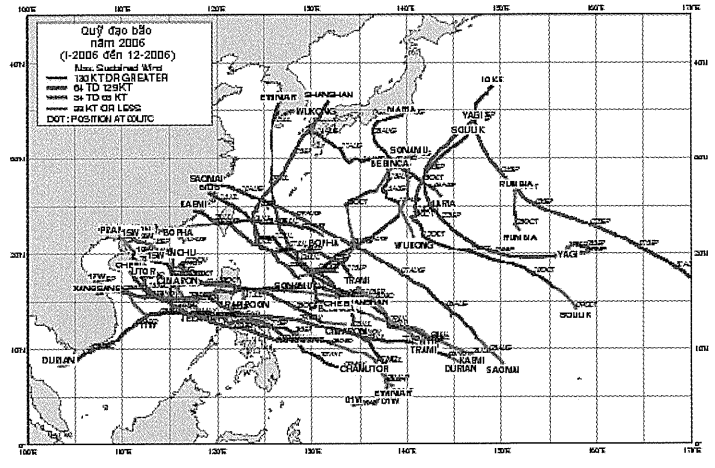

Figure 2 Typhoon tracks in the North Western Pacific Ocean & East Sea.

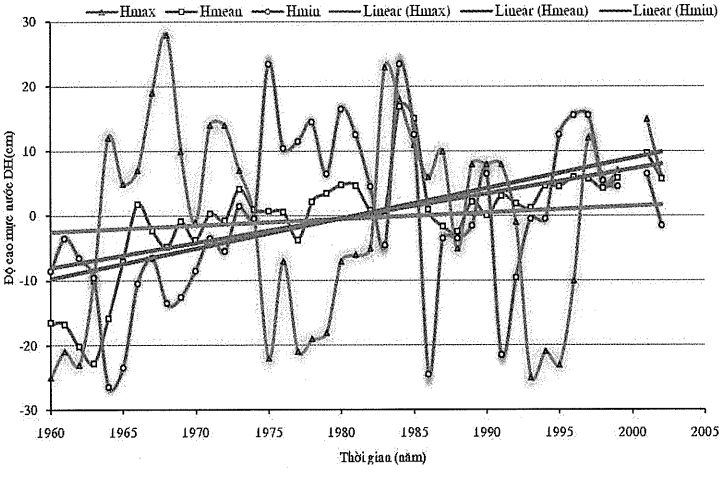

Figure 3 Changes in sea level at Hon Dau oceanographical station.

3. Climate Change Impacts on Water Resources and Agriculture

The impacts of climate change on water resources are mainly presented in the form of variability of precipitation, runoff, and groundwater regime. First, the annual distribution of precipitation in Vietnam is significantly changing resulting from temperature changes. Rainfall can concentrate in some rainy months with the amounts higher than before. Rainy season can end 1 month sooner than normal, and the dry season can be longer than normal. Second, the runoff is variable as an effect of precipitation variation. According to MONRE,[8] the runoff changes will be significant after 2030 with 10%–30% reduction if the amount of rainfall reduces

by 10% and above. A significant change will be found in Northwest and South of the Middle with the contrast trend. The pattern in runoff changes depends on the regions and conditions within the climatic regions. Third, climate change can impact the groundwater resulting in the groundwater exploitation. If the annual rainfall and runoff do not change until 2020, the decrease in groundwater will be insignificant. However, if the runoff decreases to 15%–20% in the South plain and 30% in the dry season then the groundwater level can decrease by 11 m and 17 m in comparison with the normal, respectively. Finally, climate change can impact on the other aspects such as water pollution, salinity in the coastal zone, drought, and inundation.

In terms of agriculture, climate change can influence the planting seasons, crops yield, area under mangrove forest, pest and diseases, forest fires, and disaster risks.[11] Because of temperature increase in the whole country, area under tropical crop will expanded while the area under subtropical crop has reduced.[11] The boundary of tropical trees expands to the high mountains and northward. Domestic animal productivity and crops yield are reduced causing increases of frequencies, intensities, and variability of extreme climate events. The cultivating lands also reduced due to climate change, especially in the lowlands, coastal zones, and Red and Mekong river deltas.

4. Climate Change Adaptation in Agriculture and Water Resources

4.1. *Agriculture*

Policies to respond to climate change in agriculture include the development of an agriculture that is diverse, sustainable, good agriculture practices, and effective application of scientific achievements; new and high technologies and competitive in local and international markets;[6,10] construction of new rural areas with developed and modern infrastructure with relevant economic structure of agriculture–industry–services; ensure enough employment, hunger eradication and poverty reduction, a rural model of socially civilizing, democracy and equity; ensuring food security, ecological balance and bio-diversity.

Ministry of Agriculture and Rural Development and other ministries and sectors develop a program of the climate change adaptation, among, which noticeable contents comprised of the follwing:

- Develop and improve the framework of synchronous legal documents, laws, and circulars to ensure that the agriculture increases in commodity, diversity, and sustainable development;
- Amend and improve policies and mechanisms to support the application of new technologies, modern scientific and technical solutions to change cropping pattern, livestock and new farming techniques suitable for climate change;

- Develop and implement scientific and technical activities to adapt to climate change in agricultural sector;
- Plan effective use of agricultural land and water for fishery in consideration of immediate and potential impacts of climate change to ensure sustainable agricultural production.

4.1.1. *Specific activities for adaptation in agriculture*[11]

- Increasing irrigation water use efficiency;
- Development of crop varieties resistant to drought, salt, flood, disease, and pest;
- Developing appropriate farming techniques: Change in planting and harvesting times, soil fertility maintenance, fertilizer use and application, and erosion control;
- Increasing quantity and quality of processed animal feedings as well as selecting high productive breeds;
- Development of weather early warning system;
- Restructuring the agriculture production plan and cropping patterns;
- Protecting natural forests and enhancing reforestation/afforestation;
- Increasing the efficiency of using and exploiting the forest products with forest raw materials converted to forest products;
- Use of different variety of forest trees and crops plants;
- Development/improvement of national forest fire management plans;
- Protecting and developing mangrove forests and natural forests;
- Diversification and intensification of food and plantation crops.

4.2. *Water resources*

According to National Target Program,[6] key policy to respond to climate change is utilizing water resources scientifically, properly, and cost-effectively. To ensure sufficient safe water, the following key activities must be promoted:

- Develop and improve a legal framework including laws and regulations, circulars, and policies to adapt to climate change;
- Related ministries/sectors strengthen their management mechanism over water resources at different levels in the context of the climate change;
- Develop implementation plans and programs to respond to climate change in the field of water resources at all sectors and levels;
- Identify suitable scientific and technical solutions, such as overall plan for river basins, change specifications for water use and exploitation projects, methods for cost-effective use of water sources, protection and preservation of water sources, and water pollution control;
- Raise community awareness on methods for water use in response to climate change.

4.2.1. *Specific activities for adaptation in water resources*

- Building reservoirs, upgrading existing dykes;
- Effective use of water resources;
- Enhancing residual soil moisture through land conservation techniques;
- Reforestation/afforestation to increase natural water storage;
- Conducting studies in long-term water resources prediction;
- Improving the water management system;
- Enhancement of flood controls and drought monitoring.

5. Issues and Current Challenges for Adaptation

5.1. *Issues*

Climate change impacts most economic sectors, regions, and communities in Vietnam, and it requires actions by many stakeholders, scientists, policy-makers within a coherent framework. However, there are a number of barriers to implementing climate change adaptation in Vietnam, including (a) uncertainty in the climate change scenarios; (b) weak planning, institutional setup and coordination for responding to challenges of climate change; (c) limited awareness and poor data to support planning and implementation; and (d) weak capacity to undertake climate change impact analysis and identification of cost-effective adaptation measures.[5,8]

5.1.1. *Uncertainty in climate change projections*

In the first place, Vietnam faces the critical question over what climate change scenarios can be used for future planning and investments in both adaptation and mitigation. At the moment, climate change scenarios for Vietnam have been submitted to the Vietnamese government by IMHEN,[7] but it still need to be improved and updated in order to develop reliable climate change scenarios for the country, because there is still a great deal of uncertainty over the precise scale and nature of climate change and over its social economic effects.

5.1.2. *Need for planning and institutional setup*

Climate change requires specific actions by sectors and at localities. Climate change increases vulnerability, for example, it makes storms, floods and droughts worse; and it is caused by many activities in the global economy and increasingly also in Vietnam. This calls for specific actions by sectors and localities, to reduce risks and vulnerabilities and to start investing in the development of a low-carbon economy now. Ministry of Natural Resources and Environment (MONRE) will coordinate and facilitate sectors and provinces in formulating and implementing their own action plans on climate change. The key programs/projects at the national level

will be defined in the National Target Program to Respond to Climate Change (NTP-RCC) document and supporting implementation decisions. However, there is a need for high level leadership, an appropriate institutional setup, and a coordination mechanism for both policy-making and implementation because the issues go well beyond MONRE's mandate.

5.1.3. *Need for increasing awareness*

The implications of climate change for Vietnam are not well understood and there is a lack of awareness within the Government and the general public—outside a small scientific community and a limited number of agencies. However, both internationally and in Vietnam there are practical experiences with effective approaches to response to climate change—in particular, community-level strategies and interventions to cope with climate change effects including extreme weather events. Nevertheless, especially the national experiences and successes have not been well documented and learned. A thorough review and publication of these practices will help better raise awareness and advocate and shape policy development and planning to ensure integrated policy and people-centered approaches that build on poor people's priorities and capabilities, and that respond to their needs, in terms of risk reduction and also their energy security.

5.1.4. *Weak scientific capacity*

According to Government Resolution No. 60/2007/NQ-CP of 3 December 2007 and Decision No. 158/QD-TTg dated 2 December 2008, the NTP on Dealing with Climate Change has been implemented. This has the potential to become a sound policy framework to encourage sector ministries, provinces, and others to respond to the challenges of climate change. To develop a comprehensive and feasible NTP and action plans requires vulnerability and impact assessments and thorough analysis of sources of Green House Gas (GHG) emissions, now and into the future. Climate change is an environmental, social, and economic challenge. MONRE expertise is limited to hydrometeorology and environment, and its mandate and capacity is to provide reliable and timely weather and hydrometeorological information to other stakeholders. MONRE lacks substantive knowledge and experience on the social and economics fronts while climate change requires an integrated approach. Therefore, MONRE must work with other ministries and institutions to: (i) undertake vulnerability and impact assessments, identify evidence-based adaptation measures, and develop options for adaptation; and (ii) develop policies and mechanisms for low-carbon investments and controlling GHG emissions.

5.2. Challenges

According to Le,[4] the challenges for adaptation in Vietnam are as follows:

- Policies on climate change are more commitment than implementation, more qualitative than quantitative;
- Measures on climate change focuses mainly on short-term response to disasters and weather extremes rather than risk prevention, reduction, and adaptation;
- Weak mainstreaming climate change policies into national, sector, and regional development strategies;
- Lack of concern among local policy-makers, stakeholders, and people for climate change;
- Lack of awareness, knowledge, and assessment techniques relating to potential climate change impacts and related extreme events;
- Social and economic impacts of climate change and adaptation options have not been studied adequately;
- No cost assessments for climate change impacts;
- No cost/benefit analysis available for decisions on coastal protection/dyke strengthening;
- Limited financial means and human capacities for risk reduction and adaptation efforts.

6. Conclusions

With the complexity of its climate, topography, and long coastline, Vietnam is particularly vulnerable to natural disasters. Climate change will exacerbate vulnerability, particularly in coastal regions and influence most economic sectors, regions, and communities in Vietnam. It will be important to discover the current status of climate change and define current challenges for climate change adaptation.

Water resources and agriculture are influenced by climate change. Therefore, adaptation strategies for these sectors are important at all levels of the country. The key policy for climate change adaptation in water resources is utilizing water resources scientifically, properly, and cost-effectively. In terms of agriculture, the key policies for climate change adaptation are to develop diverse, sustainable, and good agricultural practices, and effective application of scientific achievements.

There are a number of barriers to implementing climate change adaptation in Vietnam. These include (a) uncertainty in the climate change scenarios; (b) weak planning, institutional setup and coordination for responding to challenges of climate change; (c) limited awareness and poor data to support planning and implementation; and (d) weak capacity to undertake climate change impact analysis and identification of cost-effective adaptation measures.

Overcoming the above barriers requires a multipronged approach that consists of (a) reducing the uncertainty in climate projections; (b) better planning and

institutional setup; (c) raising the awareness among diverse stakeholders; and (d) improving the scientific and technical capacity building among the researchers and technicians involved in climate projections and those involved in managing agriculture and water resources.

References

1. ADB, *The Economics of Climate Change in Southeast Asia: A Regional Review* (2009).
2. D. C. Hoang, V. L. Tran, Developing various climate change scenarios of 21 century for regions of Vietnam, *Scientific and Technical Hydro-Meteorological Journal* (541) (2006).
3. IPCC, *Intergovernmental Panel on Climate Change International Federation of Red Cross and Red Crescent (2002). Lessons from the Floods*, 4th Assessment Report (2007).
4. T. S. Le, *Climate Change Adaptation in the Mekong River Delta: Issues, Measures and Challenges* (Cantho University, Vietnam, 2008).
5. MONRE, *Vietnam Initial National Communication*, United Nations Framework Convention on Climate Change (Ha Noi, Vietnam, 2003).
6. MONRE, *National Target Program to Respond to Climate Change* (Full text) (Ha Noi, Vietnam, 2008).
7. MONRE, *Climate Change Scenario, Sea Level Rise for Vietnam* (Ha Noi, Vietnam, 2009).
8. MONRE, *Vietnam Second National Communication*, United Nations Framework Convention on Climate Change (Ha Noi, Vietnam, 2009).
9. D. N. Nguyen and T. H. Nguyen, *Climate and Climate Resource in Vietnam* (Scientific and Technological Publishing House, Ha Noi, Vietnam, 2004).
10. D. N. Nguyen, Climate Change (Center for Science and Technology on Meteorology, Hydrology and Environment—GEF—SGP) (Scientific and Technological Publishing House, Ha Noi, Vietnam, 2009).
11. M. C. Nguyen, Vietnam—Climate change adaptation: Challenges and opportunities, in *The 18th Asia-Pacific Seminar on Climate Change*, 2–3 March 2009 (Ha Noi, Vietnam, 2009).
12. V. T. Nguyen *et al.*, Activities of tropical cyclones in the North-West Pacific Ocean and the East Sea in 2008, *Scientific and Technical Hydro-Meteorological Journal* (578) (2009).
13. UNDP, *Reducing Disaster Risk, A Challenge for Development* (2003).
14. UNEP and Danida, *Climate Check in Vietnam*, Final country report (2005).

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Tables should be numbered with Arabic numerals in order of appearance in the text. They should be typed double-spaced on separate pages. Each table should have a short descriptive caption. Table footnotes (indicated by superscript lower-case letters) should be typed at the end of the table.

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Figures should be numbered (with Arabic numerals) in order of appearance and should have short descriptive captions. Line drawings must be professionally drafted originals, in black ink, with lettering large enough to be legible after a reduction of 50–60%. Photographs must be glossy prints. No figures should exceed 8.5 × 11 inch in size; they should be designed to fit the proportions of the printed page. All figures should have captions typed double-spaced on a separate sheet. Illustrations in colour can be accepted only if the authors defray the cost.

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About AJEDM

This is the first journal focusing on the environment and disaster related issues in the Asian region. Asia, being the center of urban growth in the last few decades, has also created severe environmental problems, and is prone to different types of natural disasters. This journal provides a forum to communicate research findings, not only through academic research, but also incorporating field based action research.

Theory of environment and disaster management is complex, and it becomes even challenging when it is linked to field practice. There often observed a gap between the theory and practice in the field of environment and disaster management. The goal of this journal is to establish academic linkages of field practices with specific emphasis on environment and disaster management in the Asian context.

The journal will have wider authors and readers, which will include the research and academic community, non-government organizations, policy makers and international organizations. Thus, the journal encourages the field practitioners and managers to share their thoughts and experiences and to interact with the academic community so as to fill the gap of research, education and implementation.

The topics will cover wider spectrum of environment and disaster risk reduction and management.

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- Community based environment and disaster management
- Climate change adaptation
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