Technology Transfer Perspectives Series

Technologies for Adaptation

Perspectives and Practical Experiences

UNEP RISØ CENTRE

ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

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Technologies for Adaptation

Perspectives and Practical Experiences

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Front cover photo – Local villagers in north Savaii Island, Samoa, are expanding the width and depth of their main drainage canal using local technology to adapt to a changing climate. The canal connects the ocean to an inland lagoon and mangrove system, on which the village relies for food and income. Photo credit: Lars Christiansen

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Foreword

Adaptation is a process by which countries, local communities and individuals find and implement ways of adjusting to the consequences of climate change. Adaptation to climate change involves identification and implementation of a diverse and wide range of technological options which can comprise "hard" technologies such as seawalls, dykes, irrigation techniques and "soft" ones such as crop rotation patterns as well as information and knowledge. Local communities have been coping with climate variability and change over generations by using accumulated indigenous knowledge and practices. While the concept of adaptation is not new and has nowadays become clearer, the concept of technologies for adaptation has not received proper attention. In the technology transfer debate, historically, the focus has been on mitigation technologies, with limited attention given to adaptation ones. The literature as well as operational experience with adaptation technologies has been quite limited; and there is currently a lack of clarity even in terms of basic definitions and concepts related to technologies for adaptation.

I am pleased to introduce this second edition of the Technology Transfer Perspective series with adaptation technologies as the theme. This current edition of the Technology Transfer Perspective series was commissioned to bring clarity on these issues. It brings perspectives of a number of practitioners, academia and policymakers on the concept of technologies for adaptation. One of its key objectives is to further facilitate Technology Needs Assessment (TNA) processes in countries and contribute to the international discussions on technology transfer for adaptation. The publication is brought out as a part of the technical support to the 36 countries participating in the global TNA Project, which UNEP and UNEP Risø Centre on Energy, Climate and Sustainable Development (URC) are implementing across Africa, Asia, the Commonwealth of Independent States and Latin America, funded by the Global Environment Facility (GEF) as a key element of the Poznan Strategic Programme on Technology Transfer. This UNEP–GEF project which aims to provide targeted financial and technical support to developing countries in carrying out improved Technology Needs Assessments for mitigation and adaptation constitutes an important component of UNEP's work on climate change.

It is hoped that the publication will add valuable insights to the adaptation technologies by helping to clarify conceptual ambiguities and generating debate among the stakeholders, which eventually may facilitate sharing and transfer of adaptation technologies so they can serve to the most vulnerable communities, particularly those whose lives and livelihoods rely on natural resources which are exposed to continuous threats due to climate change hazards.

The publication should be of interest to policy makers and planners in developing countries, NGOs and practitioners engaged in helping communities in adaptation, experts, and other stakeholders interested in the topic.

Ibrahim Thiaw

Sara Trærup, Anne Olhoff, and Lars Christiansen
UNEP Risø Centre

Editorial

Introduction

This article serves as an introduction to the second volume of the UNEP Risø Centre Technology Transfer Perspectives Series. The current volume is related to the global Technology Needs Assessment (TNA) project, financed by the Global Environment Facility (GEF) and implemented by UNEP Risø Centre. The nine articles in this volume present a range of valuable insights and reflections from practitioners, academia and policy-makers on the concept of technologies for adaptation with the objective of further facilitating national TNA processes, as well as contributing to a broader international discussion on how to define and operationalise the concept of technologies as it applies to adaptation.

The development and transfer of technologies is an area of increasing priority on the international agenda. Following COP 13 in 2007, emphasis on the financing of technology transfer was stepped up, with the Nairobi Work Programme becoming the focal point for discussions on technologies for adaptation (UNFCCC 2010). Furthermore, the adoption of the Cancun Agreements in December 2010, including decisions to create the Climate Adaptation Framework and the Technology Mechanism, has provided the Parties with an opportunity to scale up existing work on technologies for adaptation, including adequate technical and financial support. Previously, discussions on technologies focused primarily on mitigation, but the Cancun provisions brought technologies for adaptation squarely into the institutional set up for technologies.

Due to the limited attention given to adaptation technologies historically, little operational experience is available from activities focusing specifically on adaptation technologies. Definitions of technology and the concept of technologies for adaptation remain broad and provide limited guidance on their application in practice. In this way, the IPCC (2000), in its special report on Methodological and Technological Issues in Technology Transfer, defines technology as 'a piece of equipment, technique, practical knowledge or skills for performing a particular activity'. The UNDP Handbook for Conducting Technology Needs Assessment for Climate Change (UNDP 2010) defines the concept of technologies for adaptation very generically as follows: 'All technologies that can be applied in the process of adapting to climatic variability and climate change'. A UNFCCC report on the development and transfer of technologies for adaptation to climate change recognises the difficulty of defining the concept of adaptation technologies and proposes the following definition: 'the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change' (UNFCCC 2010).

Previous technology needs assessments on adaptation have been conducted with limited emphasis on further specifying the concept of technologies for adaptation. A review by Fida (2011) of existing technology needs assessments for adaptation reveals that, possibly as a result, countries do not make a distinction between 'adaptation technologies' and 'adaptation measures', but use the terms interchangeably. Vincent et al. (2011) argue that, as a consequence of the way technology has been interpreted through the existing technology transfer framework – and in turn has been reinforced by the architecture and criteria for adaptation finance mechanisms – 'hard' technologies for adaptation, such as equipment and infrastructure, are favoured over softer types of technologies for adaptation, including, for instance, management practices and institutional arrangements.

Most developing countries have already conducted vulnerability assessments and identified priority adaptation sectors and activities, for example, through National Adaptation Programmes of Action (NAPAs) and National Communications (NCs). Technologies are embedded in such priority areas and actions. The broad conception and definition of technologies for adaptation facilitates approaching and understanding technologies for adaptation and related technology needs in the wider context of development planning and policy-making, as advocated by, for example, Gross et al. (2004). Simultaneously, however, it raises a number of methodological and operational issues that it seems pertinent to resolve, to ensure that actions on technologies for adaptation contribute effectively and efficiently to adaptation and vulnerability reduction. More specifically, and given the potential for overlaps between general adaptation efforts and adaptation efforts targeting technology aspects, questions include:

- How can an added value of technology needs assessments be ensured and demonstrated?
- How can the conceptualisation of technologies for adaptation and the approach taken to assess technology needs for adaptation as opposed to 'regular adaptation' be further strengthened?
- What are the current experiences with the practical application of technologies for adaptation and for development, and how can they inform future action?
- How can technology needs assessments and action plans be coordinated with existing adaptation frameworks to avoid duplication of processes such as NAPAs and NCs?
- How is coherence and coordination between overall development planning and prioritisation and efforts on adaptation technologies and related needs best promoted?

These are among the issues addressed in this volume in the Technology Transfer Perspectives Series. To set the scene, key issues related to conceptualising and operationalising technologies for adaptation are introduced and discussed below in sections 2 and 3. Following this, the final section provides an introductory overview of the articles included in the current volume of the Perspectives series.

Conceptualising technologies for adaptation to climate change

Differences between technologies for mitigation and adaptation

To date, climate change adaptation has rarely been approached by applying a technology lens, although most adaptation initiatives involve some form of technology or technique. Conversely, technology plays a key role in climate change mitigation and has been the subject of considerable attention in science and policy. Hence, comparing the adaptation and mitigation approaches for dealing with climate change from a technology perspective may provide a useful starting point for conceptualising technologies for adaptation. Addressing adaptation technologies is often described as more diverse and complex than addressing mitigation technologies. The following examples of the implications of the different contexts and characteristics of mitigation and adaptation for addressing the issue of technology illustrate why this is the case:

a. Climate change mitigation is a relatively new field, whereas in many cases climate change adaptation is the continuation of an ongoing process, where several techniques for adaptation have been used for generations to manage risks imposed by, for example, weather variability and extremes (such as building houses on stilts to cope with floods).

b. Given the fuzzy boundaries between adaptation and sustainable development, unlike for mitigation technologies, few technologies can be defined as technologies for adaptation per se, with the exception of, for example, genetically designed seed varieties and coastal engineering technologies (UNDP 2010). Most adaptation technologies may be suitable for accomplishing wider sustainable development objectives (for example, methods for the improvement of water quality or access, malaria abatement etc).

c. Whereas mitigation technology aspects are generally linked to a limited number of sectors, including energy and industry, technologies for adaptation are equally relevant for a wider range of sectors, with water, health, agriculture and infrastructure as prominent examples. The technology approach for adaptation is therefore by nature more cross-sectoral, involving a multitude of different stakeholders within and across sectors and spheres of society.

d. Although the application of mitigation and adaptation technologies both need to be consistent with countries' development objectives, they follow different entry modes. The entry point for identifying, prioritising and implementing adaptation technologies is primarily vulnerability assessments or similar country appraisals, where the most vulnerable sectors, regions and communities constitute the basis for adaptation technology assessments.

e. Adaptation and mitigation technologies also differ extensively in terms of scale and scope. Adaptation technologies are often less capital intensive and more likely to be suitable for small-scale interventions, which underlines the need for them to be well-adapted to the local context (UNFCCC 2006). Moreover, adaptation technologies are much more diverse and may range from advanced technologies such as earth observation systems to simpler indigenous coping techniques, with a great variation between sectors, regions and countries. Whereas an energy-efficient lamp can be used across countries with minor modifications, adaptation usually depends on local social and environmental conditions.

f. Differences also prevail in terms of the potential for assessing the impacts of adopting specific technologies. The effects of investments in technologies for mitigation in terms of reduced greenhouse gas emissions can be assessed with a high degree of certainty. Assessing the effects of investments in technologies for adaptation in the form of avoided climate change damage or reductions in vulnerability is subject to significant uncertainty and is highly dependent on the availability of projections of future climate change and related impacts at high spatial resolution. Furthermore, achievements in terms of adaptation and vulnerability reduction cannot be assessed by any one single indicator or metric, unlike mitigation, which is measured in terms of tonnes of CO_2 equivalent emissions reduced (Tamiotti et al., 2009; UNFCCC 2006).

The above examples emphasise the need for further methodological and operational guidance on technologies for adaptation, not least in light of the increased priority given to the issue in policy forums and activities on the ground.

Categories of technologies for adaptation

It has become common practice to distinguish between three categories of technologies for adaptation: hardware, software and orgware. Hardware refers to so-called 'hard' technologies such as capital goods and equipment and includes drought resistant crops and new irrigation systems. Software refers to the capacity and processes involved in the use of the technology and spans knowledge and skills, including aspects of awareness-raising, education and training. Adaptation methods and practices that may not normally be regarded as technologies, such as insurance schemes or crop rotation patterns, may also be characterised as software (UNFCCC 2006). A third distinction which is equally important to the understanding of technologies for adaptation and their implementation is the concept of orgware, which relates to the ownership and institutional arrangements of the community or organisation where the technology will be used.

Table 1 provides examples of technology types for different sectors according to the above classification.

Many adaptation technologies have been utilised for generations to cope with climate variability and improve livelihood resilience to socio-economic stresses. A sector categorisation like that illustrated in the table above is the most commonly used when addressing technologies for adaptation. However, other categorisations may be more appropriate, depending on the specific context. An overview is provided by Markandya and Galarraga (2011) in this issue.

As the table illustrates, hardware may need to be combined with software and orgware to be adequately embedded in vulnerable communities and thereby ensure the acceptance and ownership necessary for their

Table 1. Examples of technology types for different sectors

Sector/Technology type	Hardware	Software	Orgware
Agriculture	Crop switching	Farming practices, research on new crop varieties	Local institutions
Water resources and hydrology	Ponds, wells, reservoirs, rainwater harvesting	Increase water use efficiency and recycling	Water user associations, water pricing
Coastal zones	Dykes, seawalls, tidal barriers, breakwaters	Development planning in exposed areas	Building codes, early warning systems, insurance
Health	Vector control, vaccination, improved water treatment and sanitation	Urban planning, health and hygiene education	Health legislation
Infrastructure	Climate proofing of buildings, roads and bridges	Knowledge and know-how	Building codes and standards

successful implementation. Furthermore, in many cases hard technology may not be central to addressing the adaptation needs of the most vulnerable communities. Access to locally available low-cost strategies and knowledge, i.e., software, and an enabling institutional context, i.e., orgware, may be more appropriate for addressing their adaptation needs in the short term, as well as the general development actions required for longer term and lasting vulnerability-reduction through increased adaptive capacity.

Technologies in the context of adaptation and development

In spite of the technologies being available, other potential problems associated with the use of, especially hard, technology for climate adaptation would remain, even if access to technologies were greatly improved (Klein 2011; Markandya and Galarraga 2011). It seems clear that a stand-alone technology, such as physical structures and equipment, is seldom sufficient by itself and without an enabling framework.

The vulnerability of countries to the effects of climate variability and change depends not only on their exposure to climate risks and the magnitude of impacts, but equally on the capacity of affected systems and societies to manage such risks and impacts. Adaptive capacity depends on a wide range of factors that are closely related to development, including income levels, education, institutions and governance, health, knowledge, skills and technological development. Klein (2011), in this volume, stresses that, while technologies can be very important for reducing vulnerability, their effectiveness depends on the economic, institutional, legal and socio-cultural contexts in which they are deployed. Klein (2011) furthermore stresses that a narrow focus on technological adaptation options can in some cases be detrimental to development and vulnerability reduction, particularly if there is a bias towards hard technologies, which Markandya and Galarraga (2011) and Vincent et al. (2011) (both in this volume) indicate might be the case. All of the above point to the need for the coordination and coherence of general adaptation efforts and those focused on technologies for adaptation, as well as to the importance of integrating these into broader development planning and decision-making.

Technologies for adaptation in the context of existing frameworks for adaptation

In the following, emerging trends on adaptation action are examined to illustrate challenges for coherence and coordination, focusing on the risks of overlap and duplication of effort.

International political negotiations and academic discourse on climate change adaptation are increasingly happening in two parallel, if not clearly distinctive tracks: a 'general adaptation track' focused broadly on adaptation to climate change and how it can be mainstreamed into development planning and policies; and a 'technology track' focused specifically on reducing vulnerability to climate change by facilitating the transfer and diffusion of appropriate technologies for adaptation. This duality in the adaptation discourse is also reflected in the global financial architecture for adaptation, with some funds making a formal distinction between the funding of 'adaptation' and funding of 'technology transfer for adaptation'. In this way, the UNFCCC Special Climate Change Fund includes two separate windows managed independently by the Global Environment Facility, one focused on adaptation and one on technology transfer (covering both mitigation and adaptation) (GEF 2007; GEF 2008).

Another manifestation of the distinction between 'adaptation' and 'technology transfer for adaptation' is the creation of two separate tracks of planning frameworks for developing countries under the UNFCCC process. On the one hand the National Communications (NCs) and later the National Adaptation Plans of Actions (NAPAs) were mandated to identify, prioritise and report on 'measures and activities addressing national adaptation needs' and to develop plans for their implementation. On the other hand, Decision 4 of COP.7 mandated the preparation of national TNAs, which are to '[…] identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties […]' (UNFCCC 2002).

However, when further investigating the conceptual definitions underlying these negotiating texts, academic discussions and the specific activities funded by the above sources, it is generally unclear exactly how the two 'types' of adaptation are distinguished from one another. While 'adaptation' is generally defined as an 'adjustment in ecological, social or economic systems' in response to climate change impacts, 'technologies for adaptation' are 'the equipment, techniques, practical knowledge and skills' that enable this adaptive adjustment (both definitions from IPCC 2000). In other words, the two concepts are not mutually exclusive: rather, 'technology' can be regarded as one of the means through which the process of adaptation is mediated, but the breadth of the definition of technologies for adaptation makes it difficult to differentiate between such technologies and the adaptation 'measures' and 'activities' referred to in the NCs and NAPAs. Accordingly, without a more clearly defined mandate, there is a risk that the TNA process for adaptation will significantly overlap with, or even duplicate, the adaptation assessments, planning and prioritisation processes that are already happening in most developing countries and vice versa. For example, the Cancun Adaptation Framework adopted at COP 16 invites all parties to 'plan, prioritise and implement adaptation actions', including enabling financial support for the preparation of 'National Adaptation Plans (NAPs)' in the Least Developed Countries with the aim of 'identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those needs'.

More clearly delineating and streamlining the mandates and objectives of the 'general adaptation track' and the 'technology track' in the global process of adaptation would facilitate maximising the effectiveness of the overall adaptation process in developing countries, avoid the duplication of activities and take advantage of synergies whenever possible. Specific considerations regarding coherence and coordination could be an integrated part of this exercise. Whether this is best done by formally merging the two processes into one – thus making the identification and prioritisation of technologies for adaptation an integrated part of national adaptation planning processes – or by maintaining two separate processes with clearly defined and mutually reinforcing mandates is an issue that merits further analysis, although it may be overtaken by political realities in light of the Adaptation Framework and the Technology Mechanism created in Cancun.

Overview of articles in this volume

This introduction has highlighted some of the main issues that it is important to take into consideration as efforts related to technologies for adaptation continue and are scaled up. Among these are the provision of further guidance related to conceptualising technologies for adaptation and their effective deployment. The need to approach technologies from a broader perspective not only of adaptation, but also of development has been put forward. Similarly, potential challenges arising from the two adaptation 'tracks' were highlighted.

The articles in this volume explore these and other issues in further detail, with an emphasis on the context of technology needs assessments and plans. They indicate that undertaking assessments of technology needs for adaptation is not straightforward. Previous experiences with TNAs have shown that the prioritisation and selection of technologies for adaptation are biased towards 'hard' technologies. In addition, assessments tend to be quite generic, with limited inclusion of details on national circumstances, including biophysical settings and the economic, institutional, legal and socio-cultural contexts in which technologies are deployed. In such cases the articles indicate that there is a particular need to reconsider technology options, as they may otherwise fail to support countries in adapting to climate change. Increased attention to soft technologies and framework conditions, including orgware, is generally advocated in these articles. A general observation from the articles is that the definitions and conceptual framework for adaptation technologies do not necessarily need to be narrower. However, technology approaches to adaptation would be facilitated if they were better defined.

The articles that follow are structured into three main sections. The first section focuses on the concept and context of technologies for adaptation and includes the following three articles. Sharma and Moener (2011) look at the evolution of intergovernmental negotiations on both adaptation and technology and seek to highlight the central issues within both these streams, and in particular on technologies for adaptation. Following that, it discusses the adaptation and the technology debates, and provides an outlook as to how technologies for adaptation may be dealt with following the 2010 Cancun Climate Change Conference of Parties. Klein (2011) then addresses the issue of technologies in the context of development, emphasising the need to mainstream climate adaptation into development, and linking technological and non-technological approaches. Adopting an economic perspective, Markandya and Galarraga (2011) introduce a conceptualisation of technology, defining it as the use or introduction of any physical technique or source of knowledge, specifically to address climatic factors, that is useful in the production or consumption of goods and services. While reviewing the implications of economic methods for the role of technology, the article stresses that using economic methods based on a comparison of the costs and benefits of selecting adaptation technologies can favour the more physical solutions.

The second group of articles in this volume goes into further detail regarding assessments of technology needs, focusing on the operationalisation of technologies in the context of existing needs assessments and plans. Fida (2011) analyses the process of TNAs for adaptation under the first phase of TNAs, the so-called 'top-up round' running from 1998 to 2008, with a focus on the challenges and lessons learned in those countries that have developed TNAs for adaptation. To inform and improve the process of conducting future and ongoing TNAs, Fida (2011) explores how countries have interpreted the concept of technologies for adaptation and the impact of this interpretation on the final outcome of the needs assessment for adaptation technologies. For example, the majority of first-phase countries chose to select hard technologies for adaptation, with less attention being paid to soft ones. This is also well illustrated in the subsequent article by Kossam (2011), which reflects upon Malawi's experiences of taking part in the first phase of TNAs. Kossam (2011) draws a number of lessons emphasising the softer and more organisational components of technologies that could help improve the effectiveness of future TNA exercises in Malawi, emphasising capacity-building, institutional continuity and the importance of integrating the process into existing climate change processes, such as the NAPA. Importantly, the final article under the second section, by Vincent et al. (2011), suggests that existing technology needs assessments are often too generic to provide sufficient detail of national contexts, while under-emphasising the soft and organisational components of technologies relative to the hard components runs the risk of impeding effective adaptation to climate change.

The third and last group of articles highlights practical experiences from working with technologies for adaptation. Experiences from Cambodia are shared in the article by Lopez et al. (2011). The article stresses that technologies for adaption to climate change already exist among Cambodian farmers and, therefore, the priority should be to expand and strengthen existing indigenous capacity and knowledge to adapt to climate change among the farmers. Huq and Rabbani (2011) provide a brief overview of adaptation technologies in agriculture and a specific case study from Bangladesh, again emphasising the need for policy and institutional support, as well as capacity, knowledge and skills development, especially at the user's level. The ninth and final article by Seenprachawong (2011) presents a case study from Thailand focusing on coastal adaptation technologies and draws lessons from how a successful enabling environment for coastal adaptation technologies was created in Thailand.

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References

Fida, E. (2011) Experiences in conducting Technology Needs Assessment (TNA)s for adaptation from non Annex I countries under the 'top up' phase. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Global Environment Facility, GEF (2007) Programming to implement the guidance for the special climate change fund adopted by the conference of the parties to the United Nations Framework Convention on Climate Change at its twelfth session. GEF/LDCF.SCCF.2/4, Washington, DC: Global Environment Facility.

Global Environment Facility, GEF (2008) Elaboration of a strategic program to scale up the level of investment in the transfer of environmentally sound technologies. GEF/LDCF.SCCF.5/4, Washington, DC: Global Environment Facility.

Gross, R. and Dougherty, B., Kumarsingh, K. (2004) Conducting technology needs assessments for climate change. UNDP/GEF.

Huq, S., Rabbani, G. (2011) Adaptation technologies in agriculture: an experience on economics of rice farming technology from climate prone area in Bangladesh. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Intergovernmental Panel on Climate Change, IPCC (2000) Special report on methodological and technological issues in technology transfer. A special report of IPCC Working Group III, published for the Intergovernmental Panel on Climate Change.

Klein. R. (2011) Adaptation: more than technology. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Kossam, F. (2011) Synergies between technology needs assessment and national adaptation plan of action in Least Developed Countries; A case study for Malawi. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experience. UNEP Risø Centre. Roskilde, Denmark.

Lopez, T. D., Ponlok, T., Dany, V. (2011) Technological Aspects of community adaptation to climate change in Cambodia. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Markandya, A., Galarraga, I. (2011) Technologies for adaptation: an economic perspective. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Seenprachawong, U. (2011) Technology for adaptation to climate change in Thailand. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Sharma, S. and Moener, A. (2011) Historic development of the concept of 'technologies for adaptation' in the international negotiations and its current application. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Tamiotti, L., Olhoff, A., Teh, R., Simmons, B., Kulaçoğlu, V. and Abaza, H., Trade and climate change. WTO-UNEP Report. WTO, Geneva. WTO ISBN: 978-92-870-3522-6, UNEP ISBN: 978-92-807-3038-8 - Job number: DTI/1188/GE.

Thorne, S., Kantor, B., and Hossain, I. (2007) Community Based Technology Solutions: adapting to climate change, a manual for community based development in the context of climate change. SouthSouthNorth, Cape Town, South Africa.

United Nations Development Programme, UNDP (2010) Handbook for conducting technology needs assessment for climate Change. UNDP.

United Nations Framework Convention on Climate Change, UNFCCC (2002) Report of the Conference of the Parties on its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001 – Addendum Part Two: Action Taken by the Conference of the Parties. FCCC/CP/2001/13/Add.1.

United Nations Framework Convention on Climate Change, UNFCCC (2005) Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005. FCCC/SBSTA/2005/10 UNFCCC.

United Nations Framework Convention on Climate Change, UNFCCC (2006) Technologies for adaptation to climate change. UNFCCC. Bonn, Germany.

United Nations Framework Convention on Climate Change, UNFCCC (2010) Report of the Conference of the Parties on its Sixteenth Session, held at Cancun from 29 November to 10 December 2010, Addendum, Part Two: Action taken by the Conference of the Parties.

Vincent, K., Joubert, A., Cull, T. (2011) Technology needs for adaptation in southern Africa: customising responses to different country contexts. In: Christiansen, L. et al. (ed.) Technologies for adaptation: perspectives and practical experiences. UNEP Risø Centre. Roskilde, Denmark.

Section I: The concept and context of technologies for adaptation


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Sudhir Sharma
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The evolution of 'technologies for adaptation' in the international climate change negotiations

Abstract

Under the United Nations Framework Convention on Climate Change technology constitutes one central pillar in addressing climate change. While the early focus laid on mitigation technologies, adaptation technologies gained momentum once countries recognised the necessity of adapting to observed and projected adverse impacts. This paper analyses the evolution of the technology and adaptation debates, before assessing the past, present and future of technologies for adaptation. While adaptation technologies have been marginalised in the discussions on adaptation and technology in the past, the 2010 Cancun Agreements put adaptation technologies squarely in the adaptation and technology institutional setup. In order to avoid overlooking or duplicating efforts in the future, the paper proposes the adaptation stream to focus on 'what' is needed in terms of adaptation actions and support, including adaptation technologies, and the technology stream to focus on 'how' to facilitate the development, transfer and diffusion of such adaptation technologies.

Introduction

From the very inception of the discussions on climate change, technology has been seen as a key pillar in addressing the mitigation of, and adaptation to, climate change. The culmination of negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) coincided with a move from end-of-pipe solutions to addressing local and regional environmental issues to transformations of production and consumptions patterns through the development and large-scale diffusion of technology. This is reflected in decision 13/CP.1, which made Chapter 34 of Agenda 21 on 'Transfer of environmentally sound technology, cooperation and capacity-building' its starting point.

The focus of technology leading up to the adoption of the Convention in 1992 was mainly on mitigation. Indeed, the early focus of the Convention was on mitigation, as seen in its ultimate objective set out in Article 2, which is 'to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. Even though the ultimate objective does refer to adaptation, it does so only in relation to the context and timing of mitigation and the avoidance of the adverse effects of climate change. This emphasis on mitigation reflects the early understanding that action on mitigation will make the need for adaptation obsolete and that mitigation is the most appropriate and desirable strategy to deal with climate change. Adaptation was perceived to be second best, that is, curing the disease instead of preventing it. As the science of climate change became more certain, the need for adaptation and the realisation that mitigation has not been significant enough to avoid climate change have brought adaptation and adaptation technologies on to an equal footing with mitigation in terms of priority.

This paper focuses on the evolution of the intergovernmental negotiations on both adaptation and technology and seeks to highlight the central issues within both these streams, and in particular on technologies for adaptation. To assist readers in understanding these developments, the paper begins by explaining the organisation of intergovernmental negotiations (section 2). Following that, it discusses the technology (section 3) and adaptation (section 4) debates. Finally, the paper focuses on technologies for adaptation and provides a perspective regarding how technologies for adaptation may be dealt with following the 2010 Cancun Climate Change Conference (section 5).

The organisation of intergovernmental negotiations on climate change

In its Article 7, the UNFCCC established the Conference of the Parties (COP) as the highest decision-making authority of the Convention. The COP regularly reviews the implementation of the Convention and makes decisions necessary to promote its effective implementation and to meet its ultimate objectives. In addition, the Convention established two permanent subsidiary bodies: one for scientific and technological advice (SBSTA) under Article 9, to assist the COP in evaluating scientific, technical and technological assessments and information, as well as in recommending policy options; and one for implementation (SBI) under Article 10, to assist the COP in reviewing the implementation of the Convention and in implementing decisions. Besides the SBSTA and the SBI, the COP, in accordance with Article 7, 'shall establish such subsidiary bodies as are deemed necessary for the implementation of the Convention'. The COP established such ad-hoc bodies at its first session (COP 1) in 1995 (the Ad Hoc Group on the Berlin Mandate - AGBM) and at COP 13 in 2007 (the Ad Hoc Working Group on Long-term Cooperative Action under the Convention - AWG-LCA). While the AGBM was responsible for drawing up the mitigation-focussed Protocol that was adopted at Kyoto, the AWG-LCA is responsible for developing the elements necessary for the sustained and effective implementation of the Convention, both now, and up to and beyond 2012.

The COP sets the agenda for its meetings based on issues that either arise from the review of the implementation of the Convention (for example, from reporting by Parties to the Convention) or from guidance or policy on strengthening the implementation of the

Convention in accordance with obligations under it. The agendas of the subsidiary bodies (SBs) are based on tasks assigned to them by the COP. Parties too can put items on the SB agendas based on their relevance to the particular body.

At its first session in 1995, the COP further defined the role of the SBSTA and the SBI in its decision 6/CP.1. With regard to technology, the COP included agenda item 'provision of technological and financial support to developing countries' flowing from the obligations under Articles 4.4, 4.5 and 4.7 of the Convention, under which the course of action for technological support was decided (decision 13/CP.1). SBSTA was tasked with laying the groundwork for performing its advisory function on technology transfer, research and development. The SBI was tasked with the review of information by Parties included in Annex II to the Convention[1] to assess the implementation of obligation of these Parties regarding the provision of technology to developing countries. Though there was no specific COP item on adaptation, adaptation was referred to under the SBI and SBSTA, including in the context of national communications, technology transfer and guidance to the financial mechanism on priorities for adaptation funding. In addition, future aspects of adaptation and technology are being discussed under the AWG-LCA.

Though the compartmentalisation of discussions on adaptation and technology exists under the SBSTA, SBI and AWG-LCA, there are formal as well as informal exchanges, for example, through joint workshops and forwarding of information, to help coordinate discussions under the various agendas and bodies.

Evolution of the technology debate

From the very outset, technology has been a central pillar in meeting the ultimate objectives of the Convention and is captured in various articles of the Convention (see box 1), as well as in the emphasis provided to it in the outcomes of the first COP (see decisions 13/CP.1(UNFCCC, 1995a) and 6/CP.1 (UNFCCC, 1995b)).

Box 1. Technology in the UNFCCC: relevant Articles of the Convention

Art. 4.1(c): All Parties shall 'promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases […]'.

Art. 4.5 sets out more specific obligations for Annex II Parties by asking them to '[...] take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention […]'.
Art. 4.7 links the efforts by developing countries to the availability of finance and technologies, thus emphasising the strong role of development and transfer in addressing climate change.

Over the years, the technology debate under the Convention has focussed on providing a policy framework to catalyse the development and transfer of technologies by various stakeholders. This is well reflected in decision 4/CP.7 (UNFCCC, 2001a): 'The need to strike a balance between strategic and operational actions, [...]' These lead to the preparation of reports, technical papers and other tools on specific issues that provide technical inputs and operational guidance for the benefit of Parties and other users. The debate focussed on the technicalities of technology transfer, but with the aim being policy formulation. Thus there is no accepted definition of technology under the Convention, let alone a definition of adaptation technology, although, in the initial phase, some of the technical work did attempt to define the term 'technology'. The analysis defined technology to include know-how and categorised it as covering both 'soft' (information, research, training, capacity-building and other similarly softer aspects of technologies) and 'hard' technologies (UNFCCC, 1996). Except for this brief focus on defining technology, the debate has evolved from identifying the knowledge gap and

1 For a list of Annex II Parties, see <http://unfccc.int/ 1348.php>.

taking actions to plug them to provide better enabling environments for technology transfer. The focus of the technology debate has mostly been on technologies for mitigation, though from time to time it did return to exploring specific aspects of adaptation technologies relevant to the technology transfer process. In light of the increasing understanding of the technology transfer process, the need to cut emissions drastically and the need to adapt to both observed and expected climate change impacts, in recent years the focus has moved to exploring the gaps in financing and measures to address these gaps in order to provide an institutional framework to help developing countries access, adapt and deploy environmentally sound technologies. In the past, the debate on technology transfer, although covering some issues related to its financing, had limited interactions with the financial mechanism. The only specific area where technology called for funding was Technology Needs Assessments (TNAs), which were funded through top-up funds provided along with funding for National Communications from the climate focal area of the Global Environment Facility (GEF) Trust Fund. Post-2007, with a focus on financing for technology per se, the GEF was requested to develop a Strategic Programme on Technology Transfer, which was adopted at COP 14 in Poznan in 2008. This programme is to provide resources for projects developed from TNAs prepared by countries, including for the preparation of TNAs. The issue of financial support to developing countries and the oversight of the financial mechanism are discussed under a separate agenda item.

Table 1 summarises the salient points of focus within the technology agenda item divided into four distinct phases: COP 1 to COP 4, COP 4 to COP 7, COP 7 to COP 13 and COP 13 onwards.

The discussion of technology thus focussed on broader policy issues, though from time to time its focus did turn to adaptation technologies, as discussed in section 5 below. The next section explores the focus of the adaptation discussions under the Convention.

The evolution of the adaptation debate

Even though the ultimate objective of the Convention refers mainly to mitigation, adaptation is referred to in a number of Articles (see Box 2).

Box 2. Adaptation in the UNFCCC: relevant Articles of the Convention

Art. 4.1 All Parties shall:
'(b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing […] measures to facilitate adequate adaptation to climate change';

'(e) Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods';

Art. 4.4 'The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects'.

Art. 4.8 In the implementation of the commitments in this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change […]'.

Art. 4.9 'The Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology'.

Table 1. A brief description of the evolution of technology discussions under the Convention

Period	Key focus of the technology discussions under the Convention
COP 1–COP1: the information gap assessment phase	• Emphasis on collecting, collating and making available information related to: ○ Existing and new environmentally sound technologies, ○ Terms and conditions for transfer of technologies, ○ National, regional or international programmes or initiatives on transfer of technologies ○ Ongoing efforts and cooperation in technology development. ○ Creating international technology information clearing house and a network of regional and national centres to complement it.
COP 4–COP 7: developing a framework for effective action on technology transfer	• Efforts to develop a framework for enhancing effectiveness of technology transfer (decision 4/CP.4, UNFCCC, 1998) which was formalized and adopted at COP 7. • Elements of the framework: technology needs and needs assessment; technology information (under which TT:Clear was established); enabling environment, capacity-building; mechanism for technology transfer, under which the Expert Group on Technology Transfer (EGTT) was established to provide the COP with scientific and technical advice on technology transfer (decision 4/CP.7, ibid.).
COP 7–COP 13: moving towards implementation	• Further deepening of the understanding of: actions by different players to enhance the effectiveness of technology transfer; capacities in countries to identify technology needs and develop projects to facilitate technology transfer; publicly owned technologies and their transfer; and the role of governments in fostering research and the development of technologies. • Exploring possibilities channelling financial support for effecting technology transfer (UNFCCC, 2005a). • Performance indicators to review the effectiveness of actions to enable technology transfer. • A long-term strategy for the development, diffusion and transfer of technologies.
Beyond COP 13: establishing technology mechanism to enhance action on technology development and transfer	• Focus on strengthening institutional structure to enhance action on development and transfer of technology. • Establishing a Technology Mechanism (decision 1/CP.16, UNFCCC, 2010),[2] including: ○ Technology Executive Committee (TEC), ○ Climate Technology Centre and Network (CTCN). • Operational modalities of the TM, including relationship between these new institutions, their governance and links with the financial mechanism (still being finalized).

2 The TEC is replacing the EGTT as an advisory body to the COP on technology issues, including by providing an overview of needs for the development and transfer of technologies for mitigation and adaptation and of policies and actions to boost technology cooperation; and by increasing public and private investment in technology development and transfer. CTCN will facilitate national, regional, sectoral and international technology networks, organisations and initiatives. Though CTCN is still being finalised, its roles will include: mobilising and enhancing global clean technology capabilities; providing direct assistance to developing countries; and facilitating prompt action on the deployment of existing technologies. Furthermore, the centre will encourage collaboration with the private and public sectors, as well as with academic and research institutions, to develop and transfer emerging technologies to the best effect.

Until 1998 there was no specific adaptation agenda item. The technological aspects of adaptation were discussed under the relevant technology agenda items, aspects related to funding adaptation activities were discussed under the relevant finance agenda items, and issues related to vulnerability and adaptation assessments were covered by the National Communications. In order to allow for a more holistic look at adaptation, the Parties identified the implementation of Articles 4.8 and 4.9 as a key area of the Buenos Aires Plan of Action (Decision 1/CP.4, UNFCCC, 1998). The Parties set up a programme of work, through which they sought to:

- Identify the adverse effects of climate change;
- Identify the specific needs and concerns of developing-country Parties arising from such adverse effects;
- Identify and consider actions, including actions related to funding, insurance and the transfer of technology, to meet these specific needs and concerns (Decision 5/CP.5, ibid.).

The adaptation debate gained momentum with the publication of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2001. The Parties realised that adaptation is no longer a luxury but a necessity, as the adverse effects of climate change could no longer be avoided. Many developing countries, in particular Least Developed Countries (LDCs) and Small Island Developing States (SIDS), called for adaptation measures to be implemented and for corresponding financial and technological support. Following 2001, the adaptation debate focused on ensuring further financial assistance, especially for particularly vulnerable developing countries such as LDCs and SIDS, and on enhancing the understanding of adaptation so as to identify what needs to be done to facilitate adaptation in developing countries.

Financing adaptation

At COP 7 in Marrakesh in 2001, the Parties in decision 5/CP.7 (UNFCCC, 2001b) requested financial support for a range of adaptation activities, including promoting the transfer of adaptation technologies. Given that support from the GEF, the main operating entity of the Convention's financial mechanism, for adaptation was very small in comparison to mitigation, the Parties established three adaptation-specific funds: the Least Developed Countries Fund (LDCF) to support the preparation and implementation of National Adaptation Programmes of Action (NAPAs); the Special Climate Change Fund (SCCF), with specific windows for adaptation and technology transfer; and the Adaptation Fund (AF) under the Kyoto Protocol to fund concrete adaptation activities. An LDC work programme was established to help these countries identify their immediate needs and priorities for adaptation, including adaptation technologies.[3] Following the request from the Parties for financial support for 'pilot or demonstration projects to show how adaptation planning and assessment can be practically translated into projects that will provide real benefits', the GEF established the Strategic Priority for Adaptation (SPA) in 2003.

The overall implementation of decision 5/CP.7, in particular the provisions for financial and technological support, proved slow, and requests for funding for many of the same activities were repeated in 2004 at COP 10 in the Buenos Aires programme of work on adaptation and response measures.

Improving the understanding of adaptation

More progress was made on the scientific and technical front of adaptation when in 2005 the Parties established a five-year SBSTA work programme on impacts, vulnerability and adaptation to climate change in decision 2/CP.11 (UNFCCC, 2005b). The programme, rechristened the Nairobi work programme in 2006 at COP 12 in Nairobi, seeks to assist all Parties, but in particular developing countries, including LDCs and SIDS, to improve their understanding and assessment of impacts, vulnerability and adaptation to climate change, as well as to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and

3 As of September 2011, 45 LDCs have submitted their NAPAs and are in the process of implementing their priority adaptation projects through the LDCF.

socio-economic basis. The Nairobi work programme is structured around nine work areas consistent with the action-oriented sub-themes of decision 2/CP.11, one of which is technologies for adaptation. As some of the activities under the work programme, Parties and organisations were requested to provide structured information on adaptation. They were provided with a template in which to fill in their adaptation measures in the categories that they saw fit best, including type of adaptation (1. approaches and strategies, 2. practices or 3. technologies). It is interesting to note that many Parties and organisations reported previously categorised 'soft' technologies under the category of practices, and technologies previously categorised as 'hard' technologies under the category of technologies. However, this bottom-up narrowing of the definition of adaptation technology from the adaptation side did not lead to any further theoretical discussions and/or work. The Parties reviewed the outcomes of the programme thus far in June 2011 and are expected to agree on a new set of activities at COP 17 in Durban, including possible activities in the area of adaptation technologies.

Adaptation post-Bali

With the publication of the Fourth Assessment Report of the IPCC in 2007, the urgency of dealing with climate change and adapting to the observed and predicted adverse effects of climate change became more pressing. In 2007 the Parties decided to launch the Bali Action Plan to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, both now, and up to and beyond 2012. One of the main pillars was enhanced action on adaptation, and the Parties agreed to consider:

- International cooperation to support urgent the implementation of adaptation actions;
- Risk management and risk reduction strategies, including risk sharing and transfer mechanisms such as insurance;
- 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;
- Economic diversification to build resilience; and
- Ways to strengthen the catalytic role of the Convention.

Negotiations on the adaptation aspects of the Bali Action Plan culminated in December 2010 with the adoption of the Cancun Adaptation Framework. The objective of this Framework is to enhance action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the Convention. The Parties also affirmed that adaptation must be addressed with the same priority as mitigation and that this requires appropriate institutional arrangements to enhance adaptation action and support (decision 1/CP.16, ibid., p. 5).

The Cancun Adaptation Framework includes a number of provisions which need to be operationalised and implemented over the coming years, including those related to:

- Implementation
    - o All Parties are to plan, prioritise and implement adaptation actions and to use existing channels to provide information on support provided and received for adaptation actions and on activities undertaken;
    - o A process to be introduced to enable LDC Parties, building upon their experience with the NAPAs, to formulate and implement national adaptation plans (NAPs); other developing country Parties to be invited to employ the modalities formulated to support these plans;
    - o A work programme must be drawn up to consider approaches to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change.

- Support
  - o Developed country Parties to provide developing country Parties, with long-term, scaled-up, predictable, new and additional finance, technology and capacity-building;
- Institutions
  - o At the global level: establishment of an Adaptation Committee to promote the implementation of enhanced action on adaptation in a coherent manner under the Convention;
  - o At the regional level: strengthening and, where necessary, establishing regional centres and networks, in particular in developing countries;
  - o At the national level: strengthening and, where necessary, establishing and/or designating national-level institutional arrangements.

Parties are expected to agree on guidelines and modalities for the NAPs, as well as on the modalities, procedures and composition of the Adaptation Committee at COP 17 in Durban. The next steps for addressing loss and damage are expected to be taken at COP 18 in 2012.

Technologies for adaptation: past, present and future

As discussed in the previous section, the discussions on adaptation focussed mainly on assessment, planning, implementation and financial support for adaptation and marginalised technologies for adaptation. As mentioned in section 3, discussions on technology were focussed on broader policy issues and to a large extent on mitigation. Thus the focus was not on defining or setting standards in qualifying a technology as either climate change technology or adaptation technology. Unlike some of the other conventions, which provide a top-down definition of what 'technology' covers in their specific context such as the Vienna Convention on ozone-depleting substances (ODS),[4] the UNFCCC does not offer such a definition, as mitigation and adaptation cut across all socio-economic sectors, and thus it would have been difficult to define or adopt a standard definition of what technology entails in the context of climate change. At various times, however, discussions under adaptation and technology concentrated on technologies for adaptation, as seen in Table 2.

As can be seen from the information provided in the box above, the focus lay on understanding adaptation and the specificities of adaptation technologies to be considered for transfer of technologies. Thus the focus was not purely on technologies or understanding what technology means in the context of adaptation. The definition of adaptation technology never went beyond the simple categorisation of 'soft' and 'hard' and a further sub-categorisation of 'traditional', modern', 'high' and 'future' technologies. The later sub-terms were never elaborated, and the COP never took a formal decision on these categorisations, which were merely made to facilitate debate rather than to provide a basis for policy guidance on enhancing technology transfer.

The early years: Understanding adaptation technologies

Early on the adaptation technology discussions did recognise the lack of information in this area, as most efforts across institutions and organisations were focussed on mitigation technologies, including the IPCC special report. Thus initial discussions on adaptation technologies were more an attempt to define opportunities for adaptation and in that context highlight the role of technologies. Discussions also highlighted the importance of 'systems to gather climatic information and decisions tools to identify and prioritise adaptation measures' as key adaptation technologies (UNFCCC 1997, ibid., Table 2), especially as most developing countries lacked a proper assessment of their vulnerabilities and adaptation requirements.

One of the initial areas of the SBSTA work programme on technologies was 'assessing adaptation strategies and technologies'. Thus the emphasis was on

4 In Article 1.3, the Vienna Convention states that 'Alternative technologies or equipment means technologies or equipment the use of which makes it possible to reduce or effectively eliminate emissions of substances which have or are likely to have adverse effects on the ozone layer.' Available at <http://ozone.unep.org/new_site/en/Treaties/treaty_text.php?treatyID=1>.

Table 2. Activities and reports related to technologies for adaptation

Year and Report Title	Focus of the report
1996 'Technology inventory and assessment: initial report on an inventory and assessment of technologies to mitigate and adapt to climate change' (ibid., p. 4).	This report focussed primarily on mitigation by identifying types of technologies and know-how useful to the Parties to the UNFCCC. It also highlighted the lack of information on adaptation technologies.
1997 'Adaptation to climate change: options and technologies. An overview paper' (UNFCCC, 1997).	This paper provided an overview of the current knowledge and understanding of climate change adaptation, and of the availability and applicability of adaptation technologies. Thus it helped in identifying technologies and understanding what the term 'adaptation technology' covers.
1999 'Coastal adaptation technologies' (UNFCCC, 1999c).	This was a follow up to the 1997 paper and focussed on adaptation measures for coastal zones and the role of technologies in that context, thus bringing in a differentiation between measures and technologies, without explicitly defining them. Note that other proposed focus papers on technologies relating to human health, food, security, urban areas and water were never prepared.
1998 'Technology and technology information needs arising from the survey of developing country Parties' (UNFCCC, 1998b).	This paper compiled the information on technologies needs identified by countries, including technologies for adaptation.
2000 IPCC 'Special Report on Methodological and Technological Issues in Technology Transfer', prepared upon a SBSTA request in 1995.	This report contained two chapters devoted to adaptation (human health and coastal adaptation), and other chapters that discussed both mitigation and adaptation (e.g. agriculture).
2005 Report of the seminar on the development and transfer of environmentally sound technologies for adaptation to climate change (UNFCCC, 2005c).	This report focussed on specific aspects of adaptation technologies to consider in addressing transfers of technology.
2006 'Application of environmentally sound technologies for adaptation to climate change' (UNFCCC, 2006).	This technical paper focussed on assessing generic concepts in understanding how to enhance the flows of technologies. In that context it examined the role, challenge and opportunity of technologies for adaptation in five sectors: coastal zones, water resources, agriculture, public health and infrastructure. It re-iterated the broad categorization of technologies for adaptation into 'hard' and 'soft' technologies, and within that into: traditional, modern, high and future technologies.
2007 'Synthesis report on technologies for adaptation identified in the submissions from Parties and relevant organizations' (UNFCCC, 2007, ibid).	This paper compiled information on identified adaptation technologies from submissions provided by Parties and organizations.
2008 Report of the Joint expert meeting on technologies for adaptation to climate change (UNFCCC, 2008).	This report focussed on work being carried out on the transfer of adaptation technologies in order to assess, identify and evaluate technologies for adaptation by sector and at the regional, national and local levels, harmonize and consolidate findings on technologies for adaptation developed under various processes, and identify further work on the transfer of technology. The focus thus was on looking at ways to improve understanding of the needed measures for strengthening the transfer of technologies for adaptation.

adaptation technologies to help build awareness, collect information and help assess and plan adaptation measures. This focus was expressed in 9/CP.3: '… accelerating the development of methodologies for adaptation technologies, in particular decision tools to evaluate alternative adaptation strategies […]'. One of the reasons identified for this focus was the lack of complete understanding among developing countries regarding their vulnerabilities to climate change and consequent adaptive needs (UNFCCC, 1999a), which was highlighted in SBSTA consultations with Parties on the development of an effective framework for implementing technology transfer (UNFCCC, 1999b).

Technology framework: Differentiating adaptation technologies from mitigation technologies

The adoption of the technology framework allowed for the identification of technological needs through the TNA process. As the general focus of technologies moved towards a greater understanding of the necessary elements for an effective technology transfer, the discussions on adaptation technologies moved towards understanding the similarity and difference with mitigation technologies to be kept in mind for an effective transfer of technologies. Conclusions included the following: '(i) adaptation has existed within many sectors in a different context, (ii) technologies for adaptation are needed all across, (iii) many technologies for adaptation are already readily available in developing countries, and (iv) technologies for adaptation are probably not likely to be as capital intensive' (UNFCCC, 2006, ibid.).

The focus also moved towards collaboration on various aspects of technologies for adaptation between different constituted bodies under the Convention. Collaboration concentrated on enhancing the understanding of adaptation-specific aspects to make the process of technology transfer more effective and on identifying opportunities for enhancing consistency among various groups working on adaptation-related aspects. With the adoption of the Nairobi work programme, this became the focal point for discussions on technologies for adaptation, so that the adaptation focus within the technology debate decreased.

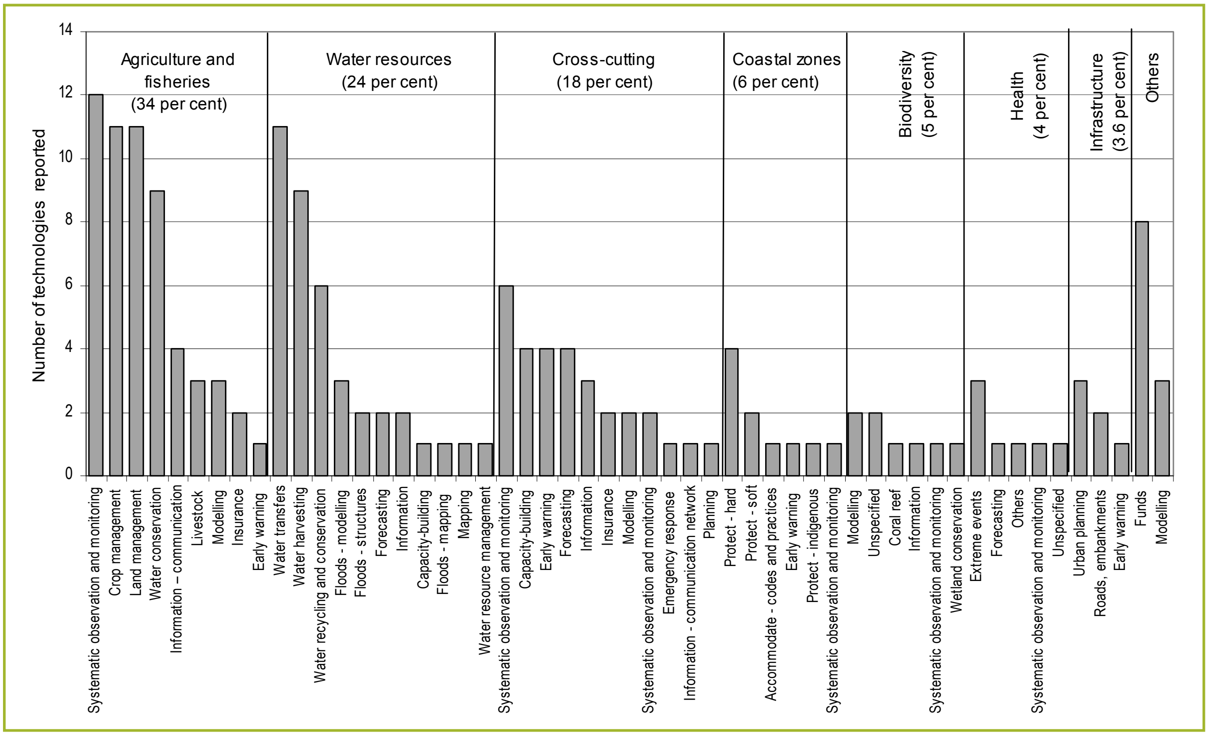
Bottom-up categorisation of technology

As mentioned earlier, the lack of information on country-specific technology needs was addressed through the TNA process. Countries reported their findings through TNA reports and other avenues under the Convention. As the Convention never defined technologies, except for a broad categorisation offered in some of the technical reports, countries had flexibility in defining their own understanding of technology for adaptation. The reports primarily presented the information by sectors. But the process of understanding adaptation did provide another framework for categorising information. This was reflected in a compilation of information in these reports on adaptation technologies, along with submissions by Parties related to access to adaptation technologies (UNFCCC, 2007, ibid., Table 2). Parties and organisations referred to over 170 technologies. As shown in Figure 1, the technologies most commonly reported were in the agriculture and fisheries sector (34 per cent), followed by the water resources (24 per cent) and cross-cutting technologies (18 per cent) sectors. A relatively low number of technologies were identified in the coastal zones (6 per cent), biodiversity (5 per cent), health (4 per cent) and infrastructure (3.6 per cent) sectors.

Specific needs indicated for the successful implementation of technologies for adaptation included building adequate human capacity and technical assistance, followed by information and awareness-raising and financial needs. In addition, Parties and organisations reported specific concerns and barriers relating to the successful implementation of technologies for adaptation, as seen in Figure 2.

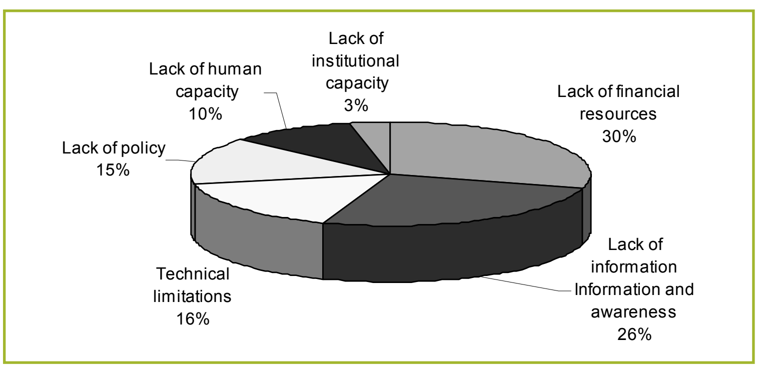
The report also indirectly took the process of categorising technologies further. The hard (new seeds) and soft (cropping pattern) technologies were equally reported (approximately 40 per cent each), and some 20 per cent of the technologies reported had both hard and soft characteristics. The report also provides clarification, through examples, of what is meant by 'modern' and 'high' technologies. It also categorised technologies into technologies for 'implementation', 'planning and design', 'raising awareness', and

Figure 1. Technologies commonly reported by Parties and organisations



Source: ibid.

Figure 2. Commonly reported concerns and barriers in the deployment of technologies for adaptation



'monitoring and evaluation'. Thus one could say that in climate change the process of defining technologies was more a bottom-up process than a top-down one. Also, the report highlights the difficulties involved in clearly defining these categories.

Finance for adaptation technologies

Section 4 presents details on the financing of adaptation, which also included adaptation technologies. In the initial years the focus of funding through the GEF was primarily on mitigation. This is partly due to the GEF instrument, which only requires the GEF to fund global environmental benefits, which are understood as being reductions in greenhouse gas emissions for climate change, thus excluding adaptation activities. Further, GEF funding in mitigation was built around specific technological areas, whereas, in the case of adaptation technologies, the funding was within the context of funding adaptation. Up until 2003, adaptation funding was primarily disbursed in the context of enabling activities, such as vulnerability and adaptation studies to support national communications, and relevant capacity-building. Since 2003, as mentioned in section 4, specific funding avenues for adaptation activities (the SPA, the LDCF, the SCCF and the Adaptation Fund) were established. Funding for adaptation was never specific to any type of adaptation technology but focused on specific adaptation activities, such as mainstreaming adaptation, or on sector-specific adaptation activities, for example, in sectors such as health, agriculture or water resources. The technology component of the SCCF, which could have been a specific funding avenue for adaptation technology, was used to support the Strategic Programme on Technology Transfer, with its focus on TNAs.

Adaptation technologies post-COP 13

With the adoption of the Cancun Agreements in December 2010, the Parties have been presented with an opportunity to scale up existing work on technologies for adaptation, including adequate technical and financial support. While technologies for adaptation have been marginalised in the discussions on adaptation and technology in the past, the Cancun provisions put technologies for adaptation squarely in the adaptation and technology institutional setup. This duplication partially comes from the larger concern of vulnerable countries that mitigation has always been accorded greater importance than adaptation and that the technological aspects of adaptation have not been given due recognition within the framework to facilitate technology access. It also arises from a clear lack of demarcation between adaptation and adaptation technologies. However, similarities in mandates under adaptation and technology in terms of institutional support and planning tools (see Table 3) risk either a duplication of work or a lack of action on either side, as it could be assumed that technologies for adaptation should be discussed under either policy stream.

Adaptation technologies: Avoiding losing them in translation

The Parties are aware of the overlaps and potential duplications. Over the course of three years of negotiations, the Parties met in joint adaptation and technology discussions to avoid overlaps, as well as to drop issues which were clearly in the realm of the other policy stream. The Parties do realise that an essential element of avoiding overlaps or duplicating effort is having clearly defined linkages between the different institutions. Identifying and clarifying the nature of these linkages and the modalities for interaction is not only essential for ensuring the overall coherence and efficiency of the post-2012 institutional architecture, but also for ensuring efficient and effective support to Parties' adaptation actions.

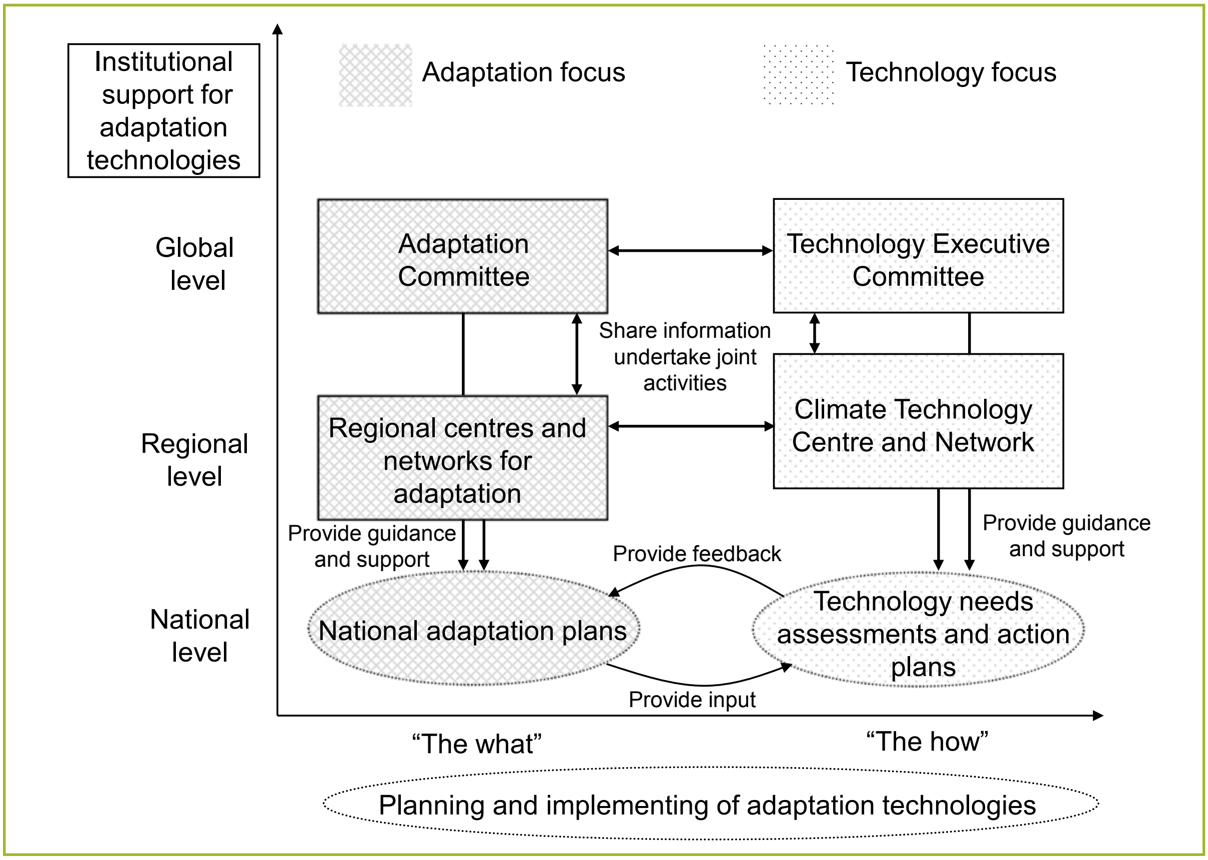
As mentioned in section 3, the focus of the technology stream is on 'how' to facilitate the transfer of technologies. To some extent in the early stages it also focussed on 'what' technologies (TNA process), but this was more in the absence of a formal process for adaptation to identify the 'what' of adaptation. The 'what', including to some extent of adaptation technologies, was taken up within the NAPAs by the LDCs and the Nairobi work programme.

The 'what' and the 'how' provide a natural dividing line for delineating responsibilities (see Figure 3). Thus in terms of planning and implementing technologies for adaptation and institutional support, the following division of work could be envisaged: processes and institutions focussing broadly on adaptation would concentrate on the 'what', that is, what is needed in terms of strategies, plans and actions, as well as financial and technological (identified adaptation technologies) support to enhance adaptation. Conversely, processes and institutions focussed on technology would concentrate on the 'how', that is, how to develop, transfer and diffuse the identified technologies needed for enhancing adaptation. Taking the TNA as a specific example, the identification of technologies would be better executed within the assessment and planning of adaptation measures, whereas evaluating barriers to identified technologies and steps to address these barriers naturally leans towards the domain of experts with understanding of technology development, demonstration and transfer.

Table 3. Overview of adaptation and technology mandates relating to planning and institutional support

	Adaptation	Technology
Planning and implementation	**National Adaptation Plans** • Means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those needs (decision 1/CP.16, para. 15).	**National Technology Plans for Adaptation** • Priority areas that could be considered under the Convention may include development and implementation of national technology plans for [..] adaptation (decision 1/CP.16, para. 120(g)).
Institutional support at global level	**Adaptation Committee** (decision 1/CP.16, para. 20): • Providing technical support and guidance to Parties on, inter alia, – Planning, prioritizing and implementing adaptation actions, including projects and programmes, and actions identified in national and subnational adaptation plans and strategies, NAPAs, national communications, TNAs and other relevant national planning documents; – Research, development, demonstration, diffusion, deployment and transfer of technologies, practices and processes; and capacity-building for adaptation, with a view to promoting access to technologies, in particular in developing country Parties; • Promoting synergy and strengthening engagement with [..] regional and international [..] centres and networks; • Providing information and recommendations [..] for consideration by the COP when providing guidance on means to incentivize the implementation of adaptation actions, including technology [..]; • Considering information communicated by Parties on their monitoring and review of adaptation actions, support provided and received, possible needs and gaps and other relevant information [..] with a view to recommending what further actions may be required, as appropriate.	**Technology Executive Committee** (decision 1/CP.16, para. 121): • Catalysing the development and use of technology road maps or action plans at the international, regional and national levels; • Providing an overview of technological needs and analysis of policy and technical issues related to the development and transfer of technologies for [..] adaptation; • Considering and recommending actions to promote technology development and transfer, in order to accelerate action on [..] adaptation; • Recommending guidance on policies and programme priorities related to technology development and transfer; • Promote and facilitate collaboration on the development and transfer of technologies for [..] adaptation between governments, the private sector, non- profit organizations and academic and research communities; • Seek cooperation with relevant international technology initiatives, stakeholders and organizations, and promote coherence and cooperation across technology activities; • Recommend actions to address the barriers to technology development and transfer in order to enable enhanced action on [..] and adaptation.
Institutional support at regional level	**Regional centres and networks for adaptation** (decision 1/CP.16, para. 30): • Facilitating and enhancing national and regional adaptation actions, in a manner that is country-driven, encourages cooperation and coordination between regional stakeholders and improves the flow of information between the Convention process and national and regional activities.	**Climate Technology Centre and Network** (decision 1/CP.16, para. 123): • Providing advice and support related to the identification of technology needs and the implementation of environmentally sound technologies, practices and processes; • Facilitating prompt action on the deployment of existing technology in developing country Parties based on identified needs; • Facilitating a network of national, regional, sectoral and international technology centres, networks, organization and initiatives.

Figure 3. Possible division of work between adaptation and technology work streams in support of adaptation technologies



For example, in its presentation on behalf of the LDC Group, Gambia presented its envisaged elements and deliverables for the NAPs during an expert meeting in September 2011. The elements included: developing a national adaptation framework and its relationship to the country's development goals; identifying adaptation activities, including capacity-building, policy reform, integration into sectoral policies and project-level activities; and developing and implementing a strategy and process for monitoring, reviewing and evaluating the plan.[5] Similarly the Least Developed Countries Expert Group suggested developing an overarching national adaptation strategy to lay out the national vision for medium- and long-term adaptation; to propose practical steps to realise that vision; to set the stage for developing sectoral/thematic/national adaptation plan(s), and to sets timelines and milestones for national actions on medium- and long-term adaptation.[6] Based on such broad and strategic adaptation planning, countries could then identify the technologies needed, among other measures to implement adaptation activities, and steps to develop and/or acquire them in specific technology action plans.

In terms of institutional support and the apparent overlaps in mandates, especially between the Adaptation Committee, the TEC and the CTCN, as a first step it would be worth sharing information and as a second step developing joint activities and work programmes so as to ensure synergy and coherence.

In terms of future financial support for technologies for adaptation, the Transitional Committee, which is tasked with designing the Green Climate Fund, is

5 <http://unfccc.int/files/adaptation/napas/application/pdf/the__gambia_presentation.pdf>.

6 <http://unfccc.int/files/adaptation/application/pdf/leg_presentation.pdf>.

currently considering the issue of thematic windows. While some members of the Committee propose windows for adaptation and mitigation only, others have called for a specific window on technology development and transfer. According to some members, such a technology window could cause an overlap between windows, which in turn could cause accounting difficulties and reduce synergies with other [..] adaptation activities (TC-3/INF.1).

It is for the Parties to learn from the past and ensure in Durban and beyond that technologies for adaptation are adequately addressed and supported technically and financially in the future, no matter whether this takes place under technology or adaptation.

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References

UNFCCC, 1995a. 'Report of the Conference of the Parties on its First Session, held At Berlin from 28 March to 7 April 1995, Addendum Part Two: Action taken by the Conference of the Parties at its First Session', pp. 40–41.

UNFCCC, 1995b. 'Report Of The Conference Of The Parties On Its First Session, Held At Berlin From 28 March To 7 April 1995, Addendum Part Two: Action Taken By The Conference Of The Parties At Its First Session', pp. 21–29.

UNFCCC, 1996. 'Technology inventory and assessment: initial report on an inventory and assessment of technologies to mitigate and adapt to climate change. Note by the secretariat. (FCCC/SBSTA/1996/4)'.

UNFCCC, 1997. 'Technological issues. Adaptation technologies. Technical paper (FCCC/1997/TP/3)'.

UNFCCC, 1998a. 'Report Of The Conference Of The Parties on its Fourth Session, held at Buenos Aires from 2 to 14 November 1998, Addendum, Part Two: Action taken by the Conference Of the Parties', p. 4.

UNFCCC, 1998b. 'Technology and technology information needs arising from the survey of developing country Parties (FCCC/SBSTA/1998/INF.5)'.

UNFCCC, 1999a. 'Development and transfer of technologies, status of the consultative process (decision 4/CP.4): Coastal adaptation technologies, other matters. Progress report - Note by the secretariat (FCCC/SBSTA/1999/11)'.

UNFCCC, 1999b. 'Development and transfer of technologies: progress report. Note by the secretariat(FCCC/SBSTA/1999/2).'

UNFCCC, 1999c. 'Coastal adaptation technologies (FCCC/TP/1999/1).

UNFCCC, 2001a. 'Report Of The Conference Of The Parties on its Seventh Session, held at Marrakesh from 29 October to 10 November 2001, Addendum, Part Two: Action taken by the Conference Of the Parties', pp. 22–31.

UNFCCC, 2001b. 'Report of the Conference of the Parties on its Sixteenth Session, held at Marrakesh from 29 October to 10 November 2001, Addendum, Part Two: Action taken by the Conference of the Parties', pp. 32–39.

UNFCCC, 2005a. 'Annual report of the Expert Group on Technology Transfer for 2005. Note by the Chair of the Expert Group on Technology Transfer (FCCC/SBSTA/2005/INF.10)'.

UNFCCC, 2005b. 'Report of the Conference of the Parties on its Sixteenth Session, held at Montreal from 28 November to 10 December 2005, Addendum, Part Two: Action taken by the Conference of the Parties', pp. 5–9.

UNFCCC, 2005c. 'Report on the seminar on the development and transfer of technologies for adaptation to climate change. Note by the secretariat (FCCC/SBSTA/2005/8)'.

UNFCCC, 2006. 'Application of environmentally sound technologies for adaptation to climate change' (FCCC/TP/2006/2).'

UNFCCC, 2007. 'Synthesis report on technologies for adaptation identified in the submissions from Parties and relevant organizations. Note by the secretariat (FCCC/SBSTA/2007/6)'.

UNFCCC, 2008. 'Report on the joint expert meeting on technologies for adaptation to climate change. Note by the secretariat (FCCC/SBSTA/2008/4)'.

UNFCCC, 2010. 'Report of the Conference of the Parties on its Sixteenth Session, held at Cancun from 29 November to 10 December 2010, Addendum, Part Two: Action taken by the Conference of the Parties'.


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Adaptation to climate change: More than technology[1]

Abstract

Technology can play a major part in reducing vulnerability to climate change. It can advance climate adaptation by developing and conveying information, by supporting planning and decision-making, and by confronting climate-related risks. However, technology by itself is not a panacea: the effectiveness of a particular technological adaptation measure depends on local and national circumstances, including the biophysical setting and the economic, institutional, legal and socio-cultural contexts in which it is deployed. Unless the technology's design and use is part of a broader strategy that acknowledges uncertainty and addresses the underlying drivers of people's current and future vulnerability, technology can become part of the problem rather than the solution.

1 The article draws from a chapter with the same title, published in the book 'Climate: Global Change and Local Adaptation' (Klein, 2011). I thank Springer for permission to use the material for this UNEP Perspective Series.

Introduction

Society has a long history of coping with and preparing for weather-related hazards such as floods, droughts and temperature extremes. Many past advances in, for example, food production, water supply and sanitation, and infrastructure development have been made possible because of technological innovation and deployment. Likewise, technology can be an important part of successful adaptation to climate change. Much of the technology needed for climate adaptation is already available; technological innovation will serve to increase the effectiveness and reduce the cost of existing technology, as well as to create new technological options.

A technical paper aimed at informing international climate change negotiators of the role of technology in climate adaptation, distinguishes between traditional technologies, modern technologies, high technologies, and future technologies (Klein et al., 2006). Traditional technologies consist of the many approaches that have been developed and applied throughout the centuries to adapt to weather-related hazards; examples include the building of houses on stilts and the construction of bunds, levees and dykes to protect against flooding. Modern technologies are those that have been created since the onset of the industrial revolution in the late eighteenth century. They make use of new materials and chemicals, new ways of generating power and facilitating transport, and improved designs.

High technologies derive from more recent scientific advances, including information and communication technology, earth observation systems and geographical information systems, and genetically modified organisms. Future technologies are those that are yet to be invented or developed. Examples might include a vaccine against malaria and crops that need little or no water. The limits to such future technologies, if any, are in the human imagination and ingenuity.

The IPCC Special Report on Methodological and Technological Issues in Technology Transfer provided examples of traditional, modern and high technologies for coastal adaptation (Klein et al., 2000). It made the point that technology can be employed not only to protect coastal populations against floods and other coastal impacts, but in any of the four steps that comprise the process of adaptation to climate change:

- Information development and awareness raising
- Planning and design
- Implementation
- Monitoring and evaluation

Technology for adaptation varies from hard to soft, from simple to highly complex, from inexpensive to very costly, and from locally available to requiring international technology transfer. Each type of technology has its own advantages and disadvantages. The suitability of any given technology for adaptation will depend on the location of deployment, the degree of climate change, and the prevailing social, economic, and environmental conditions and management practices within a country or community.

Technology: Part of the solution or part of the problem?

Many existing technologies can be used to adapt to climate change, but this does not mean that every vulnerable country and community has access to the technology that would best suit its needs, or to the knowledge that is required to develop or implement that technology. Effective adaptation by these countries and communities could therefore benefit from increasing current efforts of technology transfer.

Improving access to technology for adaptation is gradually becoming a priority for governments. For example, as part of the recent Cancun Agreements, negotiated under the United Nations Framework Convention on Climate Change (UNFCCC), countries jointly established a Technology Mechanism that explicitly considers adaptation along with mitigation. It will aim to:

> ... accelerate action … at different stages of the technology cycle, including research and development, demonstration, deployment, diffusion and transfer of technology … in support of action on mitigation and adaptation (para 115 of Decision 1/CP.16).

However, even if access to technology were greatly improved, other potential problems associated with the use of—especially hard—technology for climate adaptation remain. In addition to creating a false sense of security and the potential of lock-in (i.e., reducing future options), technology tends to address the symptom rather than the cause of people's vulnerability (e.g., a focus on protection of exposed areas rather than considering retreat and resettlement). Increased deployment of hard technology for adaptation might in fact worsen those problems if such lessons from the past 15 years are not heeded.

The traditional view of climate adaptation to climate change, developed some two decades ago, tends to assume that a national government is responsible for implementing technological adaptation measures (e.g., seeds, dams, irrigation schemes), which are selected on the basis of specific knowledge of future climate conditions. This technology-based view of adaptation has been challenged, for three reasons (Smithers and Smit, 1997; Burton et al., 2002; Adger et al., 2003).

First, even though climate science has made great advances over the past years, it is still often difficult to project future impacts of climate change in sufficient detail to justify investment in technological adaptation measures, in particular on a local scale. An important uncertainty relates to the effect of a changing climate on the frequency, magnitude and spatial occurrence of extreme weather events such as floods, cyclones, and droughts. Planning specific measures on the basis of projections of future climate conditions presents a great challenge, in particular for developing countries.

Second, technology can be important in reducing vulnerability to climate change, but it does have its limitations. Three issues need to be considered (Klein et al., 2007):

- Technological adaptation measures may be only partially effective if they do not address non-climate factors that contribute to vulnerability to climate change. For example, the technological improvement of a water supply system to ensure the availability of water during dry spells will be of limited benefit to people who do not have access to this water. The inequitable distribution of water rights or the price of the water may be more important factors than deficient water supply technology in causing vulnerability to drought.
- Technological adaptation measures may be ineffective if they are not suited to local conditions. For example, new crop varieties may indeed be very resistant to an increase in salinity, but their acceptance in a community also depends on their costs and availability, farmers' access to fertiliser and other inputs, storage constraints, ease of preparation, flavour, and so on.
- Technological adaptation measures may turn out to be maladaptive (i.e., increase vulnerability) if they are implemented without recognition of relevant social and environmental processes. For example, new coastal infrastructure could disturb the offshore sediment balance, resulting in erosion in adjacent coastal areas. Irrigation can lead to the salinisation of groundwater and the degradation of wetlands and can reduce subsistence farmers' access to groundwater and productive land.

Third, the traditional view of adaptation does not take into account the reliance of adaptation on development, and vice versa. People are vulnerable not only to climate change but also to a range of other stresses, depending on factors such as health status, education, and other socio-environmental circumstances shaped by political and economic processes. Government initiatives and technological measures designed to adapt to specific changes in climate may therefore fail to address the issues considered most urgent by local communities. These issues may include access to water and food, education, health, and sanitation concerns, as well as livelihood security.

The above three arguments lead to the conclusion that a climate adaptation strategy, in developed and developing countries alike, may need to include measures that address the underlying factors of vulnerability to climate change, particularly on a local scale. These underlying factors are typically structural issues characteristic of low development, such as high dependence on natural resources, resource degradation, inability to secure basic needs, and lack of information and capacity (Sperling, 2003). If hard technology is to be used as a means of reducing vulnerability to climate change, it needs to be accompanied by soft technology and non-technical measures (e.g., training and capacity building, institutional support) to ensure its accessibility, effectiveness, and suitability to local conditions.

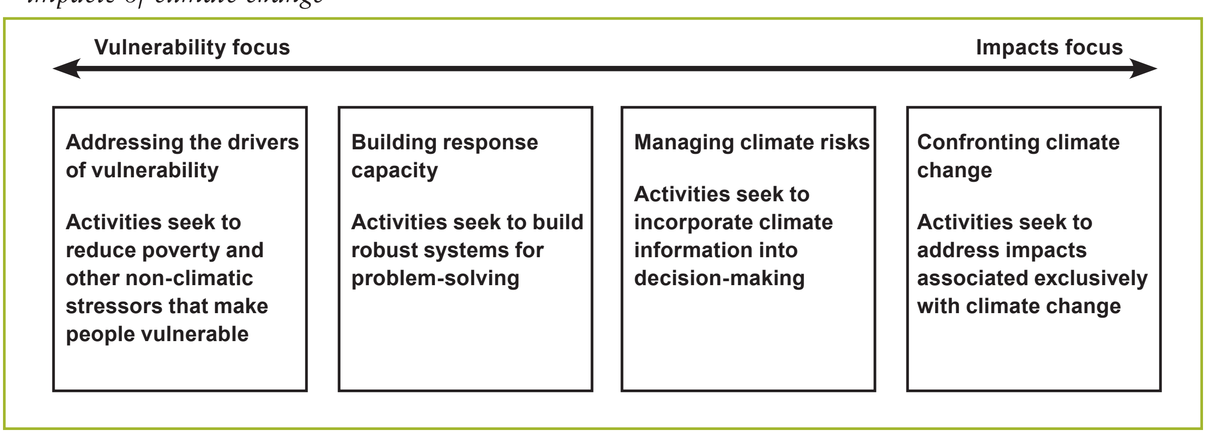
Adaptation and development: Towards a comprehensive adaptation strategy

The first empirical studies of climate adaptation have confirmed that the success of adaptation depends on broader development progress (Adger et al., 2007). When adaptation is limited to technological responses specific to climate change, it neglects the fact that vulnerability to climate change does not emerge in isolation. For example, it may be helpful to provide a rural household that grows a particular subsistence crop with a more salt-resistant variety, but a more robust and comprehensive adaptation strategy would seek to improve food security through a set of coordinated measures that include agricultural extension, crop diversification, integrated pest management, and rainwater harvesting. In addition, a poor rural household is more likely to use these options if it has a literate family member, access to investment capital through local financial institutions, can draw on relatively intact social networks, and hold policy makers accountable. In other words, it takes more than narrow, climate-focused measures to adapt successfully.

Another study provides further confirmation. It reviewed more than 100 initiatives in developing countries labelled as adaptation and found that in practice there was little difference between these initiatives and what can be considered good development (McGray et al., 2007). The difference lies more in the definition of the problem and the setting of priorities than in the implementation of solutions. The study presents adaptation as a continuum, ranging from more narrowly defined activities aimed specifically at dealing with the impacts of climate change to actions designed to build response capacity and address the drivers of vulnerability (see Figure 1). As the links between climate adaptation and human and economic development have become apparent, the term mainstreaming has emerged to describe the integration of policies and measures that address climate change into development planning and ongoing sectoral decision making. The benefit of mainstreaming would be to ensure the long-term sustainability of investments as well as to reduce the sensitivity of development activities to both today's and tomorrow's climate (Beg et al., 2002; Huq and Reid, 2004; Agrawala, 2005; Klein et al., 2007).

Mainstreaming is proposed as a way of making more efficient and effective use of financial and human resources than designing, implementing, and managing adaptation strategies separately from

Figure 1. Adaptation is a continuum from addressing the drivers of vulnerability to confronting the impacts of climate change



Source: McGray et al., 2007.

ongoing activities. Mainstreaming is based on the premise that human vulnerability to climate change is reduced not only when successful adaptation to the impacts takes place, but also when the living conditions for those experiencing the impacts are improved. Although mainstreaming is most often discussed with reference to developing countries, it is just as relevant to industrialised countries. In both cases it requires the integration of climate adaptation and sectoral and development policies. The institutional means by which such linking and integration is attempted or achieved vary from location to location, and from sector to sector, as well as across spatial scales.

Mainstreaming climate adaptation into development can mean different things to different people, depending on whether they hold a technology-based or a development-based view of adaptation. In the technology-based view, mainstreaming largely refers to ensuring that projections of climate change are considered in the decision making of relevant government departments and agencies, so that the technologies chosen are suited to the future climate. For example, in an area projected to experience more intense rainfall events, water managers would fit a drainage system with bigger pipes when replacing old ones, and agricultural extension services concerned about the possibility of increased drought would advise farmers to select crop varieties that are better suited to dry conditions. This type of mainstreaming has also been referred to as climate-proofing. It focuses on the two right-hand boxes in Figure 1.

In the development-based view, adaptation to climate change is not restricted to such activities as installing bigger pipes and planting drought-resistant crops but instead takes a comprehensive approach that seeks synergies with development. Mainstreaming then means, in addition to climate-proofing, to ensure that development addresses non-climate issues that cause people to be vulnerable to climate impacts (e.g., securing equitable distribution of water rights to groups exposed to water scarcity). This type of mainstreaming considers the full continuum of Figure 1. It recognises that adaptation involves many actors, from individual households to national governments, but that an enabling environment must be created to ensure that these actors can adapt successfully and without creating conflicts over the use of resources. This approach includes removing existing financial, legal, institutional, and knowledge barriers to adaptation and strengthening the capacity of people and organisations to adapt.

When linking adaptation with development in developing countries, it is important to recognise that poverty reduction does not always mean reduction of vulnerability: in that case, synergies between adaptation and development may not exist (Eriksen and Kelly, 2007). There are well-documented instances of activities aimed at reducing poverty that have in fact increased vulnerability. For example, the conversion of mangrove forests into shrimp farms may generate economic gains but leaves coastal communities more vulnerable to coastal hazards such as storm surges. New roads in developing countries often affect settlement patterns; even if a new road is constructed so as to withstand climate change, it is equally important to consider whether it would attract new settlers to areas exposed to natural hazards.

Lessons learnt

Since climate change was recognised as a global concern in the late 1980s, the major focus of decision-makers has been on mitigation rather than adaptation. However, interest in adaptation has increased since the beginning of the century, because even the most radical mitigation efforts can no longer avoid at least some level of climate change, and impacts have become inevitable.

The vulnerability of people and their activities to impacts of climate change is determined not only by the magnitude and rate of climate change, but also by non-climate factors, often linked to poverty and poor governance. Such factors increase people's exposure to hazards or limit their individual or collective ability to prepare for and respond to climate change. The existence of multiple and interacting stressors suggests that adaptation based primarily on the use of technology to address impacts (i.e., climate-proofing) may not always be the best approach to reducing vulnerability. Climate-proofing needs to be complemented with efforts to confront non-climate factors that create high vulnerability in the first place. Without taking a broader, development-based view of adaptation, technology deployment may well be only partially effective at best, or even maladaptive.

The need to link adaptation with development, and technological with non-technological approaches, has led to calls for integrating or mainstreaming climate adaptation into development. Similar calls have been heard before, for example in relation to integrated coastal management. More proactive and integrated planning and management of coastal areas has been widely suggested as an effective mechanism for strengthening sustainable development, and as providing an opportunity to consider climate risk and adaptation (Cicin-Sain, 1993; Ehler et al., 1997). However, a recent assessment of integrated coastal management efforts shows that the theory and rhetoric of the 1990s in part built on illusions that betray a lack of genuine understanding of the actors and actions involved (Billé, 2008). Progress in implementing integrated coastal management has therefore been slow.

Can a similar dichotomy between theory and practice be avoided for the mainstreaming of climate adaptation into development? There is no single magic formula for mainstreaming, but lessons can be learned from experiences in sustainable development, environmental policy integration, and integrated coastal management. One basic lesson is that climate adaptation is not a one-off activity, but a participatory process. It comprises more than the deployment of some hard technology; it also includes considering soft technology and non-technological options to complement and facilitate the use of technology.

The key message of this paper is that while technology can be important in reducing vulnerability to climate change, its effectiveness depends on the economic, institutional, legal, and socio-cultural contexts in which it is deployed. Adaptation is not the exclusive domain of engineers. If adaptation is to succeed, the greatest challenges are now to be addressed by social scientists.

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References

Adger, W. N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., Takahashi, K., 2007. Assessment of adaptation practices, options, constraints and capacity, in: Parry, M.L., Canziani, O.F., Palutikof, J.P., Van der Linden, P.J., Hanson, C.E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 717–743.

Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to climate change in the developing world. Progress in Development Studies, 3(3), 179–195.

Agrawala, S. (Ed.), 2005. Bridge over Troubled Waters: Linking Climate Change and Development. Organisation for Economic Cooperation and Development, Paris, France, 153 pp.

Beg, N., Corfee Morlot, J., Davidson, O., Arfrane-Okesse, Y., Tyani, L., Denton, F., Sokona, Y., Thomas, J.P., La Rovere, E.L., Parikh, J., Parikh K., Rahman, A., 2002. Linkages between climate change and sustainable development. Climate Policy, 2(2,3), 129–144.

Billé, R., 2008. Integrated coastal zone management: four entrenched illusions. Surveys and Perspectives Integrating Environment & Society, 1(2), 1–12.

Burton I., Huq, S., Lim, B., Pilifosova, O., Schipper, E.L., 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. Climate Policy, 2(2,3), 145–159.

Cicin-Sain, B., 1993. Sustainable development and integrated coastal management. Ocean & Coastal Management, 21(1–3), 11–43.

Ehler, C.N., Cicin-Sain, B., Knecht, R., South, R., Weiher, R., 1997. Guidelines to assist policy makers and managers of coastal areas in the integration of coastal management programs and national climate-change action plans. Ocean & Coastal Management, 37(1), 7–27.

Eriksen, S.H., Kelly, P.M., 2005. Developing credible vulnerability indicators for climate adaptation policy assessment. Mitigation and Adaptation Strategies for Global Change, 12(4), 495–524.

Huq, S., Reid, H., 2004. Mainstreaming adaptation in development. IDS Bulletin, 35(3), 15–21.

Klein, R.J.T., Alam, M., Burton, I., Dougherty, W.W., Ebi, K.L., Fernandes, M., Huber-Lee, A., Rahman, A.A., Swartz, C., 2006. Application of Environmentally Sound Technologies for Adaptation to Climate Change. Technical Paper FCCC/TP/2006/2, United Nations Framework Convention on Climate Change Secretariat, Bonn, Germany, 107 pp.

Klein, R.J.T., Buckley, E.N., Aston, J., Nicholls, R.J., Ragoonaden, S., Capobianco, M., Mizutani N., Nunn, P.D., 2000. Coastal adaptation, in: Metz, B., Davidson, O.R., Martens, J.-W., Van Rooijen, S.N.M., Van Wie McGrory, L.L. (Eds.), Methodological and Technological Issues in Technology Transfer, Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 349–372.

Klein, R.J.T., Eriksen, S.E.H., Næss, L.O., Hammill, A., Tanner, T.M., Robledo, C., O'Brien, K.L., 2007. Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. Climatic Change, 84(1), 23–44.

McGray, H., Hammill, A., Bradley, R., Schipper, E.L., Parry, J.-E., 2007. Weathering the Storm: Options for Framing Adaptation and Development. World Resources Institute, Washington, DC, USA, v+57 pp.

Smithers, J., Smit, B., 1997. Human adaptation to climatic variability and change. Global Environmental Change, 7(2), 129–146.

Sperling, F. (Ed.), 2003. Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation. AfDB, ADB, DFID, EC DG Development, BMZ, DGIS, OECD, UNDP, UNEP and the World Bank, Washington, DC, USA, xii+43 pp.

UNFCCC, 2010. The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention. Decision 1/CP.16, FCCC/CP/2010/7/Add.1, http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf, 2–31 pp.

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Technologies for adaptation: An economic perspective

Abstract

This paper discusses the role of technology in adaptation to climate change. Such adaptation requires, among other things, "technological" measures. Both hard and soft adaptation options have a technological component but in the case of soft options the technology is possibly indirect. For example, reducing water demand may be implemented by raising the tariffs, which in turn require changes in water metering or water saving devices.

An important pathway for technology to influence adaptation is through research and development. R&D is required to develop new methods and tools as the current set is inadequate to meet future needs with climate change. In addition some of the most effective technologies are not available in developing countries and thus technology transfer also has a major role to ensure availability.

The economic tools for selecting adaptation measures are based on a comparison of the costs and benefits. These can favour the more physical solutions (where measurement is relatively easy) compared to the softer solutions. To work effectively the range of options considered has to be as wide as possible. There is also the important issue of uncertainty, and the fact that knowledge about climatic impacts is continuously changing. These can be addressed using tools such as Real Options Analysis to determine the timing of major physical investments.

Introduction

It is now well acknowledged that policies and measures to adapt to climate change will have to take many forms. There is a distinction, for example, between "hard" engineering options, such as constructing a sea wall or building a reservoir and "softer" ones involving changes in behaviour, such as reducing the demand for water, making people better informed about climate change and extreme events and moving homes from areas likely to be affected by extreme weather events. Second there is the question of whether the adaptation consists of action before an event has occurred (i.e., pro-active) or after (reactive). Examples of the first would be anticipatory measures to reduce the risk of malaria by increasing the use of bed nets; examples of the second would be treatment of cases of malaria once they have occurred. Third there is the question of how to treat actions taken in pursuit of other goals, principally economic development, that have the added benefit of increasing the adaptability of the population to climate change and reducing its vulnerability? Certainly it is the case that a country with sound infrastructure and a higher level of education is better equipped to cope with climate change than one that does not have these features.[1]

Several other categorisations of types of adaptation options can also be distinguished (Burton et al., 1993; Carter et al., 1994; OECD, 2008; Smit et al., 1999 and 2000; Stakhiv, 1993; UKCIP, 2007):

- Based on the nature of agents involved in the decision-making can be private or public. Note that this distinction can also be referred as autonomous or "market driven" versus planned or "policy-driven" adaptation.
- Based on the spatial scope, adaptation measures can be localised or widespread. Adaptation is primarily local, since the direct impacts of climate change are felt locally and responses have to address local circumstances. However, for these measures to be implemented most often they must also be supported by national or even international policies and strategies.
- Based on the temporal scope, adaptation measures can be short-term or longer term. Again, we can illustrate this distinction with two types of adaptation measures that can be adopted by a power plant operator. The distinction between short-run and long-run adaptation has to do with the pace and flexibility of adaptation measures.
- Based on the form, adaptation measures can be infrastructural, behavioural, institutional, regulatory, financial and informational.
- Based on their ability to face associated uncertainties and/or to address other social, environmental or economic benefits, measures can be no-regrets options, low-regrets options or win-win options. No-regrets adaptation measures are those whose socio-economic benefits exceed their costs whatever the extent of future climate change. Low-regrets adaptation measures are those for which the associated costs are relatively low and for which the benefits under projected future climate change may be relatively large. Win-win adaptation measures are those that minimise social risk and/or exploit potential opportunities but also have other social, environmental or economic benefits.

In all these dimensions there is the thread of what role is played by technology. In order to answer this we need to have a clearer understanding of what we mean by that word. In some cases it is interpreted narrowly as involving the methods of production, consumption or distribution of goods and services and the sense is that a change in technology consists of new physical gadgets or tools. In fact technology is defined more widely: the Webster Dictionary states that it consists of "making, usage and knowledge of tools, techniques, crafts, systems or methods of organisation in order to solve a problem or serve some purpose".[2] This opens up an interpretation that includes changes in

1 The link of development to adaptation is sometimes referred to as the adaptation deficit. An adaptation deficit is said to exist when a county is inadequately adapted to current climate risks.

2 http://en.wikipedia.org/wiki/Technology

knowledge for different agents, as well as alterations in organisation and institutional practices.

In the context of adaptation the narrower definition of technologies would focus on the role of changes in methods of cultivation in agriculture to ones that are more resilient to climate variations, construction of buildings, roads etc., using methods that tolerate better the changes in climate (e.g., melting of permafrost or increased erosion as a result of heavier rainfall), and responding to groundwater contamination in coastal areas by building desalination plants. The wider definition would include the introduction of early warning systems where none existed before, increased use of water saving devices by households, introduction of insurance markets to spread risk and so on.

If we take the widest interpretation of technology then almost all activities relating to adaptation would come under that rubric and the discussion would simply come down to a discussion of what is good adaptation as opposed to what role technology has to play in adaptation. Thus we will take a narrower view of technology, as the use or introduction of any physical technique or source of knowledge, specifically to address climatic factors, that is useful for production or consumption of goods and services. This does not imply that the technique in question is new to the country, although there is a role for innovation and research and development in generating new technologies specifically for adaptation. With this definition we could leave out measures such as changes in energy or water saving information devices.[3]

With this in mind this note is structured as follows. Section II gives examples of the adaptation policies and measures that should be considered in each sector and the role of technology in these. Section III discusses the main issues that arise in evaluating the different options from an economic perspective and what issues arise with respect to the role and choice of technology. Section IV provides some concluding comments and suggestions.

Policies and measures for adaptation and the role of technology

Table 1 summarises the main sectors where adaptation to climate change will be required, and identifies those where there is a specific role for technology. Tables A1-A5 in the annex give specific examples of technological options for the different sectors. The extent to which technology is involved in each of the adaptation measures is indicated by the number of stars (one to three).

The tables show that technologies, even in the more narrow sense, have a major role to play in most sectors. This is particularly the case for coastal zones, water, energy and infrastructure sectors and in the case of adapting to extreme events. In addition we draw attention to the following:

a. Technology also has a role to play in providing information in a more effective way to agents who are likely to be affected. This is the case for coastal zones, agriculture and extreme events.
b. In some cases new techniques need to be developed so that responses are more effective. This is clearly an area where technology is involved and arises especially in the agricultural sector.
c. The choice of technology can be influenced by the range of options considered and in some cases technology options need to be evaluated in combination with management rules. Ebinger and Vergara (2011) offer some examples of energy systems where reductions of exposure to future risks to coastal power plants can be addressed through power plant siting rules to minimise flood risk or by installing solar photovoltaic technology to reduce effects of peak demand thus reducing the need for additional structures. As a related example a purely reactive approach aims only to alleviate impacts on installed technologies/supply systems, for instance

3 The distinction between a wider and a narrower definition is of course not precise. It is a matter of degree and context and one can think of items that could be considered under a narrow definition or could be excluded from that definition. An example would be water metering systems. Introducing these involves the use of technology but it also represents a measure that works through a change in behaviour.

Table 1. Adaptation options and role of technology

Sector/Impact	Examples of Policies and Measures	Examples of the Role of Technology
Coastal Zones	Policies fall under headings of *protect, accommodate* and *retreat*. Protect includes construction of sea defences etc. Accommodate include modification of land use so that it is not affected by SLR. Retreat means abandonment of an area for most uses.	Provide effective low cost defences Improve early warning systems
Agriculture	Changes in crops and cropping practices Development of new varieties that are more resilient to higher temperatures and water shortages Information to farmers about techniques and weather	Improve information delivery systems Produce new varieties and new cultivation methods
Water	Increase storage availability where needed Increase supply by irrigation Increase supply from desalination Reduce demand though changes in practices	All supply side measures entail some technology Demand side measures could be enhanced with technology
Extreme Events inc. Floods	Control of water flow systems Strengthening of infrastructure to withstand events Early warning systems Reclassification of land use and relocation of people	Control systems for water to mitigate flooding Early warning systems
Energy	Redesign hydro systems to take account of changed availability of water and flooding etc. Redesign other components to allow for extreme events, water availability	Technology is involved in all of these. Choices between them are influenced by how wide is the range of options.
Health	Reduce risks of vector borne diseases through anticipatory methods Reduce risks of water borne diseases through better water supply and sanitation Early warning systems for heat related effects Support systems for those affected by high temperatures	Technologies to reduce risks of infection.
Infrastructure	Design infrastructure to withstand climatic variations	Technology is involved in all of these
Tourism	Design of tourist facilities, taking account of changes in demand and period of demand	Mainly in ensuring physical structures are sound.

reinforcing existing energy infrastructure with more robust control solutions that can better respond to extreme weather-related service interruption. A pro-active approach on the other hand also looks at alternative technological solutions for energy provision that reduce the risks to existing infrastructure.

d. The situations where technologies play a relatively small part are in changing demand or in modifying land use to accommodate the climatic variations. Such measures will be required as a response to climate changes in coastal zones as well as to extreme events and possibly even agriculture.

Deciding on which policies and measures to use

The use of economic methods

From an economic perspective a simple approach would be to select the policies and measures on the basis of their respective costs and benefits. This can be seen in terms of an outline set out in the UK Climate Impacts Programme[4] (Boyd and Hunt, 2006) and is shown in Figure 1, with the total economic costs (vertical axis) against time (horizontal axis). The methodology outlines three steps:

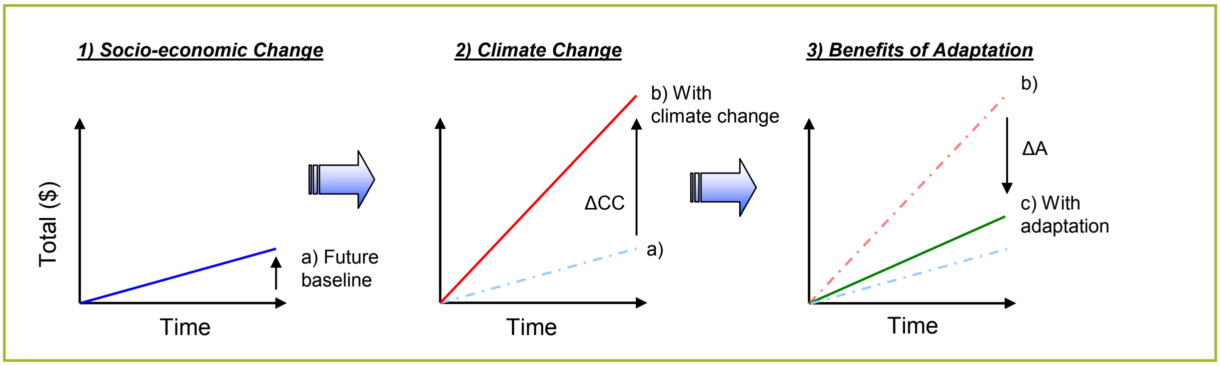
A. The economic costs in a given sector are first measured against a baseline estimating the value of impacts that would be expected to occur in the absence of climate change, shown with the blue line (a). This is because the economic impacts of any future climate are strongly influenced by socio-economic change, due to population growth, increased wealth, land-use change, etc. Thus even if there was no change from the current climate in future years, there would still be changes in the levels of economic costs (or to express another way, failure to account for these socio-economic changes assumes that climate change will take place in a world similar to today). Previous studies show that these future socio-economic changes are as important as climate change in determining future economic costs. These projections are, however, uncertain.

B. To this baseline the additional impact of climate change is added (ΔCC). This provides the total future effects (the gross effects) of socio-economic change and climate change together, shown in red (b). Note that in some cases, climate change may lead to economic benefits, not economic costs.

C. Adaptation is then introduced, which reduces the impacts of socio-economic and climate change downwards, shown in the green line (c). The reduction (ΔA) provides the economic benefits of adaptation and this can be compared against the costs of adaptation. The benefits will be estimated as the reduction in the potential damages as a consequence of the adaptation measures. The costs will be those directly or indirectly linked to the measure in place. Construction of a wall to avoid the impacts of sea level rise will avoid damages in important infrastructures (benefits) that can be easily estimated, while other negative impacts on ecosystems and cost attached to construction. Environmental economics provides several methodologies to measure damages in ecosystems. Some interesting studies on the topic include Galarraga et al., (2011), Markandya and Watkiss (2009) and Parry et al., (2009).

4 http://www.ukcip.org.uk/

Figure 1. Stylised framework for adaptation benefits



Source: Adapted from Boyd R. and A. Hunt (2006).

If the economic benefits of adaptation outweigh the costs, then there are net benefits. If not, then the potentially leads to mal-adaptation.[5] Importantly adaptation reduces the impacts, but it does not remove them completely. The line in green (c) refers to the level of adaptation where the marginal benefit of spending one more £ is equal to the marginal cost of the action and thus no more adaptation is justified in economic grounds. This still does not take us down to the original line (2) and thus even after adaptation there will be some residual damages. Such damages can be controversial. By definition they are damages that should not be adapted to and yet there will be situations where those responsible for public action will not wish vulnerable groups to suffer any damage as a result of climate change (see discussion below for the health sector). In such cases one could argue that residual damages should be zero on distributional grounds. But there will also be situations where reducing all damages caused by climate change is extremely costly and some residual impact after adaptation should be tolerated.

However, this simple framework comes up against several problems in practice:

- The future baseline (a) is not a business as usual scenario based on historic data. It is a complex construction, made difficult by the projections of development, socio-economic trends, autonomous adaptation, etc. There could also be some vulnerability to the current climate, often referred to as the 'adaptation deficit'.
- Unlike mitigation, which is associated with a common goal to reduce GHG, there is an extremely wide coverage of potential effects to adapt to. The effects of climate change shown by (b) can therefore include different types of climate signals (average temperature increase, seasonal changes, probabilities of extreme events, etc.) acting individually or together, and varying strongly with time period and geographical locations. The benefits (ΔA) could thus also be multi-dimensional.
- There is often a problem in defining or attributing adaptation benefits (ΔA). This can be particularly difficult for adaptation due to confounding factors, and it is not helped by the general lack of existing ex-post data to demonstrate benefits. In some cases, it is difficult to distinguish whether an action should be classified as development or adaptation to climate change (the distinction between the two is often blurred) or similarly between an intervention to the current climate or future climate change.[6]
- While adaptation reduces impacts, it does not reduce them entirely and thus there are still residual impacts and economic costs (c), even after adaptation. Studies which focus only on the costs of adaptation therefore omit these residual costs. This point is relevant in any discussion of adaptation funding, as the costs of residual impacts are additional to the costs of adaptation. Studies often do not distinguish these components, or often do not report them cleanly.
- There are major spatial and temporal issues. Climate change (ΔCC) presents a changing problem over time and any adaptation response needs to be a dynamic response, rather than a single static consideration. The figure also presents all changes as occurring linearly over time, when in reality, this is unlikely to be the case for costs or benefits: the marginal costs of adaptation may often rise non-linearly with each progressive unit of adaptation implemented (and conversely the marginal benefits may fall non-linearly). There can be thresholds of effects to contend with, rather than smooth future outcomes, and there are potential limits or thresholds for adaptation.

5 The term mal-adaptation is controversial as there are several definitions and Types of it (Barnett and O'Neill, 2010). One of these states that mal-adaptation occurs if the economic costs of the action are high compared to other alternatives. An alternative is to refer to mal-adaptation as actions that impact adversely on, or increases the vulnerability of other systems. We consider the first definition as useful, indicating a misuse of resources.

6 Previous UNFCCC analysis has defined actions by a declaration of intent, e.g., for the purpose of adaptation, but this leads to other issues in itself.

In addition to the above the following also need to be taken into account:

- The costs and benefits are extremely site specific. For mitigation there are common non-monetary units of 'benefits' that apply irrespective of location and technology, i.e., a tonne of GHG abated, and also common metrics for comparing the costs of measures, in terms of £/tCO_2e abated. There are no such comparable units of adaptation. Indeed, the only common metrics are monetary (£). However, there are a wide range of 'benefits' that are not easy to monetise, including non-market sectors (e.g., ecosystem services), adaptive capacity and the value of information. Moreover, physical (and economic) benefits of adaptation vary with sector and they vary with location, technology, etc.
- Many adaptation responses involve linkages with other costs and benefits, i.e., other than solely with respect to future climate change. There is a need therefore to consider indirect effects, cross-sectoral linkages and even wider economic costs. Adaptation actions that are beneficial to some groups may be harmful to others or may have negative effects in other sectors.
- Many studies highlight that common objectives for adaptation are to be efficient, effective and equitable as well as feasible, politically legitimate and perhaps most importantly, flexible (e.g., Adger et al., 2005; Möhner and Klein, 2007; Smit et al., 1999). An economic analysis will need to recognise these aspects. Thus, as for most project appraisals an adaptation policy or option will consider not only the aggregate net costs and benefits but may also the distribution of these costs and benefits.
- The fundamental issue of uncertainty pervades the entire framework and analysis of adaptation. This starts with – but is not limited to – the projection of future climate. It includes the uncertainty with the projection of socio-economic trends, development, physical impacts, monetary valuation etc. While Figure 1 presents the framework as single central lines, in practice there will be considerable ranges around costs and benefits. Indeed, there will often be effects where information on risks, levels of benefits, etc., are simply unknown with respect to physical or economic outcomes.

Implications of economic methods for the role of technology

As far as technology is concerned these comments on the economic methods have the following implications:

a. There is a tendency in many cases to go for the "hard" physical solutions, which means that the softer options do not get fair consideration. In the case of coastal zones for example, the effects of sea level rise and storm surges can be reduced by improving the state of wetlands and impacts can be mitigated by changes in the use of land near the coasts. Yet, such options are often neglected at the expense of more costly engineering ones, where "technological" solutions are emphasised. However the distinction between hard and soft options is not the same as that between technological and non-technological solutions. Many of the softer options also have a technological component, only that it is one removed from the problem at hand. For example actions to recover wetlands or arrest soil erosion by environmental means such as tree planting can also involve new technologies.

b. There is also evidence that research and development (R&D) resulting in new products and technologies needs to be part of an optimal adaptation plan. For example in the case of agriculture there is strong evidence in general that R&D in producing new varieties that are heat resistant can yield significant benefits in excess of costs Agrawala and Fankhauser (2008). Likewise in the case of energy R&D clearly has a role to play. Ebinger and Vergara (2011) identify six research priorities including improving understanding of cooling efficiency potential; progressing in water demand and water use information systems; understanding climate change impacts on local wind and solar energy production; improving technologies for energy supply systems; understand the role of interconnections and distributed generation and assess the impacts of extreme weather events on sub-sea pipeline systems. The evidence does not suggest, however, that these 'technological' benefits are necessarily higher than those from less technological measures such changes in planting dates and crops. Both go together and the right combination has to be decided on the basis of their respective cost and benefits.

c. Softer options such as demand management and changes in land use have strong co-benefits such as less environmental damages and less waste of resources. Often such advantages are ignored because such benefits are not accounted or measured. Examples would include the water sector and response to extreme events. Some interesting examples include seasonal forecasting, which has been improved at the farmer level through research, networks and dissemination of rain information to increase productivity (the Climate Forecasting for Agricultural Resources project) in Burkina Faso; the Floating Agriculture project in Bangladesh based on traditional practices as an option to adapt to increase flooding circumstances; and new irrigation methods learned by Mexican farmers to reduce water stress (UNFCCC, 2006). All these also have important technology components.

d. The application of technology will be an iterative process with many changes taking place continuously through time as less costly and more innovative solutions are developed (UNFCCC, 2006). This is a reason for not "locking in" current technological solutions and retaining flexibility in response wherever possible (Markandya and Watkiss, 2009). In some cases flexibility can be obtained by choosing the softer options; in others there may actually be a premium for the flexibility that we pay now (in terms of design), so that modifications can be made in the future when new information becomes available. One method for doing that is through Real Options Analysis. Box A describes how this might work to help us select the appropriate technology.

Box A. Real options analysis: How it can determine technological options

Consider the case where there are two options for protecting a coastal area against sea level rise. The first is to build a sea wall to protect against a one metre rise by 2030. The second is to build a wall that protects against a one metre rise but also includes stronger foundations such that the wall could be raised to protect against a two metre rise should that be discovered to be necessary in 2030. We assume that the higher wall will only be built in 2030 if it is found to be necessary and that we will know for certain whether it is required in 2030.

Table 2 lays out some costs and benefits. The trade-off is between incurring a higher cost now for the option of being able to protect against a higher risk in the future. The cost of a simple wall now is 100, while the more flexible wall is 130. If the simple wall is put up the benefits with a one metre rise are 200, but if the seal level rise is 2 metres, we will be forced into a retreat (it will be too late to put up a protective barrier when we get to know about the 2 metre rise) and there will be a loss of 200. With the flexible wall this second eventuality is avoided, but at an additional cost of 50.

The comparison hinges on what the probability is of a 2 metre rise. With a small probability of 5% the simple wall option has a higher expected value. With a probability of 10% the two options have the same expected value and with any probability greater than 10% the flexible option is preferred. Of course we may choose the flexible option even with a 5% probability of the 2 metre rise if we place enough of a premium on protection against the risk or having to retreat.

e. In the case of the energy sector Ebinger and Vergara (2011) define technological responses as the capacity to "invest in new or adapted technologies to reduce the vulnerability of energy assets or strengthen their resilience to the consequences of global warming". Technology in a narrow sense of the term plays a major role in all these options, including:

- Physical protection: retrofitting of energy infrastructures in coastal zones or preparing them for more intense flooding and winds.
- Improvements in design to increase resilience of energy systems.
- New technologies such as smart grids to enhance the integration of renewable energies in traditional energy systems by ensuring stability of the systems.

Although these technological options are important, they are not the only ones and it is critical that other alternatives (both technological and non-technological) are considered at the same time. These include the use of insurances and or derivative markets to address the increased risks of damage from extreme events. Box B describes some of these alternatives, which act both as substitutes for technological alternatives, as well as guiding such alternatives in the right direction – i.e., towards the more cost effective technological solutions.

f. When dealing with infrastructure more generally options consist of combinations of changes in organisation as well as modifications in design of building and transport systems to make them more resilient to climate change (see Table A5). As with the other sectors a combination of the two will be required and appropriate changes in organisation will feed through to better choices of technologies. As far as technological choices are concerned solutions will tend to be determined by acceptable risk; as climate change increases the risks of things like subsidence or structural failure, additional measures are needed to reduce that risk. Rules for the use of such methods are well developed and can be applied to climate adaptation.

g. To understand the problem, we need to look for appropriate technologies that fit the needs and idiosyncrasy of the country (analytical techniques that reflect the local nature are necessary, ECA, 2009) in which they will be introduced and that are cost effective. As technology used in a given location might be properly transferred to somewhere else "technology transfer" will play a major role. This is one of the main issues being discussed at the UNFCCC and Kyoto Protocol meetings. In fact, the Cancun meeting (COP 16) agreed on the creation of the so called

Table 2. Real options analysis: Costs and benefits

	Period 1		Period 2			Probability of 2 M Rise	Expected Value
	Costs	Benefits	PV of Costs	PV of Benefits			
				1m Rise	2M Rise		
Option 1	100	0	0	200	-150	5%	82.5
Option 2	130	0	50	200	200	5%	67.5
Option 1	100	0	0	200	-150	10%	65.0
Option 2	130	0	50	200	200	10%	65.0
Option 1	100	0	0	200	-150	15%	47.5
Option 2	130	0	50	200	200	15%	62.5
Option 1	100	0	0	200	-150	25%	12.5
Option 2	130	0	50	200	200	25%	57.5

"Climate Technology Centre and Network" as one of the significant contributions to global climate policy. The aim of this centre is to match the demand and the supply for technologies with a special emphasis in the technologies that are available in developed countries to be effectively (and also cost-effectively) transferred to developing ones. The Clean Development Mechanism of the Kyoto Protocol, The Poznan strategic programme on Technology Transfer or the Handbook on Conducting Technology Needs Assessments for Climate Change (UNDP, 2010) are examples of the efforts made at United Nations framework to deal with this issue. This transfer has a major role not only in mitigation policies as has been addressed several times but also in adaptation strategies (Metz et al, 2000). Agriculture, health or water sectors are some of the most sensible ones to this transfer.

Box B. Insurance markets can act as low cost adaptation options and help guide technological choices

Adaptation solutions also include the use of insurances and or derivative markets to address the increased risks of damage from extreme events. These can often be designed as weather derivatives for those high probability events or insurances for those significant damage risks with low probability. Examples include:

- Customised weather coverage to stabilise revenues and protect against income loss due to weather changes affecting power generation; to control costs associated with purchasing power to address shortages in supply due to weather-related events; and to manage cash reserves in a more effective way.
- Other services provided by The World Bank Group to mitigate the impacts of disasters and weather events include:
    - o Catastrophe Risk Deferred Draw-down Option, a special loan for those suffering a natural disaster.
    - o Sovereign Budget Insurance providing advising services to access international catastrophe reinsurance markets on competitive terms.
    - o Insurance Linked Securities, in the form of multi-country catastrophe bond to poll the risks and transfer the diversified risk to capital markets.
    - o Catastrophe Property Insurance, to promote insurance markets and increase catastrophe insurance penetration.
    - o Indexed-Based Weather Derivatives, intermediation services on an index-based weather derivative.

The Weather Risk Management Association (WRMA) is an industry association devoted to enhance public awareness of the weather risk industry and promote the growth and general welfare of the weather risk market offers many information and weather trading advices. Other initiatives such as the renewable energy insurance facility offer similar coverage and instruments.

If companies can meet spikes in future demand and failures in supply through special arrangements to purchase power, which can be covered by insurance, they will not need to build additional capacity to achieve the same goal, which will almost certainly be a cost saving. Additionally insurance markets will force them to seek low cost, reliable suppliers, thus ensuring that any additional capacity in that sector is also efficiently supplied.

Conclusions

Adaptation to climate change requires "technological" measures as well as ones that consist of alterations in organisation and in the demand for certain services. If we interpret technology as the use or introduction of any physical technique or source of knowledge then we see that it has a very wide role in adaptation to climate change. At the same time it would be a mistake to ignore the important roles of changes in planning laws and of market signals that reduce the demand for goods and services that will be more costly to provide or that encourage the supply of those goods and services that are more resilient to the new climate conditions. Indeed, these non-technological solutions are important in ensuring that the right technological options are selected.

Technology has a role in adaptation that is wider than just the introduction of physical structures and equipment.

More widely, the choice of technology will be very much influenced by the range of options considered. There is a tendency to focus on options close to the ones already in use and not to look at those that are further removed or that offer an indirect way of providing the services that were being provided by the traditional technologies. This needs to be overcome by taking a wider perspective when designing the options. The distinction between hard and soft options is not the same as that between technological and non-technological solutions. Both have a technological component but in the case of soft options the technology is possibly indirect. For example, reducing demand for water may be implemented by raising the tariffs, which in turn require changes in water metering or the use of water saving devices.

While not all the technological options that are to be adopted will be new, in some cases new methods and tools will have to be developed. Research and development will therefore have an important role. In addition, some of the most effective technologies are not available in developing countries. As part of a globally cost effective solution to adaptation to climate change technology transfer has an important role as it is often highlighted in international climate negotiations. This is especially important in the agriculture, infrastructure, health and water sectors.

The economic tools for selecting adaptation measures are based on a comparison of the costs and benefits. These can favour the more physical solutions, where measurement of these items is relatively easy, compared to the softer solutions. There is also the important issue of uncertainty, and the fact that knowledge about climatic impacts is continuously changing. These features can be addressed using tools such as Real Options Analysis, which help in determining the timing of major physical investments.

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References

Adger, W. N., Arnell, N. W. and Tompkins, E. (2005). Successful adaptation to climate change across scales. Global Environmental Change 15(2), 77-86. pdf file (240 kb)

Agrawala, S., and S. Fankhauser (2008). Economic Aspects of Adaptation to Climate Change. Costs, Benefits and Policy Instruments. OECD Publishing, Paris, France.

Barnett, J. and O'Neill, S. (2010), Editorial: Maladaptation. Global Environmental Change, vol 20 (2), pp. 211-213.

Boyd and Hunt, 2006, Boyd R. y Hunt, A. (2006), "Costing the local and regional impacts of climate change using the UKCIP costing methodology", Metroeconomica Limited.

Burton, I., R. W. Kates, and G. F. White (1993). The Environment as Hazard. Guildford Press, New York.

Carter, T. P., M. L. Parry, H. Harasawa, and N. Nishioka (1994). IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations. University College London, London.

Ebinger , J. and Vergara, W. (eds) (2011), Climate Impacts on Energy Systems: Key Issues For Energy Sector Adaptation. World Bank.

ECA (2009). Shaping climate-resilient development. A framework for decision-making. A Report of the Economics of Climate Adaptation Working Group. Climate Works Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank and Swiss Re.

Galarraga, I., Osés, N., Markandya, A., Chiabai, A. and Khatun, K. (2011), Aportaciones desde la economía de la adaptación a la toma de decisiones sobre Cambio Climático: un ejemplo para la Comunidad Autónoma del País Vasco. Economía Agraria y Recursos Naturales (Forthcoming).

Markandya, A. y Watkiss, P. (2009). Potential Costs and Benefits of Adaptation Options: A review of existing literature. UNFCCC Technical Paper. F CDCeCce/mTPb/e2r0 20090/29. Available at: <http://unfccc.int/resource/docs/2009/tp/02.pdf>.

Metz, B., O.R. Davidson, J.-W. Martens, S.N.M. van Rooijen, and L. Van Wie McGrory, ed. 2000. Methodological and Technological Issues in Technology Transfer. Cambridge: Cambridge University Press.

Möhner, A. and Klein, R. J. T. (2007), The Global Environment Facility: Funding for Adaptation or Adapting to Funds?. Climate & Energy Working Paper, Stockholm Environment Institute, June

OECD (2008). Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments. Organisation for Economic Co-operation and Development, Paris.

Parry, M., Arnell, N., Berry, P. Dodman, D., Fankhauser, S., Hope, C., Kovats, S., Nicholls, R., Satterthwaite, D., Tiffin, R., Wheeler, T. (2009), Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London.

Smit, B., I. Burton, R. J. T. Klein, and R. Street (1999). The Science of Adaptation: a Framework for Assessment. Mitigation and Adaptation Strategies for Global Change 4: 199–213.

Smit, B., I. Burton, R. J. T. Klein, and J. Wandel (2000). An Anatomy of Adaptation to Climate Change and Variability. Climatic Change 45: 223–251.
Stakhiv, E. (1993). Evaluation of IPCC evaluation strategies. Institute for Water Resources, U.S. Army Corps of Engineers, Fort Belvoir, VA, draft report.

UKCIP (2007). Identifying Adaptation Options. UKCIP Technical Report, United Kingdom Climate Impacts Programme, Oxford.

UNDP (2010), Handbook on Conducting Technology Needs Assessments for Climate Change. (Available at http://unfccc.int/ttclear/pdf/TNA%20HANDBOOK%20EN%2020101115.pdf).

UNFCCC (2006), Technologies for Adaptation. Bonn, Germany.

Williamson, L. E., H. Connor and M. Moezzi (2009), "Climate-Proofing Energy Systems", Helio-International. (http://www.helio-international.org/uploads/Global%20Report.En.pdf)

Annex: Examples of technological options for adaptation by sector (The extent to which technology is involved in each of the adaptation measures is indicated by the number of stars)

Table A1. Examples of adaptation technologies for water

USE CATEGORY		Supply side	Demand side
MUNICIPAL OR DOMESTIC		Increase reservoir capacity ** Desalinate ** Make inter-basin transfers **	Use "grey" water Reduce leakage * Use non-water-based sanitation ** Enforce water standards
INDUSTRIAL COOLING		Use lower-grade water	Increase efficiency and Recycling **
HYDROPOWER		Increase reservoir capacity **	Increase turbine efficiency ***
NAVIGATION		Build weirs and locks **	Alter ship size and frequency of Sailings *
POLLUTION CONTROL		Enhance treatment works ** Reuse and reclaim materials **	Reduce effluent volumes ** Promote alternatives to Chemicals ***
FLOOD MANAGEMENT		Build reservoirs and levees ** Protect and restore wetlands *	Improve flood warnings * Curb floodplain development
AGRICULTURE	Rain-fed	Improve soil conservation **	Use drought-tolerant crops**
	Irrigated	Change tilling practices ** Harvest rainwater *	Increase irrigation efficiency** Change irrigation water pricing

Table A2. Examples of adaptation for agriculture

Response strategy	Some adaptation options
Use different crops ***	Carry out research on new varieties ***
Change land topography to improve water uptake and reduce wind erosion *	Subdivide large fields Maintain grass waterways Roughen the land surface Build windbreaks *
Improve water use and availability and control erosion **	Line canals with plastic films ** Where possible, use brackish water Concentrate irrigation in periods of peak growth Use drip irrigation **
Change farming practices to conserve soil moisture and nutrients, reduce run-off and control soil erosion *	Mulch stubble and straw * Rotate crops * A void monocropping Use lower planting densities *
Change the timing of farm operations **	Advance sowing dates to offset moisture ** stress during warm periods *

Table A3. Examples of adaptation for health

Health issues	Technical options
Extreme weather events including thermal Stress	Urban planning to reduce heat island effects ** Air conditioning **
Air quality	Improved public transport * Catalytic converters ** Tall chimneys *
Vector-borne diseases	Vector control Vaccination, impregnated bednets *
Water-borne diseases	Genetic/molecular screening of pathogens ** Improved water treatment and sanitation *

Table A4. Examples of adaptation for energy

ENERGY SYSTEM	Anticipation	Technology and design
MINED RESOURCES	Emergency planning *	Replace water cooling systems with air cooling *** Improve design of gas turbines (inlet guide vanes, inlet air fogging, inlet air filters, compressor blade washing techniques etc.)***
HYDROPOWER		Changes in water reserves and reservoir management * Regional integration through transmission connections
WIND		Improve design of turbines to withstand higher wind speeds ***
SOLAR	Repair plans to ensure functioning of distributed solar systems after extreme events *	Improve design of panels to withstand storms ***
BIOMASS	Early warning systems (temperature and rainfall) * Support for emergency harvesting of biomass *	Introduce new crops with higher heat and water stress tolerance *** Substitute fuel sources **

Tables A5. Examples of adaptation in infrastructure

Energy and technologies	Land Use and Planning Measures
BUILDING SECTOR	
Lay out cities to improve the efficiency of combined heat and power systems and optimize the use of solar energy ** Minimize paved surfaces and plant trees to moderate the urban heat island effects and reduce the energy required for air conditioning *	Limit developments on flood plains or potential mud-slide zones Establish appropriate building codes and standards Provide low-income groups with access to property
TRANSPORTATION SECTOR	
Control vehicle ownership through fiscal measures such as import duties and road taxes as well as through quotas for vehicles and electronic road pricing Develop urban rail systems ** Modify road and rail alignments to reduce risk of subsidence***	Promote mass public transportation Use a comprehensive and integrated system of planning Link urban transport to land-use patterns * Cluster homes, jobs, stores *
INDUSTRIAL SECTOR	
Use physical barriers to protect industrial installations from flooding **	Reduce industrial dependence on scarce resources ** Site industrial systems away from vulnerable areas

Section II: Assessments of adaptation technology needs


Photo credit: Lars Christiansen

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Assessing technology needs for adaptation under the 'top-up' round

Abstract

This paper provides an analysis of the process of the TNAs for adaptation under the 'top-up round', with a focus on the challenges and lessons learned in those countries that have developed TNAs for adaptation. The paper explores how countries have interpreted the concept of technologies for adaptation and the impact of this interpretation on the final outcome of the needs assessment for adaptation technologies. The paper further stresses that insufficient funding and lack of guidance were the main barriers to TNAs for adaptation conducted in this round. In spite of challenges in the process and the gaps and limitations seen in the studies, the 'top-up' TNAs have provided important information on the integration of adaptation issues into national and local development. It is hoped that the analysis can inform improvements in the process of conducting TNAs for adaptation as countries move towards a second round of TNAs.

Background to the TNA process under the top-up round

In response to a request by the Conference of the Parties of the UNFCCC, the Global Environment Facility (GEF) has provided assistance to 92 non-Annex I Parties through Additional Financing for Capacity-building in Priority Areas – Enabling Activities Phase II (also known as 'top-ups'). Of these, 78 Technology Needs Assessments (TNAs)[1] have being supported by the United Nations Development Programme and 14 by the United Nations Environment Programme. (FCCC/SBSTA/2009/INF.1).

Countries have seen the TNA process under the top-up round as a transition phase between the Initial and the Second National Communications, which helped to maintain the national capacities that were developed during the Initial National Communication. This explains the significant impact that national communication processes had on the TNA process set up. Many of the TNA reports under the top-up round are considered to be a phase II of the initial National Communication.

The TNAs under the top-up round span a relatively long period of time, with the first one dating back to 1998 and the most recent ones submitted in 2008. TNAs have been completed by developing country Parties from all geographical regions of the world, including Parties classified as least developed countries (LCDs) and small-island developing states (SIDS).

In total, 70 Parties have completed and assessed their up-to-date technology needs, the results of these assessments being presented in their TNA reports. Some of them presented those results in their National Communications too. A total of 52 Parties addressed technologies for both mitigation and adaptation in their TNAs, while 18 Parties focused exclusively on mitigation technologies; no countries decided to focus only on adaptation under the top-up round.

The second UNFCCC report synthesising the TNA reports submitted in the top-up round shows that countries that decided not to conduct TNAs for adaptation cite limited resources as a barrier to this exercise. Some of them report that this is an outcome of the recommendations made by stakeholders (FCCC/SBSTA/2009/INF.1).

Besides the technology needs assessment report, information on needs for technologies is provided by Parties in several reports, such as National Communications and National Adaptation Programs of Actions (NAPAs) with regard to technologies for adaptation to climate change. However, these reports fall outside the scope of this paper.

The purpose and scope of this paper

This paper provides an analysis of the process of TNAs for adaptation conducted under the top-up round. It primarily addresses the questions of how countries have carried out their TNAs for adaptation, with a focus on experiences, lessons learned and the challenges that have emerged from this process (specifically, from conducting, implementing and reporting TNAs for adaptation). In addition, the paper tries to explore how countries have defined and applied the concept of 'technology' for adaptation, i.e., how was the concept of technologies for adaptation interpreted in the top-up phase, and what were the practical consequences and challenges of this interpretation.

The paper focuses on the stand-alone TNA reports for adaptation prepared by developing countries under the top-up round of the TNA. It is built on a previous paper co-written by the author for the UNFCCC secretariat, namely 'Best practices in technology needs assessments' (Fida, E., Nayamuth, R., 2007), which has now been refocused to cover the TNAs for adaptation only, revised to include a discussion of how the concept of technologies for adaptation was interpreted in the TNAs, and identifies the practical consequences of such an interpretation. The author

1 In response to the guidance of the CoP 14 of the UNFCCC, in 2009 GEF launched a second phase of TNAs. 36 countries have already received support through a global GEF-funded project implemented by UNEP through which countries will carry out improved TNAs within the framework of the UNFCCC, including the national Technology Action Plans (TAPs). This round does not fall within the scope of this paper. See section 2.

has used additional information on the new TNAs for adaptation, which were not available at the time the previous paper was written.

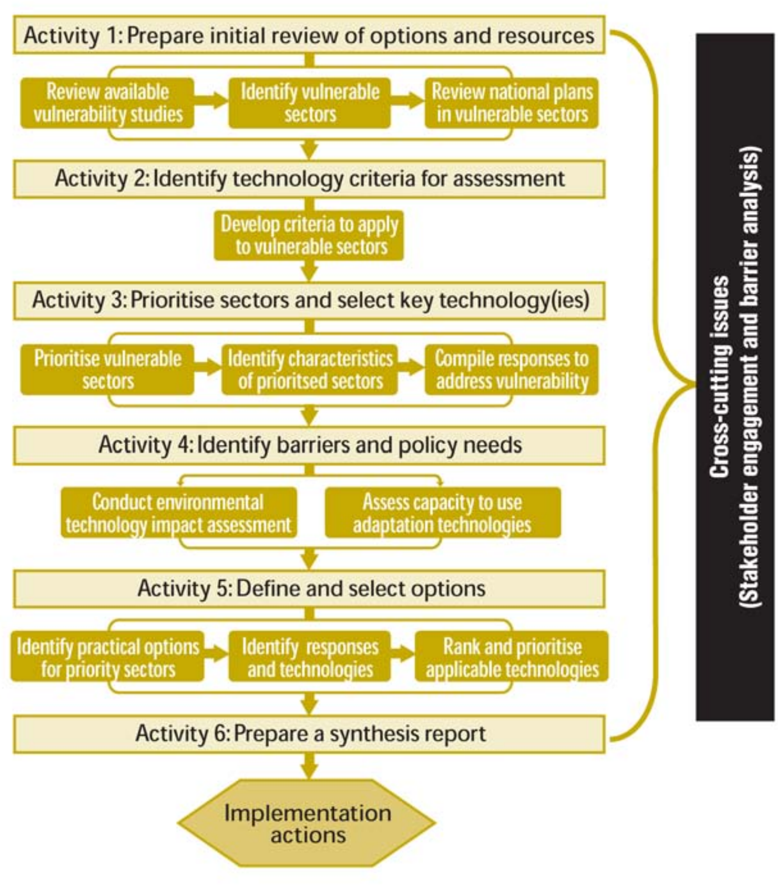
The paper follows the main stages of the TNA process for adaptation as shown in Figure 1. It also analyses the methodological approach used by countries for TNA for adaptation, as well as cross-cutting aspects of this process such as stakeholder involvement and barrier analysis. A set of conclusions is also provided at the end of this paper.

The process of conducting TNAs for adaptation in the top-up round.

The process followed by the Parties in conducting their TNAs for adaptation (see Figure 1) includes a set of steps such as selection of target areas; initial review of sectors and options; criteria setting; selection of key sectors; prioritisation of technologies; identification of barriers; identification of measures to address barriers; identification of capacity-building needs; description of stakeholder participation; identification of next steps; and establishment of a list of project proposals (Gross et al., 2004). The last step was not considered to be a compulsory component of the TNA process. However, project proposals were included in 35% of TNA reports for adaptation.

Conducting a TNA involves a set of managerial tasks, such as deciding on the methodological approach to be applied, assessing data and information needs, establishing expert teams, establishing a network to collect and share data and the necessary information on technologies, adopting rules and procedures for writing reports, and developing and securing the ongoing involvement of stakeholders (Gross et al., 2004).

Figure 1. Simplified representation of the technology needs assessments process.



Source: UNDP Handbook on Conducting TNA for Climate Change, 2004.

The review of the TNA reports under the top-up round, including those which were focused on adaptation, shows that a few TNA reports described the arrangements made for conducting the TNA, including those for adaptation. Some of the reports describe arrangements such as holding scoping workshops, preparing TNA terms of reference for the teams undertaking the TNA or drawing up lists of the stakeholders involved. During a workshop organised in 2005 by UNFCCC, UNDP and UNEP on TNAs countries, it was reported that, since the majority of TNAs carried out so far have been funded by GEF, the institutional arrangements followed the standard procedures for the implementation of GEF Enabling Activities projects. In most countries, TNAs have been hosted by the relevant national ministries in charge of National Communications. The teams already engaged in the preparation of the National Communication, and specifically those related to the vulnerability and adaptation studies, were usually involved.

Methodological approaches to conducting TNAs for adaptation under the top-up round

Many of the TNA adaptation studies under the top-up round, in particular those developed before 2004, were undertaken and completed without dedicated methodological guidance. Countries used improvised methods in conducting TNAs, including for their own understanding of the concepts of technology transfer, TNA and technologies for adaptation.

In the majority of the TNA reports there is no section on the methodological approach taken, and relatively few details are provided. The findings on the methodological approach are based on the analysis of the TNA reports and country experiences reported at relevant workshops organised by the UNFCCC secretariat and GEF implementing agencies, UNDP and UNEP.

Several studies of technologies have considered, either explicitly or implicitly, the TNA process, although none of them has dealt solely with the TNA except for a TNA handbook on conducting the TNAs on climate change developed by UNDP in 2004. A number of organisations, such as the Intergovernmental Panel on Climate Change (IPCC), the United Nations Environmental Programme, UNEP Risø, the United Nations Development Programme and the Climate Technology Initiative (CTI), have looked at methodological issues in respect of technology transfer, including the nature of the technologies and the process of technology transfer. The UNDP TNA handbook of 2004 (referred here as the TNA handbook) draws upon these and seeks to complement those reports that deal with particular technologies and practices. The TNA handbook[2] was published as a living document with the aim of providing guidance on how to conduct the TNA in both thematic areas: GHG mitigation and adaptation. The handbook lays out the key steps, decisions, methods and resources needed for the TNA, taking into consideration the fact that country circumstances and needs are different. This approach ensures the flexible nature of the handbook and its applicability in country-specific conditions.

Following the recommendation of the SBSTA at its 26th session, in 2007 a UNFCC technical paper on best practice was prepared and made available to the Parties that had yet to conduct their TNA or that may wish to update their TNA reports. This paper was intended to complement the UNDP handbook, Conducting Technology Needs Assessment for Climate Change (TNA handbook), and to be used along with it, as well as provide useful input for the future revision of this handbook, as requested by the SBSTA at its twenty-sixth session.

The analysis of the TNA reports shows that the TNA studies did to a large extent follow an assessment process closely resembling the one outlined in the TNA handbook.

The similarities in the process adopted by the majority of countries and that recommended in the TNA handbook can be explained through countries using the approaches cited in the reports produced by

2 By its decision 3/CP.13, COP requested the secretariat, in collaboration with the EGTT, UNDP, UNEP and CTI, to update the TNA handbook. A revised handbook was made available in 2009 following a technical paper on best practice in TNAs and a UNFCCC workshop on best practice in TNAs held in Bangkok in 2007.

different organisations such as UNEP, CTI and the IPCC in the absence of any methodological guidance, although these reports did not focus on the TNA itself. On the other hand, the methods adopted or improvised by countries served as a reference point for the compilation of the TNA handbook. The handbook drew upon relevant sources (e.g., the CTI, UNEP and the IPCC) and feedback received from countries undertaking TNAs, as well as upon discussions, recommendations and country presentations made in relevant workshops.

The TNA handbook contains a section on TNAs for adaptation which provides a methodological framework for conducting the TNA on adaptation (methods, tools, approaches). The handbook highlights the large difference between TNA for adaptation and TNA for mitigation: in fact it acknowledges that, while there is a large literature on available technologies for mitigation, technologies for adaptation are less well defined and not clearly labeled as adaptation per se, except perhaps for coastal engineering technologies. Unlike for mitigation, the handbook does not provide a list of technological options for adaptation. The authors of the handbook justify this by saying that, at the time the handbook was published, the science of adaptation was in a stage of development where the boundaries between adaptation and development were still unclear.

The concept of 'technology for adaptation' under the top-up round

A definition of TNAs was only adopted in 2001 at the 7th session of the CoP of the UNFCCC. In 2001, through Decision 4/CP.7, the Parties to the UNFCCC decided to adopt the framework for meaningful and effective actions to enhance the implementation of Article 4, Paragraph 5 of the Convention. Under this framework, technology needs and needs assessments were defined as 'a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties… They involve different stakeholders in a consultative process to identify the barriers to technology transfer and measures to address these barriers through sector analyses. These activities may address soft and hard technologies, identify regulatory options and develop fiscal incentives and capacity-building'. According to the framework, 'the purpose of technology needs assessments is to assist in identifying and analysing priority technology needs, which can form the basis for a portfolio of Environmentally Sound Technologies (EST) projects, and programs which can facilitate the transfer of, and access to, the ESTs and know-how in the implementation of Article 4, paragraph 5, of the Convention'. However, beyond these definitions the framework did not provide specific guidance on TNAs.

Unlike the case of the TNA definition, countries have conducted their TNAs on adaptation without a clear definition of 'technologies for adaptation'. While the TNA handbook describes all the steps towards the TNA for adaptation, it does not provide a clear definition of adaptation technologies. Rather, it notes that adaptation technologies may be 'soft' (know–how) or 'hard' or both. In addition, the TNA handbook uses the phrases 'adaptation technology' and 'adaptation measures' interchangeably.

The IPCC also distinguishes 'soft' and 'hard' protection measures in the context of coastal adaptation (IPCC TAR, 2001). The UNFCCC process has not yet defined the term of technology or adaptation. In a seminar[3] on the development and transfer of environmentally sound technologies for adaptation to climate change held in 2005 in Trinidad and Tobago, an 'operational definition' for technologies for adaptation was suggested: 'the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change'. Technological approaches to adaptation include both "hard" technologies such as capital goods and hardware, as well as "soft" technologies such as knowledge of methods and techniques which enable "hard" technologies to be applied. This operational definition links the technology for adaptation to 'vulnerability reduction' and 'resilience enhancement' and notes that technologies for adaptation may be 'hard' or 'soft'.

3 (FCCC/SBSTA/2005/8).

The UNDP Adaptation Policy Framework, which provides guidance on designing and implementing projects that reduce vulnerability to climate change by both reducing the potential negative impacts and enhancing any beneficial consequences of a changing climate, considers technologies for adaptation to be coherent packages of 'soft' and 'hard' adaptation responses.

A technical paper on the application of environmentally sound technologies for adaptation to climate change, published in 2006 by the UNFCCC secretariat and the Expert Group on Technology Transfer (EGTT), carried out a review of adaptation technologies. (FCCC/SBSTA/2005/8). While the review provides a brief introduction to the principles and methodological approaches to adaptation and the practical steps that can be taken to put them into practice, it does not provide a definition of the technologies for adaptation and uses the words 'adaptation technology' and 'adaptation measures' interchangeably.

Analysis of the TNA reports from the top-up round shows that, while the methodological approach available for TNAs for adaptation does not make a distinction between 'adaptation technologies' and 'adaptation measures', countries chose to use them interchangeably. Some of them associate the term 'adaptation technology' more with hard technologies and 'adaptation measures' when they include soft measures as part of the proposed packages. For example, in the TNA for adaptation Antigua and Barbuda use the term 'adaptation technologies' for coastal protection technologies such as sea wall revetments or beach nourishments, and 'adaptation measures' for public awareness and coastal zone management programs. Azerbaijan chose to refer to 'adaptation technologies' throughout the report where only hard technological options have been proposed. Bhutan chose to use the term 'adaptation measures' when referring to soft options such as cropping calendars, research, policies and early warning, and 'physical adaptation measures' when referring to irrigation techniques.

Sectors targeted and technologies selected

Sectoral focus

In many cases the thematic TNA focus and other considerations regarding key sectors and technologies have been defined without a proper strategic analysis or the comprehensive involvement of stakeholders. Thus, for example, it appears inefficient that some countries such as Ethiopia, Chad, Laos Togo, Chile and Columbia, which are highly vulnerable to climate change, decided to focus on mitigation when adaptation should have been defined as a priority for achieving the Millennium Development Goals (MDGs).

The lessons drawn from successfully conducted studies and the TNA handbook recommend that not more than two to three sectors be prioritised. TNAs covered many sectors and priorities, but the rationale for technology choices and implementation feasibility was not always clear, thus resulting in a wide range of possible technologies. However, most of the studies lack explicit explanations as to why they were focused on a certain targeted area and/or sector.

In a few cases the TNA reports highlight the restricted financial and technical resources as being the main reasons for the limited focus of the study (either of thematic area or sector). In some cases the national circumstances and findings from the National Communication have been highlighted as the reasons for focusing on specific sectors. For example, coastal adaptation played a major role in countries with large coastal zones and high vulnerability to climate change vis-à-vis water resources, agriculture, health, natural disasters and hydrometeorological events. The protection of coastal zones assumed the greatest importance for many coastal countries (Albania, Antigua and Barbuda, Benin, Comoros, Croatia, Ecuador, Egypt, Guinea, Guyana, Indonesia, Jamaica, Kenya, Madagascar, Malta, Niger, Samoa, Senegal, Sri Lanka, Tajikistan, Thailand, Tunisia, United Republic of Tanzania and Vietnam), owing to the concentration of numerous economic activities in the coastal zones of these countries. Agriculture, forestry and water resources played a significant role in 93% of

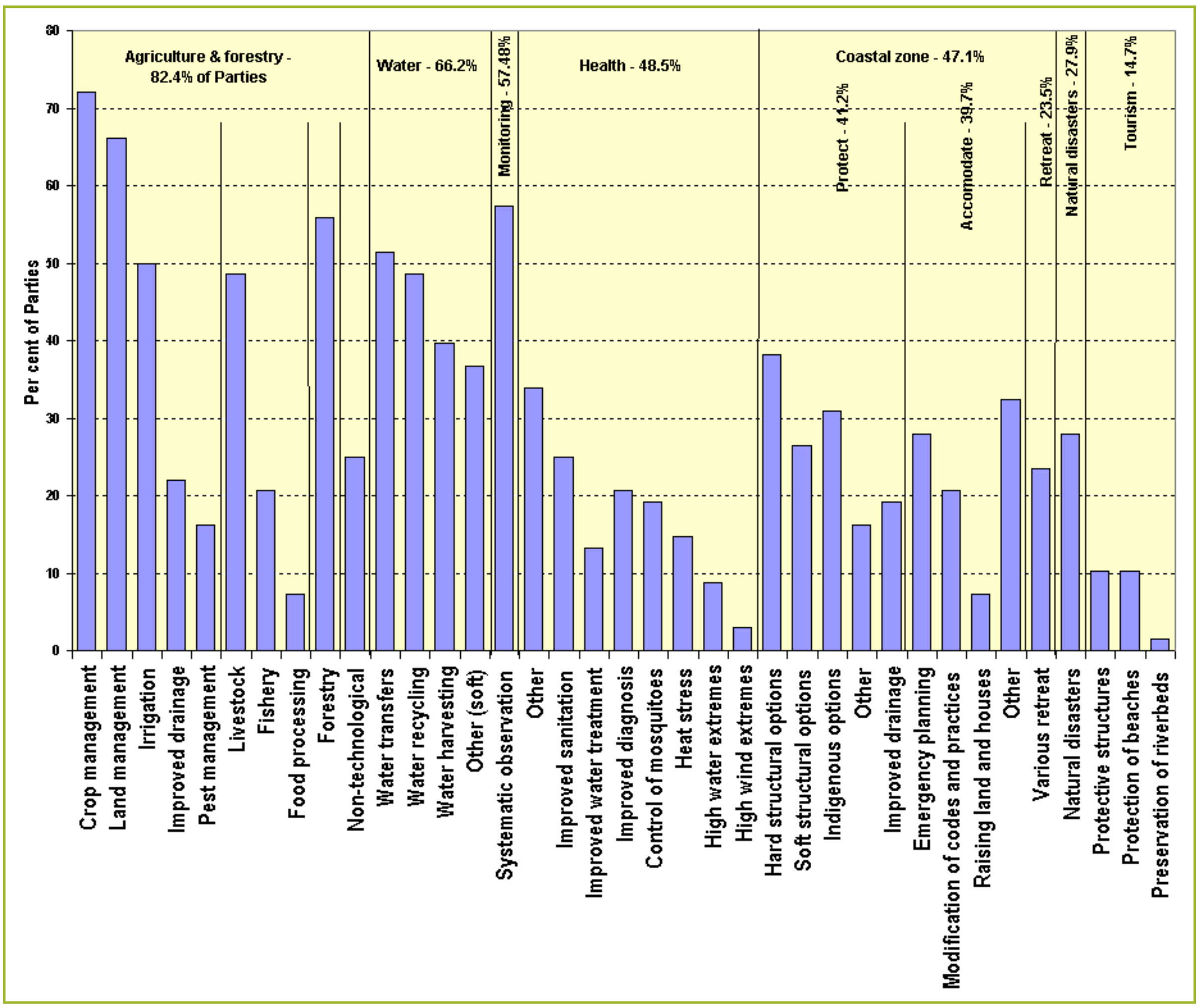
TNAs for adaptation from African countries (FCCC/SBSTA/2009/INF.1).

Technologies identified

The UNFCCC analysis, and even the review of the TNA reports made by GEF Implementing Agencies of TNA projects, shows that all countries who undertook TNAs for adaptation focused their need assessments for adaptation on sectors already identified as vulnerable to climate change under their Initial National Communication (agriculture, forestry, water resources, coastal zone, health, tourism, systematic observations).

The most commonly identified technology needs for adaptation were related to crop management, efficient water use, improving irrigation systems, early warning systems for forest fires, technologies for afforestation and reforestation, and technologies to protect against and accommodate rises in sea level (see Figure 2). Some countries included information on indigenous technologies that have been applied to adapt to weather hazards. Examples included traditional housing designs, bunds, levees, dykes and mangrove plantations. For these technologies, the needs mainly relate to deployment and dissemination, as well as to further improvements in their design and quality, based on their capacity for research and development.

Figure 2. Technology needs for adaptation identified in TNAs by sector



Source: FCCCC/SBSTA/2009/INF.1S.

In addition to technological options, countries also identified policies, regulations, standards and codes. Little attention was given to the soft technology options needed to create an environment conducive to the adoption of hard technologies. This could be explained through the limited understanding of the concept of the technologies for adaptation by the countries. More specifically, it shows that countries have understood technologies for adaption more as 'hard' technologies.

Criteria for prioritising identified technology options

The adaptation technologies identified have been assessed in accordance with a set of selected criteria. In some TNA studies the criteria considered are not indicated explicitly. In most of the TNA studies a list of the preliminary technology options for adaptation was identified, taking into consideration a variety of factors such as national circumstances, expert judgment and stakeholder consultations. The majority of the TNA studies for adaptation considered some general criteria, namely development goals, contribution to climate resilience and market potential. In addition, a variety of sub-criteria were considered depending on country-specific priorities and development needs. For example, the contribution to development goals involved issues like food security, health, job creation for the poor, social acceptability and the local environment, even to the extent of matching the MDGs. The contribution to adaptation involved respectively a quantitative evaluation degree of reduction of climate risk to a certain vulnerable system. While for mitigation technologies many countries also assessed the market potential through an analysis of the capital and operating costs relative to commercially available technologies, for adaptation technologies this was not possible due to difficulties in estimating their costs. Most countries preferred to prepare exhaustive lists of candidate technologies and wait for the prioritisation process to identify the best option. Some preferred to limit these lists to those technologies that have the best chance of being transferred. Technologies that may become attractive in the long term are rarely considered in TNAs under the top-up round.

Tools and methods applied

The analysis of the TNA reports found that a variety of methods and tools have been used by countries in the technology prioritisation process. Each of these methods and tools has its strengths and weaknesses, meaning that the selection of the best tool is country-specific. The TNA reports suggest that, in the majority of cases, the tools are used to help in the decision-making process rather than to drive it. A survey carried out during a UNFCCC workshop on best practice in TNAs held in Bangkok in 2007 shows that multicriteria analysis is the most favoured method of adaptation technology selection. The top ranked technologies were usually selected as priority technologies for implementation. In addition to the multi criteria analysis, countries used other tools such as questionnaire surveys, interviews and workshops with stakeholders.

Description of stakeholder involvement in the top-up round of TNAs

Stakeholder consultations and participation were key features of most TNAs for adaptation. Most of the TNA reports mention stakeholder involvement, but how this was secured during the process is very often not explicitly reported. This is explained by the lack of reporting guidelines for this round.

In most cases stakeholder involvement was limited to prioritising technology needs, initial reviews of needs and setting the criteria for ranking technology needs. The improvised methods of involving stakeholders that were reported consist of holding inception workshops and/or final TNA report presentation workshops, or conducting a questionnaire survey. In most cases a list of stakeholders who have participated in the exercise has been provided. Consultation with stakeholders at the grassroots level is barely reported, even where the transfer of selected technologies concerns them directly as recipients.

Only five TNA reports for adaptation (from Paraguay, Senegal, Sri Lanka, United Republic of Tanzania and Vietnam) provided detailed information on stakeholders, including their positions, roles in the team, and the level of their involvement in the concrete steps of the TNA process. The Seychelles used stakeholders from different backgrounds for each requested technology and capacity-building needs in order to create the appropriate mix. In the reports from Albania, Antigua and Barbuda, Botswana, Congo, Guyana, Indonesia, Madagascar, Paraguay and Zimbabwe, the details of the consulted experts were provided, but no description of their roles in the team was given. Ecuador, Guinea, Lesotho, Malawi, Mauritania, Namibia and Tajikistan identified stakeholders in the introduction to their TNA reports, while the actual roles of these stakeholders were detailed in the main body of the report.

Key stakeholders include policy-makers, technocrats, NGOs, academia, sectoral experts, the private sector and civil society representatives. The stakeholders that add most value are the sectoral experts.

In many instances countries have preferred to work with two groups of stakeholders: a core group of direct participants, and a wider group of affected and interested parties. The core group deals with the most substantive issues in the TNA process, such as management, resource assessment, technology costing and preparation of reports and other materials. Setting up sub-teams or sectoral working groups during preliminary consultations to push ahead in specific areas has proved effective. The wider group of affected and interested parties participates in consultation and engagement activities, such as workshops, public hearings and consultation papers.

The involvement of stakeholders, especially of those stakeholders who will be the beneficiaries or end users of technologies, has shown to be essential to ensuring that ill-suited technologies are not prioritised. Most adaptations will be carried out by individual stakeholders and communities. Therefore, the government's primary role is to facilitate and steer this process…' (IPCC TAR, WGII,). Country experiences have shown that stakeholder involvement is key in all steps in the TNA process, though involving all categories of stakeholders in the process of weighting selection criteria results in an effective and transparent technology assessment. The experiences of countries suggest there is no other activity in the TNA process in which stakeholder involvement is more important.

While the preparation of National Communications is mainly driven by public-sector actors, a successful technology transfer would require the active involvement of private actors in the TNA process. Private-sector stakeholders were not involved mainly because the TNA process was hosted by the National Communication process. In cases where stakeholders from the private sector have been present, they have shown a narrow conception of technology transfer for adaptation, excluding most soft items, with the exception perhaps of transfers of know how to operate and maintain, and in some cases produce or adapt a given technology.

Barriers to TNAs for adaptation

Barrier analysis is another cross-cutting issue in the TNA process, including that for adaptation. Experience with TNAs under the top-up round shows that barriers exist at each stage of the TNA process, whether technology-, sector- or country-specific. Identifying and understanding them and the ways they can be effectively addressed and removed is of key importance to an effective TNA process. For example, barriers exist at various levels: they may relate to policies, regulation, financial availability, markets, education and awareness, institutional, or technical and human capacity, among others, and in some cases they are specific to the technologies themselves. At all evels they can only be identified by the stakeholders.

The analysis of the TNA reports shows that countries have not identified barriers to TNAs. Rather, the majority of countries have identified barriers to technology transfer and measures to address them. The information is very often not clearly reported for facilitating follow-up actions. Some countries identified barriers in a general manner as opposed to identifying specific barriers to the transfer of the selected individual technologies. A survey by the UNFCCC secretariat in 2007 shows that the resources available for conducting TNAs are not sufficient and that the level of resources available has a bearing on the scope of the TNAs, including coverage of sectors, technologies assessed and the involvement of stakeholders. Countries also report challenges such as reading the methodological approach to conducting TNAs, in particular with regard to the prioritisation of adaptation technology options.

Although some barriers may apply across the board, others specifically hinder the successful transfer of certain technologies. Barriers to the transfer of prioritised technologies were addressed in many TNA reports for adaptation, and approaches to the identification of these barriers varied. Numerous Parties (e.g., Benin, Bhutan, Botswana, Congo, Haiti, Islamic Republic of Iran, Niger, Senegal, Thailand, Uganda and United Republic of Tanzania) identified barriers to individual technologies, whereas others listed barriers by sector (e.g., Croatia, Kenya, Madagascar, Malta, Paraguay, Saint Kitts and Nevis, Samoa and Vietnam).

The main barriers to technology transfer that were identified were economic and market barriers. Other important barriers included lack of information and awareness regarding ESTs, and lack of institutional, regulatory and human capacity to tackle the technology transfer process successfully. Lack of governmental strategies for the implementation of the results of the TNAs was considered as one of the major barriers to technology transfer (FCCC/SBSTA/2009/INF.1).

There is a prominent role for stakeholders in the identification of barriers and policy needs. While engagement does not in itself guarantee equity, fairness or buy-in, it will contribute to a more robust understanding of key barriers and identify what segments of the population are most disadvantaged by them (Gross et al., 2004).

The good practice guidance on TNAs has shown that that identifying barriers during each stage of the TNA process with a focus on the priority sectors and technologies, and considering the experience of other countries in barrier identification and validating and adopting those at country specific level, are helpful approaches.

Steps towards the implementation of TNAs for adaptation in the top-up round

Following the identification of the key adaptation technologies, countries must then identify a set of next steps for implementing the findings of the TNA, which will in turn affect the whole technology transfer exercise. The review of the TNA reports from the top-up round shows that not all countries have included their plans for next steps in their TNA reports. In some reports, it is difficult to distinguish between next steps and measures to remove barriers. The majority of Parties that did report on next steps for the respective technologies presented them in the form of project proposals provided in annexes. In total, 24 countries developed concrete ideas, proposals and/or concepts for projects and/or programs based on their priority technology needs, with fourteen of these countries having developed project ideas or concepts for adaptation. Sectors and themes covered by these projects include coastal zones, water resources, health, systematic observations, communication, capacity-building and public awareness. Most technology projects for adaptation (DRC, Dominican Republic, Cape Verde, Ecuador, and Samoa) have been proposed for systematic observation systems, climate change impact information and awareness-building campaigns, and capacity-building measures. Only three countries (Albania, Tajikistan and Azerbaijan) propose projects for water and health, and four other countries (Antigua and Barbuda, Samoa, Cape Verde and Vietnam) propose coastal adaptation projects.

The majority of project proposals on adaptation vary in quality and content. Not all of them include the same level of information. Most of them consist of project concepts or ideas rather than full proposals. No template has been made available for countries to define the set of issues to be considered in a project concept or idea. Therefore countries have designed for themselves the layout of a project concept template and provided that in the TNA report. Project concepts have usually been appended as annexes in the TNA reports. They include certain information such as a justification for the project, the motivation, general and specific objectives, a time frame with activities, inputs and deliverables, a list of stakeholders, barriers to be overcome, capacity-building needs, adaptation capacity, awareness programmes, training and a list of likely beneficiaries. While for project concepts that address TNA for mitigation, countries tend to analyse the viability of the investment and internal rate of return (IRR) of such investment, in the case of the adaptation project concepts those elements are missing.

The UNFCCC synthesis report on TNAs has also shown that very few TNAs contained comprehensive implementation plans with extensive coverage of technology transfer issues. Also, very few countries received funding for adaptation technologies identified under the top-up round. Reasons include a lack of funding and the unsuitability of some projects for private-sector financing. The only funding opportunity from GEF-supported funds at this point was the SPA (Strategic Priorities for Adaptation) under GEF. Because the Special Climate Change Fund (SCCF) Technology Transfer window addresses only the technology transfer needs related to mitigation, the technology needs for adaptation were not eligible under this funding.

Reporting TNAs for adaptation

Unlike for National Communications, the UNFCCC did not require Parties to report on the findings of their TNAs under the top-up round.[4] At the same time, no guidance was provided to countries on how the latter may report their TNAs, including for adaptation, if they wished to do so. The lack of reporting requirements and guidance has proved to be an important constraint in the effort to compile TNA reports. Despite the lack of guidance on reporting, all countries that have carried out a TNA have prepared a report which has been guided by GEF Implementing Agencies that have supported countries in developing TNAs, including for adaptation.

In 2005, through the national climate change focal points, the UNFCCC Secretariat requested Parties to submit their TNA reports on a voluntary basis. The Expert Group on Technology Transfer (EGTT) also encouraged countries '…to make these reports available to the Secretariat.' The lack of reporting requirements and templates has made very difficult the review of the reports and synthesis of their findings. 52 reports include a section on TNAs for adaptation in addition to the TNAs for mitigation. Following the request from the EGTT, TNA reports have been collected and analysed by implementing agencies (e.g., UNDP and UNEP), and most of them are available on the website of the National Communications Support Programme (NCSP) of the GEF, UNDP and UNEP and on TT:CLEAR.

There are similarities in the presentation of information to National Communication reports. Countries have followed the UNFCCC reporting guidelines for national communications and adapted them in compiling TNA reports. All countries that covered technology needs for both mitigation and adaptation reported them in two separate chapters. TNA reports which followed the guidance in the TNA handbook were more complete and showed better quality in terms of reporting compared to reports which were developed without any guidance.

The compilation of an executive summary for the TNA report, in some cases published as a stand-alone document written in memo style, has proved useful. In particular, it has served to raise awareness among governmental officials, other stakeholders concerned and the financial community of the findings of the TNA. Archiving and documenting the information collected, processed and synthesised for the TNA were found to be good practice, as it will help to improve the quality of future results and reports over time. This practice has drawn on experience from the national communication process, especially the GHG inventory exercise.

Developing a TNA report was found to be a challenging task, especially in the absence of any guidance. In a survey organised by the UNFCCC secretariat during the Bangkok workshop on TNAs held in 2007, 50%

4 Non-Annex I Parties are encouraged to make information on the results of TNAs available in their national communications (NCs), other related national reports and channels for consideration by the Subsidiary Body for Scientific and Technological Advice (SBSTA) on a regular basis.

of the respondents reported that compiling the TNA report is not easy. Some of the respondents have listed the need for a greater focus on adaptation technologies as a means of improving the quality of the TNA studies and reports. Despite the challenges faced, the majority of countries have published the TNA report in hard copy and/or as CD ROMs, distributed during the Conferences of the Parties, Subsidiary Bodies of the UNFCCC.

Conclusions and recommendations

Several conclusions emerge from the paper:

- TNAs for adaptation under the top-up round were found to be challenging. Key challenges for the TNA for adaptation process include limited funding and a lack of guidance. Other challenging factors include the cutting-edge nature of adaptation science, the local dimensions of adaptation, and difficulties in assessing the costs of adaptation interventions.
- In the absence of dedicated methodological guidance, countries improvised methods and chose to build on the national communications process and findings that have affected the scope and outcomes of the assessment. The majority of countries chose to select hard technologies for adaptation, with less attention paid to soft ones. In most of the TNA reports for adaptation, the terms 'adaptation technology 'and 'adaptation measures' are used interchangeably, with a few countries using the latter to describe soft technologies.
- Stakeholder involvement is crucial to the TNA exercise. A majority of countries did not undertake a proper stakeholder consultation, and this has affected the outcomes of the assessment.
- Although the TNAs conducted under the top-up round contain some gaps and limitations, they provide an important source of information and a tool for the implementation of the Convention and integration of adaptation issues into national and local development. Project ideas for adaptation developed by some countries under the TNAs provide useful information concerning the implementation of the TNAs for adaptation. A very limited number of these projects have secured funding.

The paper suggests the following:

- The existing methodological guidance on TNAs for adaptation must be updated with new lessons learnt and good practice collected during the second round of TNAs.
- While funding has been provided and methodological guidance has been strengthened for the second round of the TNAs, including for adaptation, the existing guidance still lacks a clear definition of 'technologies for adaptation'. Guidance is needed regarding the concept of technologies for adaptation. In the absence of such a definition, countries must be aware of the lessons learnt and the consequences of the different interpretations of the concept of 'technologies for adaptation '
- Countries must be aware of the importance of stakeholder involvement in the TNA process, including for the consequences of an inadequate stakeholder involvement.
- Countries must be equipped with tools with which to assess the costs of adaptation technology options. This will contribute towards a proper analysis of the costs and benefits of adaptation technologies, an important criterion in prioritising technology options.
- In order for TNAs for adaptation to be implemented, proper guidance is needed in terms of financing such technologies. This must include guidance on (i) accessing the adaptation finance available; (ii) project formulation; and (iii) project implementation.

About the author

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References

CTI 2002, Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities: Experiences of Developing and Transition Countries.

Expert Group on Technology Transfer (EGTT), 2008, Preparing and presenting proposals: UNFCCC Guidebook on Preparing Technology Transfer Projects for Financing; http://unfccc.int/ttclear/jsp/Guidebook.jsp

Fida, E., Nayamuth R., Technical paper: best practices in technology needs assessments; FCCC/TP/2007/3, 2007.

Gross, R., Dougherty, W., and Kumarsingh, K. (2004); 'Conducting Technology Needs Assessments for Climate Change'; UNDP, New York, US, 26 pp.

IPCC 2000, IPCC Special Report: Methodological and Technological Issues in Technology Transfer, http://www.ipcc.ch/ipccreports/sres/tectran/index.htm

IPCC 2001, Climate Change: Impacts, Adaptation and Vulnerability. The Contribution of Working Group II to the Third Assessment Report, Cambridge: CUP http://www.ipcc.ch/ipccreports/tar/wg2/index.htm

Klein, R.,Doughertty, W., Alam. M., Rahman, A., Background Paper: Technology to understand and manage climate risk; UNFCCC, 2005.

Klein, R., Tol., L., Technical paper: Adaptation to climate change: Options and Technologies.

UNEP-GEF, Technology Needs Assessment, Project document, 2010.

UNFCCC, 2007; Synthesis report on technology needs identified by Parties not included in Annex I to the Convention.

UNFCCC 2009; Second synthesis report on technology needs identified by Parties not included in Annex I to the Convention.

UNFCCC, 2006, Application of environmentally sound technologies for adaptation to climate change.

UNFCCC, 2006, Technologies for adaptation.

UNFCCC, 2006, Report on the seminar on the development and transfer of technologies for adaptation to climate change.

Zou Ji, 2002. Methodologies and Tools for Technology Needs Assessments: An Overview, presentation at SBSTA-16, Bonn, Germany, June 2002, available at: http://ttclear.unfccc.int/ttclear/presentations/SBSTA16/Zou 2002, Tools and Methodologies in Assessing Technology Needs.

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Synergies between technology needs assessment and national adaptation plan of action in Malawi

Abstract

The aim of the paper is to review and analyse the TNA and NAPA processes for Malawi to identify possible synergies, strengths, gaps and opportunities and suggest practical ways in which any future TNA could enhance the implementation of the NAPA and other adaptation actions. The analysis could also inform a possible second round of TNA preparation in Malawi. The paper draws a number of lessons that could help improve the effectiveness of any future TNA in achieving its objectives, in particular in relation to the identification of sources of technical and financial support in implementing identified technologies, the institutional continuity of project teams and expertise, implementation planning and follow up activities, contributions to overall development process and political involvement and endorsement.

With the establishment of a process to enable the LDCs to formulate and implement national adaptation plans, an avenue for mainstreaming national adaptation planning and TNAs further was opened and needs further exploration.

Introduction

In the last several years, the issue of adaptation to climate change has moved high up the United Nations Framework Convention on Climate Change (UNFCCC) negotiating agenda. Several decisions have been adopted to enhance the implementation of adaptation actions in developing countries, particularly in the least developed countries and small-island developing states. This includes, among other things, a decision to mandate the preparation of National Adaptation Programmes of Actions (NAPAs) in LDCs made at COP7 in Marrakech. At its thirteenth session, and by its decision 1/CP.13 (the Bali Action Plan), the Conference of the Parties to the climate change convention identified adaptation as one of the key building blocks required for a strengthened future response to climate change to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, both now, and up to and beyond 2012. At the Cancun Climate Change Conference in December 2010, the Parties to the climate change convention established the Cancun Adaptation Framework with the objective of enhancing action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the convention.

In parallel to the discussions on adaptation, the Parties to the climate change convention have also taken decisions to promote the development and transfer of environmentally sound technologies. Among other things, this included a push to prepare Technology Needs Assessments (TNAs) in non-annex I developing countries.

Malawi implemented a United Nations Climate Change Enabling Activities Project- Expedited Phase II from March to June 2003. Among the activities of Expedited Phase II was the preparation of Malawi's first TNA. The Climate Technology Initiative (CTI) was approached for technical assistance for the technology transfer and needs assessment, having earlier undertaken a similar function for some of the Southern African Development Community (SADC). The climate change project unit, under the Environmental Affairs Department, spearheaded the initial national consultations. The stakeholders who took part in this process included public and private companies, academia, research institutions, government departments and Non-Governmental Organisations (NGOs). The final report of the first Malawian TNA was submitted to UNFCCC in June 2003.

Later, between 2004 and 2005, Malawi formulated and submitted its National Adaptation Programs of Actions (NAPAs) as a means of identifying and addressing its urgent and immediate adaptation needs. Specifically, the document aims at (i) identifying a list of priority adaptation activities, (ii) formulating priority adaptation options, (iii) building capacity for adaptation to longer-term climate change and variability, and (iv) raising public awareness of the urgency of adaptation to the adverse effects of extreme weather events. The country is now in the implementation phase and has developed one full-size project from the NAPA.

The TNA and NAPA processes for Malawi are fundamentally different in at least two ways. First, their mandates were to identify priorities for 'technologies' and 'urgent and immediate adaptation needs' respectively. Secondly, in practice, the first TNA process in Malawi did not consider technologies for adaptation (although it was mandated to do so), but, due to a number of factors, was quite narrowly focused on mitigation technologies. Still, as the two processes are both aimed at identifying national priorities within the theme of climate change and development, it is interesting to compare the two in terms of their consultative processes, methodologies used for prioritisation, political embeddedness, institutional set-ups and ultimate impacts vis-à-vis their stated objectives. Due to the above differences in scope and focus, this paper will limit its analysis to the effectiveness of the processes themselves rather than their specific outputs and outcomes.

The main aim of the paper is thus to review and analyse the TNA and NAPA processes for Malawi to identify possible synergies, strengths, gaps and opportunities and suggest practical ways in which any future TNA could enhance the implementation of the NAPA. Also, the analysis could inform a second round of TNA preparation in Malawi. The second round of TNAs are currently being implemented in 36 countries through a Special Climate Change Fund grant implemented by the UNEP Risø Centre. Malawi is not currently included in this programme, but could be so later, as it is expected that the programme will expand further with additional countries joining in the coming years.

Overview of TNA and NAPA processes in Malawi

This section discusses some of the main differences between the TNA and NAPA processes. Table 1 below provides an overview of some key parameters of each process.

Criteria for prioritisation

The first round of TNA in Malawi mainly looked at mitigation technologies, even though it has a clear

Table 1. Overview of the TNA and NAPA processes in Malawi

Issue	Technology Needs Assessment (TNA)	National Adaptation Plan of Action
Period of formulation	March 2003-June 2003	December 2003-March 2006
National executing institution	Department of Environmental Affairs	Department of Environmental Affairs
Funding source	GEF Trust Fund through UNDP as GEF Agency	GEF-LDCF through African Development Bank as GEF Agency
Purpose	Identify the technology needs for mitigation and adaptation	Identify and implement urgent and immediate adaptation needs
Political Involvement Government endorsement and Commitment	The final TNA report was signed by the Permanent Secretary to the Ministry and submitted to UNFCCC in June 2003	Officially launched by the President of Malawi in February 2008. The document was signed by the Minister and the Permanent Secretary to the Ministry
Formulation Process	A task force Technology Team, with five technology sub-teams for PV-Systems, Biomass, Biogas, Wind, and other technology	The NAPA Project Steering Committee, a multi-disciplinary team of consultants in the agriculture, water, fisheries, and human health, energy, forestry, and wildlife and gender sectors, prepared sectoral reports, which formed the basis of the NAPA.
Criteria for Prioritization	Developed through consultative workshops and special taskforce teams. General considerations regarding developmental benefits, market potential and effects on the environment including contribution to GHG emission reduction. Technical support from the CTI was used during the process.	Developed through consultative workshops based on the generic criteria as proposed by the Least Developed Countries Expert Group (LEG) and outlined in the 'Annotated Guidelines for the Preparation of National Adaptation Plan of Action.' These are degree of adverse effect of climate change, poverty reduction to enhance adaptive capacity, synergy with other multilateral environmental agreements, and cost effectiveness. The NAPA Project Steering Committee endorsed the developed criteria before the prioritization process was started.

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Implementation Process and follow-up activities	No follow-up activities since submission of the report in 2003	1. Formation of a Government of Malawi/Donor Working Group on Climate Change. 2. Inventory of institutions involved in climate change-related activities established. 3. Development and funding of the NAPA project, 'Climate Adaptation for Rural Livelihoods and Agriculture (CARLA) Project', which is ready for implementation. 4. Development and submission of the Project Identification Form, for the 2nd NAPA project, 'Increasing the resilience of agriculture to the effects of climate change in the Shire River Basin'. development of PIF for the 3rd NAPA project ' Improving Climate Monitoring to enhance Early Warning Systems in Malawi', ongoing. 5. Inventory of information on activities implemented on the NAPA priorities by other institutions with other sources of funding. 6. A climate investment plan, within which an adaptation programme has priority is currently being developed. 7. Implementation of other adaptation activities in the vulnerable areas identified by NAPA through the Africa Adaptation Programme (AAP)
Stakeholder involvement	Public and private companies, academia, research institutions, government departments and Non-Governmental Organisations (NGOs).	Public and private sector organizations, including local leaders, religious and faith groups, academicians, non-governmental organizations (NGOs), civil society, Community Based Organisations and highly vulnerable rural communities. Policy-makers, including members of the Technical Committee on the Environment (TCE), the National Council on the Environment (NCE), and the Parliamentary Committee on Agriculture and Natural Resources
Link to other national development processes	Took into account some of the needs outlined in the Initial National communication and Energy Policy	Took into account the needs identified in development strategies such as the Malawi Growth and Development Strategy, Malawi Vision 2020, Malawi Poverty Reduction Strategy, and the National Environmental Action Plan.

mandate to include both mitigation and adaptation needs in its assessment. The reasons for this bias are not entirely clear, but may indicate that the TNA team in Malawi did not have sufficient understanding of, and sensitivity to, the need for adaptation technologies and that the concept of technologies for adaptation might not have been well understood by local stakeholders. In general, and as indicated in UNFCCC (2006), technology transfer was at the time mostly focused on mitigation issues for political reasons, being primarily for the energy sector and typically having involved transferring ideas or equipment from developed to developing countries. There may thus have been a temptation to envisage transfers for adaptation following the same pattern. In practice, however, technologies for adaptation are quite different from those of mitigation. Most importantly, adaptation, rather than being concentrated in one sector, i.e., energy, will essentially be ubiquitous, dispersed across all socio-economic sectors, including water, health, agriculture and infrastructure – each of which presents its own challenges and will involve a myriad of stakeholders in different if overlapping groups. In many respects, compared with mitigation, adaptation is thus far more diverse and complex.

Institutional continuity of project teams and expertise

For any future TNA, it will be important to consider bringing together the teams that were involved in the TNA and NAPA processes to ensure that activities are streamlined into the ongoing development and climate-related processes in Malawi. These teams will have institutional memory that could be useful for enhanced assessments and identification of suitable adaption actions, as well as associated technologies. For instance, efficiency gains were achieved during the NAPA process in that the same Government of Malawi climate change technical committee oversaw the production of initial national communications, which played a critical role in the NAPA process. In contrast, no reference was made to the use of the team that led the TNA in the NAPA, despite the fact that the NAPA process started after the conclusion of the TNA. In this vein, it will be important in future climate change interventions to maintain similar teams to ensure that that there is cross-referencing of issues that have already arisen and also to promote local expertise as a means of stronger national ownership of adaptation programmes. This would also help improve the efficiency and effectiveness of climate change programmes.

Implementation planning and follow-up activities and funding

Since the establishment of the least developed countries fund (LDC Fund) at COP7, the NAPA process has received a lot of public and political attention, as most LDC governments looked to this fund as the only one that could support their urgent and immediate adaptation needs. Further to this, COP9 adopted guidance for the LDC Fund to enable funding for the actual implementation of those urgent and immediate adaptation activities. As a result, most governments were very keen to finalise the NAPA preparation since funds were to be available for immediate implementation. Unlike the NAPA process, the TNA process did not receive such political attention as there were no readily available funds to support the immediate implementation of the technologies that had been identified. In line with this availability of funds for implementation, almost all LDCs were able to formulate their NAPA implementation plans and strategies so that they could go straight into implementation without further delays once the funds became available. However, due to limited funds in the LDCF, most NAPAs still have to receive funding for full implementation The implementation plan for Malawi also included several follow-up activities that were to clear the ground for the smooth implementation of the NAPA projects. This did not happen with the TNA process in most LDC countries, like Malawi, where no follow-up activities were planned after the submission of the TNA document. Therefore it can be seen that for any future TNA there is need to identify sources of technical and financial support clearly for its full implementation and a clear understanding of what would be the future steps after the initial assessments to enhance their implementations.

Contribution to overall development process

Another theme noticeable in Table 1 is that both these processes can contribute to the overall development of the country. Even though the TNA process had its own shortcomings, it tried to take into account some of the needs outlined in the initial national communication and energy policy document at that time. The NAPA also took into account the needs identified in the development strategies such as the Malawi Growth and Development Strategy, Malawi Vision 2020, Malawi Poverty Reduction Strategy 2004 and the National Environmental Action Plan. As a result of this, the Government of Malawi views the NAPA as a short-term national planning document, not only for climate change adaptation, but also for development in a broader sense. As such, the information provided in the NAPA is used in other initiatives, such as UNDP's work on sustainable land management and the Green Belt Initiative developed by the government to promote irrigation farming, in additional to various projects implemented by local NGOs. This is a very important lesson in that, if these types of climate change intervention are carried out well, they could effectively instigate the mainstreaming of climate risk information into broader national development strategies. They should, therefore, be seen as aiding the implementation of governments' overall development agendas. Furthermore, there is always the risk that adaptation technologies (as is the case for any technology) will be more accessible to wealthier communities and thus exacerbate existing inequality. There is thus a clear need to ensure that new forms of adaptation technologies do not heighten inequality, but rather contribute to a reduction in poverty.

Political involvement and endorsement

The involvement of multiple stakeholders and disciplines ensures that the outcomes of the NAPA are fully owned by those who prepare it, and endorsing the NAPA at higher political levels of government further ensures that it is fully owned by the national government. In addition to this, it also shows the government's full commitment in implementation of the adaptation actions. Political involvement in, and endorsement of, the NAPA process also helped raise awareness of the impacts of climate change in Malawi and the need for adaptation. The NAPA process helped push the climate change agenda at the government level and led to a revision of the overarching developing strategy for the government: 'the Malawi Growth and Development Strategy', to include climate change as one of the key priority areas for national development.

Summary of technology needs for NAPA implementation

The NAPA document indicates that there are a number of specific technologies that will be needed for effective and full implementation of the activities identified in the NAPA process. These are summarised in Table 2 below and are useful to consider in relation to potential future efforts on technologies for adaptation in Malawi. In Malawi, which has a predominantly agricultural-based economy, frequent droughts and floods are a major challenge to the agricultural sector and hence to the economy, threatening the economic gains that the country has achieved this far. As such, the technology needs indicated in the NAPA mostly cover areas such as seasonal weather and climate forecasts, improved crop varieties and water harvesting techniques, early warning systems and flood management. Some of the technologies are already being practised, but they need further improvement such as seasonal weather forecasting, irrigation and crop weather insurance.

For example, seasonal weather and climate forecasts in Malawi currently use scientific relations between sea surface temperature in the global oceans and total monthly rainfall over Malawi. These seasonal forecasts have previously been issued with relatively low certainty, particularly in the distribution of rainfall over a growing season, as they only forecast total rainfall amounts in a growing season from October to December and January and March. However, as a general planning tool the seasonal forecasts have been useful. As a consequence, in Malawi, even farmers with limited resources benefit from climate forecasting by making small adjustments in their livelihoods and agricultural production strategies. However, if they are to make full use of the forecasts, farmers will need more price forecasts and greater support to interpret them. In addition, adaptation should be based on the best-available scientific-understanding of climate change risks, impacts and vulnerabilities, and for any climate change adaptation plan there is a need for extensive use of modelling tools and relevant technologies. This calls for enhanced capacity building to use and interpret the climate models and their associated technologies.

Table 2. A summary of technology needs in Malawi's NAPA priority projects

NAPA Priority Project	Examples of Supporting Adaptation Technologies
Improving community resilience to climate change through the development of sustainable rural livelihoods	Hard Technology: Geospatial technologies, improved varieties, water and food storage systems Soft Technology: Crop and farm management skills
Restoring forests in the Shire River Basin to reduce siltation and the associated water flow problems	Hard Technology: Geospatial technologies Soft Technology: Growing of tree seedlings and land management skills Orgware: Creation of buffers
Improving agricultural production under erratic rains and changing climatic conditions.	Hard Technology: Geospatial technologies, irrigation technologies Soft Technology: Community radios, short messages. Seed multiplication technologies and animal breeding technologies, improved farm management, seasonal forecasts
Improving Malawi's preparedness to cope with droughts and floods	Hard Technology: embankments for flood control, water harvesting and recycling, wetland restoration, drought-resistance varieties and those varieties that can cope with a lot of water Soft Technology: Crop weather insurance, seasonal forecasts Orgware: Floating agriculture for areas that remain inundated
Improving climate monitoring to enhance Malawi's early warning capability and decision-making and sustainable utilization of Lake Malawi and lakeshore area resources	Hard Technology: Geospatial technologies, automatic weather stations and floating buoys, community flood information systems Soft Technology: knowledge and skills

Crop weather insurance is another new soft technology that has been implemented in Malawi for some years now. It uses a simple and objective crop weather index that is used as a proxy measure of the countrywide exposure of crop production to drought and hence serves as a nation-wide food-security indicator on which an insurance payout could be made. Insurance provides protection against crop failures caused by drought or excess rain and enables farmers to access credit in order to purchase quality seeds and fertilisers and thus maximise output. By linking farms to local weather stations and introducing an automatic payout process where farmers are not required to file a claim or go through an expensive loss verification process in the event of crop failure, the tool has been working in selected areas and for selected crops such as maize and tobacco. However, for the scheme to cover the whole country there is need for improved weather stations and methods used in coming up with the required index for more crops.

In an agriculturally based economy such as Malawi's, adaptation will mainly take place at the farm level, where technologies could be identified, e.g., for increasing crop yields, or at the systemic level where technologies could facilitate, e.g., financing and policies in the agriculture and disaster risk management. Agricultural systems are generally fairly flexible, and if farmers have access to the right information and tools they should be able to make many of the necessary adaptations on their own.

As indicated in Table 1, Malawi is in the process of developing the third NAPA project on enhancing early warning systems. This project will call for the identification of relevant technologies and capacity building on the use and maintenance of such technologies. Once the early warning system is up and running, the suppliers of the technologies will need to hand over operation and maintenance to a local institution. In this way, adoption and ownership of the technology will be enhanced. An example of how such an arrangement has been made is the Shire Zambezi Water Way project. This project involves the construction of a World Inland Port that will provide a direct water way transport system between Nsanje in southern Malawi and the port of Chinde in Mozambique, a distance of 283 km. The project is designed to link land-locked Malawi to the Indian Ocean through the port of Chinde. Mota Engil, a private company from Portugal, is currently constructing the port at Nsanje and will provide the necessary technical support after signing an agreement with the Government of Malawi to run the port for a specified period.

Table 2 indicates that any future round of TNA preparation in Malawi could also greatly benefit the full and effective NAPA implementation by including in its assessment technologies dealing with early warning systems, flood management systems, water harvesting and improving crop varieties and seasonal forecasts. Therefore technologies for adaptation should form a vital part of the broader frameworks for integrated climate change management. Whatever the envisaged levels of technology, there is a need to devise national strategies for adaptation, assessing the communities and the locations at greatest risk and planning appropriately. The Government of Malawi needs to assist this process by deliberately planning interventions offering new knowledge or equipment or even seeking new technologies.

Conclusions

From the above discussion of the TNA and NAPA processes, a number of lessons can be drawn that could help improve the effectiveness of any future TNA in achieving its objectives. In particular, there is a need to consider carefully the following issues:

(a) Identification of sources of technical and financial capacity for the implementation of identified technologies. This will ensure that everyone is aware that the assessment is not just being done as a stand-alone activity but that there will be follow-up activities for full implementation and use of the identified technologies. As illustrated in previous sections, Malawi did not carry out any follow-up activities after submission of the TNA report, and there was no further technical support to local project developers in converting ideas identified in the TNA into projects that meet the standards of international financial institutions who might fund such projects. Such technical support could include, e.g., guidebooks on preparing technology transfer projects for financing, as well as on accessing the available funding. This information could have been useful to convert project ideas resulting from TNAs and other sources into project proposals for financing. Regional workshops on project preparation could also enhance the capacity of project developers in preparing fundable project proposals on adaptation technologies. On the other hand, it is important to develop a clear implementation plan to ensure that the initial assessments are converted into concrete follow-up activities and impacts. The NAPA process was a very good example of this.

(b) The level of political involvement and endorsement is very important, as illustrated in the case of the NAPA discussed above. Therefore any future TNA should consider how to stimulate political attention so that all Malawians are aware of what is happening and thus will be eager to participate in the process.

(c) Institutional continuity is very important since the people who are involved will have an institutional memory of how things are supposed to be done and hence will improve the effective implementation of activities.

(d) Importance of integrating the process in existing climate change processes and institutions. Climate change interventions may be of limited usefulness if they take place in a vacuum. Future assessment processes will need to ensure that their outcomes feed into and improve the implementation of existing policies and strategies.

The NAPA preparation process has already drawn important conclusions regarding adaptation technology needs in Malawi, and it can be seen from the identified priority projects that for their full effective implementation there is a need to strengthen and identify relevant technologies further. Further assessments on how these technologies can be scaled up and scaled out could be useful in feeding into any future TNA process. Therefore any future TNA could make use of such information and build upon it.

The NAPA implementation process has also shown that, on top of the physical element of 'technology transfer', there is a need to focus on local capacity building to implement and maintain technologies sustainably once projects have been completed on the ground. This capacity building should take place at both the institutional and individual level for those who will be involved in the implementation of relevant activities and maintenance of the technologies.

With decision 1.CP.16 at the 16th session of the UNFCCC Conference of Parties in Cancun, Mexico, the COP to establish a process to enable LDCs to formulate and implement national adaptation plans covering medium and long-term adaptation actions and avenues was also opened up to further mainstream national adaptation planning and TNAs. This process will build upon the experience and lessons learnt in preparing and implementing national adaptation programmes of action. Since this process will cover medium and long-term adaptation actions, there is a need for a comprehensive assessment all climate-sensitive sectors, which should logically include technology needs assessments for adaptation. By integrating the TNA process into the preparation of National Adaptation Plans (NAPs), technology assessments will be further streamlined and mainstreamed into the national adaptation planning process, thus minimising costs and avoiding duplication of effort.

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References

Fankhauser S. 1997. The Cost of Adapting to Climate Change. Working Paper No.13 Global Environmental Facility, Washington DC USA

UNFCCC November 2006. Technologies for Adaptation to Climate Change, <http://unfccc.int/ttclear/pdf/tech_for_adaptation.pdf>

UNFCCC May 2011. Training Package on Preparing Technology Transfer Projects for Financing <http://unfccc.int/ttclear/pdf/Training/TRAINING_PACKAGE_COMPLETE.pdf>

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Technology needs for adaptation in southern Africa: Does operationalisation of the UNFCCC and associated finance mechanisms prioritise hardware over software and orgware?

Abstract

Technology is an integral part of global responses to climate change, and is enshrined in the UNFCCC and its associated adaptation finance mechanisms. In this paper we argue that the operationalisation of these has had the (probably unintended) consequence that hardware for adaptation (concrete infrastructure) is favoured over software ("soft skills" required to make behavioural and socio-cultural changes) and orgware (the institutional set-up and coordination mechanisms required to support the implementation of hardware and software). We examine three southern African countries - South Africa, Swaziland and Mozambique – and suggest that technology needs assessments are often too generic to provide sufficient detail on national contexts; and that under-emphasising software and orgware relative to hardware runs the risk of impeding effective adaptation to climate change. Furthermore we make the case for treating hardware, software and orgware more integrally, as they are interdependent.

Introduction

Technology is an integral part of global responses to climate change. The United Nations Framework Convention on Climate Change (UNFCCC) incorporates technology in a number of ways. In the framework convention itself and its Kyoto Protocol, technology transfer is enshrined as a mechanism of support for reducing levels of greenhouse gases in the atmosphere. In the reporting requirements that are common to all parties to the UNFCCC,[1] the National Communications, technology needs are explicitly met. For Least Developed Countries the National Adaptation Programmes of Action (NAPAs) are implicitly built around technology needs to be met through the provision of climate finance, and there is also an option for countries to submit technology needs assessments to the UNFCCC Secretariat. However, reading this national documentation tends to be very similar for many countries: the biggest emphasis is on a wish-list for hardware, accompanied by poorly-defined 'capacity building' for software, and very little recognition of the orgware required to bring about effective adaptation.

We define three types of technologies for adaptation: hardware, software and orgware. Hardware refers to tangible, 'concrete' measures, such as infrastructure like a dam. Software refers to the 'soft skills' required to make behavioural and socio-cultural changes, for example, training around different planting techniques. Orgware refers to the institutional set-up and coordination mechanisms (and change) that are required to support the implementation of hardware and, in particular, software. In this paper we argue that the way that technology has been interpreted through the technology transfer framework, and in turn reinforced by the architecture and criteria for adaptation finance mechanisms, has had the (probably unintended) consequence that hardware for adaptation is favoured over software and orgware. Our experience in three southern African countries – South Africa, Swaziland and Mozambique – suggests that technology needs assessments are often too generic to provide sufficient detail on national contexts; and that under-emphasising software and orgware relative to hardware runs the risk of impeding effective adaptation to climate change. Secondly, deconstructions of the publicly-stated technology needs in UNFCCC reports (National Communications, NAPAs and Technology Needs Assessments, or TNAs) show that context-specific nuances are often overlooked, which also has implications for whether or not technology transfer promotes sustainable adaptation.

1 Parties are those countries that have signed the UNFCCC and ratified it into national law. Signatories are those countries that have signed but not yet ratified the agreement.

Technologies and adaptation: The background

The climate change debate and international policy process is typically polarised around two issues: mitigation and adaptation. On the international scale, this in turn tends to translate into a situation of developed countries prioritising mitigation (to meet their greenhouse gas emissions targets under the Kyoto Protocol) and developing countries prioritising adaptation, in order to reduce the adverse impacts of climate change. Adaptation to climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as 'adjustments in natural or human systems in response to actual or expected climatic stimuli, or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2007). The capacity to adapt is dependent on such factors as health, governance and political rights, literacy and economic well-being (Adger and Vincent, 2005), and it is possible to adapt in anticipation of change (known as anticipatory adaptation), or in response to change (known as reactive adaptation) (Smit et al., 2000).

Of critical importance to debates on technology transfer and adaptation is the fact that, unlike mitigation, adaptation is very difficult to monitor and evaluate (although some progress has been made recently; see Villanueva, 2011). In many cases, whether or not adaptation has been successful can only be determined at some point in the future after exposure to a hazard (Füssel, 2007). The Monitoring, Reporting and Verification (MRV) of reductions in greenhouse gas emissions in the atmosphere is still being debated in the context of the post-2012 regime around climate

(Breidenich and Bodansky, 2009). However, there are at least accepted empirical and quantitative measures that are used in National Communications (Eggleston et al., 2006). The apparent intangibility of adaptation software contributes to the fact that the international policy architecture and resulting finance mechanisms seem, whether advertently or inadvertently, to favour hardware.

Technology and the UNFCCC

The concept of technology transfer is enshrined in the United Nations Framework Convention on Climate Change. Along with committing its parties to 'stabilising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (article 2), article 4.3 of the framework convention commits developed countries to transferring technology to their developing country counterparts in order to support this objective. Since 1992, much progress has been made in operationalising the transfer of technology and mechanisms to support these, particularly through UNFCCC-related flexible mechanisms (De Coninck et al., 2007; Schneider et al., 2008; Seres et al., 2009). However, despite the fact that software and orgware are theoretically included in the term 'technology', in practice it seems that technology transfer has focused on the transfer of hardware. Whilst in many cases hardware can support adaptation, its efficacy is typically limited by the absence of the related software and orgware transfers that are required to manage it effectively. Empirical, documented examples of this are difficult to find, since monitoring and evaluation typically end with the project life, but the authors are aware of anecdotal examples of hardware-based projects where the benefits have not been sustained beyond the life of the project due to the failure to put in place the necessary software and orgware structures (including where that orgware refers to informal, local institutions).

The first steps towards operationalising the technology transfer component of the framework convention were taken at the 4th Conference of the Parties, held in Buenos Aires in 1998. A consultative process was launched, resulting in a framework to enhance technology transfer, that was launched at the 7th Conference of the Parties in Marrakesh in 2001 through the Marrakesh Accords. The Technology Transfer Framework comprises five main themes; technology needs assessment, enabling environment, technology information, capacity-building, and mechanisms for technology transfer.

Technology needs assessment

The purpose of the Technology Needs Assessment was to identify the barriers to technology transfer and measures to address those barriers. Activities were foreseen to include both software and hardware for both mitigation and adaptation, including the identification of regulatory options and development of fiscal and financial incentives and capacity building (4/CP.7, available online at http://unfccc.int/resource/docs/cop7/13a01.pdf#page=22). Support was available through the Subsidiary Body for Scientific and Technical Advice, the Expert Group on Technology Transfer, and the 2001 IPCC Special Report on Methodological and Technological Issues in Technology Transfer. Various UN agencies and the Climate Technology Initiative also facilitated several workshops to share experience and best practice, and made available a number of technical support tools (with Climate Technology Investment (CTI) providing technical support to South Africa, among a number of other countries). The ultimate purpose was to identify and analyse priority technology needs. As of September 2011, 70 countries had submitted a Technology Needs Assessment report to the UNFCCC.

Enabling environment

The Enabling Environment refers to government policies that create an environment that is conducive to the effective transferring technologies. As such, it includes the existence of national institutions for technology innovation, research and technology development, and national legal institutions that introduce codes and standards and protect intellectual property rights – all of which support private- and public-sector technology transfer. All parties are encouraged to improve the enabling environments for the transfer of technologies through the identification and removal of barriers and using positive incentives. Although there have been round tables and various events, the assessing of enabling environments is difficult (so, as with most soft skills, it has largely been ignored).

Technology information

The Technology Information theme defines the means required to facilitate the flow of information between different stakeholders to enhance the development and transfer of environmentally sound technologies. It includes the hardware, software and networking aspects, and can provide information on these parameters as inputs into the technology needs, and to support the effective transfer of technology. A technology information clearing house was developed by the UNFCCC, although it was under-used. More recently, several international technology centres have been designated in order to support the availability of technology information (FCCC/SBSTA/2005/INF.9, available online at http://unfccc.int/resource/docs/2005/sbsta/eng/inf09.pdf).

Capacity-building

The Capacity-building theme is concerned with building, developing, strengthening, enhancing and improving existing scientific and technical skills, capabilities and institutions in developing countries parties to enable them to assess, adapt, manage and develop environmentally sound technologies. Particular aims include the provision of environmentally sound technology demonstration projects, strengthening the capacity of national institutions relevant to technology transfer, training in the development, management and operation of climate technologies, and improvement of knowledge on energy efficiency. As with other themes, various seminars and workshops have been convened in order to support the development of capacity for technology transfer.

Mechanisms for technology transfer

Mechanisms for Technology Transfer are intended to facilitate the support of financial, institutional and methodological activities by encouraging cooperative efforts and facilitating the development of environmentally sound technologies. In particular, the expert group on technology transfer supports this theme, and reports back to the Conference of the Parties to the UNFCCC, the Subsidiary Body for Scientific and Technological Advice (SBSTA) and Subsidiary Body on Implementation (SBI). Many of the group's discussions to date have focused on financing options for the development and transfer of technologies. To date, the focus has been on the transfer of technologies for the mitigation of greenhouse gas emissions (for example, solar heaters, photovoltaics, biomass, energy efficiency projects). But recent resolutions have focused on encouraging support for adaptation using the transfer of environmentally sound technologies.

Ongoing support for technology transfer was reiterated at COP16 in Cancun, when a Technology Mechanism was established to facilitate the implementation of enhanced action on technology development and transfer in order to support action on mitigation and adaptation to climate change. The Technology Mechanism comprises a Technology Executive Committee and a Climate Technology Centre and Network. A decision is expected at COP17 to operationalise this mechanism in 2012 (see the Cancun Agreements on Climate Change, available online at http://cancun.unfccc.int/).

Based on the above five themes, theoretically the concept of technology transfer within the UNFCCC refers to both mitigation and adaptation; and it recognises the need for hardware, software and ogware in both. Recent developments, for example, with regard to the mechanisms for technology transfers, have recognised the need to pay particular attention to supporting adaptation. This is because to date mitigation has received more emphasis than adaptation (as within the UNFCCC in general). However, the reality of observing adaptation projects in many countries shows that disproportionate emphasis is placed on the hardware element, relative to the software and orgware. In an attempt to interrogate why this is so, this paper now turns to adaptation finance, before looking at three case studies in southern Africa.

Finance for technology transfer and adaptation

As well as the development of extensive frameworks to support technology transfer, various mechanisms under the UNFCCC make financing available for adaptation. Article 4.3 of the convention states that developed countries should meet the agreed incremental costs of adaptation in full, while article 4.4 commits developed countries to assisting developing country parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation.

Throughout the course of negotiations on the UNFCCC and the Kyoto Protocol, three major funds have been established for adaptation activities: the Special Climate Change Fund, the Least Developed Countries Fund (under the UNFCCC), and the Adaptation Fund (under the Kyoto Protocol) (see Table 1). All of these funds are managed and administered by the Global Environment Facility, which has also been funding adaptation since 2004 under its Strategic Priority Areas. At COP15 in Copenhagen, developed countries pledged to provide new and additional resources approaching US$30 billion for the period 2010-12, targeting both adaptation and mitigation – known as fast start finance (FCCC/CP/2011/INF.1, available at http://unfccc.int). Following up on this pledge, a decision at COP16 in Cancun reaffirmed that funding for adaptation will be prioritised for the most vulnerable developing countries, including the Least Developed Countries and Africa (FCCC/CP/2010/7/Add.1, available at http://unfccc.int). Also at COP16 governments decided to establish a Green Climate Fund that will support projects, programmes, policies and other activities in developing countries using thematic funding windows targeting both adaptation and mitigation. Following a design phase in 2011, the modality of operation is due to be unveiled at COP17 in Durban.

Table 1. Summary of the three adaptation funds under the UNFCCC and Kyoto Protocol

Source	Fund name	History	Intended applications	Expenditure to date
UNFCCC	Special Climate Change Fund	Created in 2001	To support long-term and short-term adaptation and technology transfer in all developing country parties to the UNFCCC.	$218 million disbursed through 31 projects in 50 countries
	Least Developed Countries Fund	Created at COP11	To support preparation and implementation of NAPAs (since most LDCs have now prepared NAPAs, the focus is on implementation)	$415 million disbursed through 47 projects in 48 countries
Kyoto Protocol	Adaptation Fund	Created at COP6	To finance concrete adaptation projects in developing countries that are party to the Kyoto Protocol	$60.57 million allocated to 10 projects in 10 countries

Source: based on various fund descriptions from the Global Environment Facility website (www.thegef.org/gef/SCCF, www.thegef.org/LDCF, www.adaptation-fund.org).

Table 1 shows that there are already three significant funds in operation that target adaptation activities. Of particular note is the Adaptation Fund, which specifies that funding is available for 'concrete adaptation projects'. This criterion explicitly refers to hardware, whilst simultaneously excluding software and orgware projects from consideration. Since its operationalisation in 2010, the Adaptation Fund has disbursed monies for ten projects in Africa, Asia and South America, and although aspects of the enabling environment may be addressed, its primary aim and focus concerns the implementation of adaptation hardware technologies. Whilst this is important, we argue that excluding software and orgware applications from the primary adaptation funding mechanism in the UNFCCC serves to reinforce a situation where the most urgent needs (and opportunities for greatest returns) in southern African countries go unmet. It also risks the long-term sustainability of hardware projects, which require supporting orgware after the end of the project life.

Does technology transfer ask the right questions for adaptation?

In assessing the five themes, the Technology Transfer Framework of the UNFCCC seems to be comprehensive. Technology is only considered for transfer if needs can be identified and if the enabling environment is deemed appropriate to receive them, including reference to technology information (and structures to enable the flow of information) and capacity-building where appropriate. As such, it could be argued that there is consideration of hardware, software, and orgware. However, the premise of this paper is that software and orgware are too often only considered in relation to hardware, and not in their own right. We believe that this is a fundamental flaw of the Technology Transfer Framework, as in many cases enabling adaptation in the developing world requires the building or streamlining of software and/or orgware without necessarily the requirement for hardware. We now explore this premise in relation to three southern African countries.

South Africa

South Africa is in a unique position with regards to climate change. Classified as a middle-income developing country and a non-Annex 1 country to the UNFCCC, it has no mitigation commitments under the Kyoto Protocol first commitment period. This is despite the fact that, on a per capita basis, South Africa is among the top twenty biggest emitting countries in the world, due to its heavy reliance on coal for energy, which it supplies to many neighbouring countries. With a high degree of income inequality, the responsibility for mitigation and need for adaptation falls along a cleavage similar to the developed/developing split within the UNFCCC. Therefore, internally, policy commitments exist for both mitigation and adaptation. In addition, South Africa has completed a Technology Needs Assessment under the UNFCCC.

South Africa conducted its Technology Needs Assessment in 2007, with technical support from CTI. The TNA was managed by the Department of Science and Technology, the line ministry with responsibility for research and development and the country's vision for transition to a knowledge economy. The consultation took place within the remit of the multi-stakeholder National Climate Change Committee and involved representatives from a variety of line ministries, parastatals and academia (Department of Science and Technology, 2007).

The process of the TNA involved several steps for prioritisation. The first step involved assessing options for mitigation and adaptation according to five different criteria: relevance to climate change (mitigation and vulnerability), alignment with national goals (strategies and targets, sustainability and competitive advantage), market potential (cost/benefits, utilisation scale, and maturity), skills and capacity-building (support systems, users, and indigenous knowledge) – with each having a weighting of between 1 and 3. Priority sectors were then defined according to the number of technologies assigned to them: for adaptation, these were agriculture, land use and forestry (with 6 technologies), human health (2), water resources (1) and built environment (1). Table 2 outlines the technologies identified within each sector, together

Table 2. Scores for priority technologies for adaptation within South Africa's TNA

Sector	Technology	Score
Human Health	Provision of water supply and sanitation	90.4
	Control of the spread of vector-borne disease	87.1
Agriculture, land use and forestry	New crop species and cultivars	88.6
	Information technology	87.1
	Macroeconomic diversification and livelihood diversification in rural areas	82.6
	Pest management	80.3
	Vulnerability research	80.1
Water resources	Technologies that promote water efficiency	81.8
Built environment and infrastructure	Climate sensitive building design	81.1

Table 3. Cross-cutting themes in the TNA

Overarching issue	Technology option	Score
Cross-cutting	Improved data management, processing and integration	75.4
	Improved communication and response in disaster management	74.6
	Networks for information sharing and data integration	72.8
Financial mechanisms	Incentives for energy efficiency	88.6
	Incentives for renewable energy	75.4
	Disincentives for high fuel consumption vehicles	72.8

with their score calculated by multiplying the expert score by the weighting, normalising, and then dividing by the maximum possible score (of 66). In addition, a number of cross-cutting themes across mitigation and adaptation were identified (Table 3).

It is clear that South Africa does explicitly consider hardware and software as technologies it requires for adaptation. Examples of hardware adaptations in Tables 2 and 3 include the provision of water supply and sanitation, new crop species and cultivars, and technologies that promote water efficiency. Examples of software include control of the spread of vector-borne disease, livelihood diversification, pest management and the financial mechanisms identified in cross-cutting themes. Orgware is also recognised, particularly in the cross-cutting themes (improved communication and response in disaster management, and networks for sharing and data integration).

As a middle-income developing country, South Africa's eligibility for the international adaptation finance mechanisms is limited to the Adaptation Fund. As yet no applications have been made by the country to the Fund. In September 2011, however, it was announced that the South African National Biodiversity Institute (SANBI) had been approved as a National Implementing Entity, meaning that it is eligible for direct support (as opposed to monies being managed by the Multilateral Implementing Entities, such as the UN agencies), so this situation may change. So far, the Technology Needs case studies do cite one example – testing solar stoves. This is an example of a project that is classified both as mitigation (reducing emissions from coal or charcoal-fired stoves) and adaptation (enabling rural people to improve their livelihoods in the context of warmer temperatures), but it falls firmly within the realm of hardware.

In its Second National Communication, currently released in draft format, the government of South Africa cites 'the key constraints to technology adoption in South Africa are project finance and the development of human resources to implement and maintain the technologies' (Department of Environmental Affairs, 2010a, p. x). Further in the document, emphasis is placed more on mitigation technologies (upon which the Designated National Authority, the Department of Environmental Affairs, has stated that its mitigation commitments are contingent). Relative to other middle-income countries, including its neighbours in southern Africa, South Africa is technologically advanced with regards to adaptation. Even within orgware, which is often the most elusive and difficult to define, South Africa has made progress. A National Climate Change Response Green Paper has recently closed its period for questions, and a White Paper is in the process of being drafted (Department of Environmental Affairs, 2010b). The Department of Environmental Affairs has set up a new branch on Climate Change, which includes an Adaptation Unit, charged with the development and implementation of the policy – hence putting in place the orgware.

Whilst the inclusion of orgware in adaptation measures is a positive sign, the way that technology transfer and adaptation finance has been set up in the UNFCCC is not conducive to supporting this. Representatives of the Adaptation Unit at the national level have worked hard to undertake a comprehensive consultative process to define the National Climate Change Response Strategy. However, they recognise that substantial challenges exist with regards to orgware at the sub-national level, i.e., in the provinces and municipalities that will take responsibility for the implementation of the policy (Mpandeli, 2010, pers.comm), where the biggest need is for training and capacity-building around climate change, and the challenges and opportunities of mainstreaming climate change for adaptation. However, such software and orgware is not within the realm of the technology transfer aspect of the UNFCCC, nor is it eligible for financial support through the Adaptation Fund.

Swaziland

Neighbouring Swaziland is also classified as a middle-income developing country. As a result it has not been obliged to prepare a NAPA, nor is it eligible for the Least Developed Countries Fund. Unlike South Africa, Swaziland has not submitted a Technology Needs Assessment, and thus the only reported references to technology and adaptation come from its First National Communication, produced in 2002.

While at first sight Swaziland's technology needs appear to be very similar to South Africa's, there are in fact critical differences between the two. As a non-Annex 1 country, Swaziland has no mitigation commitments under the UNFCCC, but unlike South Africa the country is a net absorber of greenhouse gas emissions, meaning that the capacity of the country's plantations to act as a sink exceeds the small quantity of greenhouse gases emitted (Government of Swaziland, 2002). That said, as in South Africa, there is a high degree of income equality. This exists to the extent that if the top tier of earners were removed from the equation, the aggregate levels of income of the majority of Swazis would put them alongside citizens of Least Developed Countries. With a high degree of dependence of the rural population on climate-sensitive natural resource-based livelihoods such as farming, adaptation is critical in Swaziland (Matondo et al., 2004).

As well as being ineligible for adaptation finance targeted at Least Developed Countries, no Swaziland-based project has yet to be approved and financed by the Adaptation Fund. There has been one project under the Special Climate Change Fund, which aims to promote integrated water resources management, given Swaziland's dependence on transboundary river basins. As well as involving hardware technology through the generation of model outputs on climate change projections and their likely impacts on streamflow, the project does involve software such as the dissemination of information to communities to raise awareness of climate change. It also supports the development of orgware, with the establishment of a national platform/coordinating mechanism, national policy dialogues around the National Water Policy and collaborative partnerships between the meteorological services and policy makers to ensure improved access to climate information.

Whilst South Africa is in the process of developing its own orgware to promote adaptation internally, with the inter-ministerial Government Climate Change Committee, National Climate Change Committee and an emerging policy framework, Swaziland does not have explicit climate change policies and legislation as yet (although climate change is taken into account in a number of sectoral policies, such as energy and forestry). The National Communication does suggest a number of priority adaptation projects, most of which refer to hardware (e.g., dam construction, new water supply infrastructure), although there is also reference to behavioural practices related to different farming and forestry techniques. It also recognises the constraints of the institutional framework, the existing technology capacity and the available technology. However, given the way technology transfer has been conducted in the UNFCCC, combined with the availability of finance, it is likely that hardware will be prioritised over software and orgware.

Mozambique

In contrast to South Africa and Swaziland, Mozambique is classified as a Least Developed Country. In addition to its National Communication (Ministry for the Coordination of Environmental Affairs, 2003), therefore, it has also produced a NAPA (Ministry for the Coordination of Environmental Affairs, 2007). It is also eligible for, and has received funding from, the Least Developed Countries Fund and the Special Climate Change Fund.

Mozambique's National Communication and NAPA both highlight the role that software and orgware play in bringing about adaptation. The National Communication cites the need to 'strengthen the country's socio-economic development, closely dependent on the integration of environmental issues with development efforts, and implement sustainable management of the country's resources in a multi-sectoral context, with harmonisation of plans and programmes and involvement of all the stakeholders implicated in the exploration and utilisation of natural resources' (Ministry for the Coordination of Environmental Affairs, 2003, p. xii). Slightly later in the document, it refers to the need for 'technology transfer of know-how' (ibid., p. xiii), again explicitly recognising the need for transfers of soft skills. Likewise Mozambique's NAPA outlines four main priorities: improvement of early warning systems, improving capacity of farmers to adapt to climate change, reductions in the coastal impacts of climate change, and managing water resources.

Mozambique has also been more successful to date in accessing adaptation finance than either South Africa or Mozambique, likely reflecting the fact that as a Least Developed Country it is eligible for a wider range of funds. In addition to funds from the Least Developed Country Fund to develop the NAPA, Mozambique has a project on adaptation in the coastal zones with Least Developed Country Fund monies, another on coping with drought and climate change with money from the Special Climate Change Fund, and various other international financing sources outside the UNFCCC.

Given that Mozambique has a large number of climate change adaptation-related projects focusing on software, it is essential that the orgware is in place to make sure that these efforts are coordinated and that lessons learned in one project inform others. Even though Mozambique, like Swaziland, has no climate change policy per se, climate is incorporated into other sectoral policies, and a number of non-UNFCCC financing mechanisms are encouraging the further mainstreaming of climate change (for example, the Japan-funded, UNDP-implemented Africa Adaptation Programme and World Bank Pilot Programme for Climate Resilience). With so many projects and no one overarching policy framework, ensuring that software transfer is accompanied by the development of orgware is essential to ensure sustainability. Indeed, there is already evidence that coordination is one aspect of orgware that needs to be promoted. Whilst the Ministry for the Coordination of Environmental Affairs is the Designated National Authority (DNA) and the official government lead on climate change and adaptation, the National Disaster Management Institute (INGC - Instituto Nacional de Gestão de Calimadades) has concurrently been making great strides with disaster risk reduction in the country. Clearly there are overlaps and synergies between the two (and INGC is addressing the 'improvement of early warning systems', stated as an adaptation priority in the NAPA).

Conclusion

This paper has reviewed the way in which technology for adaptation is included in the UNFCCC, concluding that the way it has become operationalised, at least, has tended to prioritise hardware over software and orgware. This is partly due to successful adaptation often being hard to monitor or observe. As a result, the adaptation finance mechanisms seem to favour hardware, particularly in the case of the Adaptation Fund, where 'concrete adaptation' is explicit. The Mozambican case study has shown that eligibility for different funds is very important, but the South African and Swaziland case studies indicate that this is not the only factor. South Africa and Swaziland are both only eligible for the Adaptation Fund, but only South Africa has made progress towards accessing this fund (through the approval of SANBI as a NIE). We argue that a critical reason for this is that, relatively speaking, South Africa has much more robust software and orgware than Swaziland. The interlinkages between hardware, software and orgware show that an emphasis on hardware can doubly disadvantage a country in that it is difficult to access funding for software and orgware, and without these it is also much more difficult to access money for hardware. This is because the institutions and coordination mechanisms (orgware) are a prerequisite to be able to apply for, receive and manage any technology and/or international finance.

The three case studies in the paper also highlight the importance of context when determining adaptation needs and the types of hardware, software and orgware that are funded – one size does not fit all. Mozambique, relative to Swaziland, has much more developed orgware (many institutions involved in climate change issues), but coordination between these institutions is lacking. Swaziland is a good example of how underdeveloped orgware is hampering that country's ability to access funding, while South Africa has a need for software in order to promote implementation, since in its case the orgware is already in existence.

Furthermore, the way in which technology needs are reported tends to result in fairly generic wish-lists, which do not do justice to the specific contexts in different countries that need to be taken into account in order to bring about adaptation. Although it may require more innovative ways of monitoring success, looking at the institutional structure to support adaptation and ensuring the effective coordination of efforts, both horizontally between government departments and vertically at different levels of government administration, it is essential for adaptation in these southern African countries. Opportunities for sharing orgware technology through best practice can be encompassed within the Technology Transfer Framework, but further flexibility is required in the adaptation finance mechanisms that support it.

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References

Adger, W. N. and K. Vincent, 2005: Uncertainty in adaptive capacity, Comptes Rendus Geosciences 337(4), 399-410.

Breidenich, C., and D. Bodansky, 2009: Measurement, Reporting and Verification in a Post-2012 Climate Agreement. Paper prepared for the Pew Center on Global Climate Change. Available online at http://www.pewclimate.org/docUploads/mrv-report.pdf

De Coninck, H., Haake, F., and N. van der Linden, 2007: Technology Transfer in the Clean Development Mechanism, Climate Policy 7(5), 444-456.

Department of Environmental Affairs, 2010a: South Africa's Second National Communication under the United Nations Framework Convention on Climate Change, Pretoria: Department of Environmental Affairs.

Department of Environmental Affairs, 2010b: National Climate Change Response Green Paper. Pretoria: Department of Environmental Affairs.

Department of Science and Technology, 2007: South Africa's Climate Change Technology Needs Assessment Synthesis Report. Pretoria: Department of Science and Technology. Available online at http://unfccc.int/ttclear/jsp/CountryReports.jsp

Eggelston, S., Buendia, L., Miwa, K., Ngara, T. and K. Tanabe, 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Tokyo: Institute for Global Environmental Strategies.

Füssel, H-M., 2007: Adaptation planning for climate change: concepts, assessment approaches, and key lessons, Sustainability Science 2(2), 265-275.

Government of Swaziland, 2002: Swaziland's First National Communication to the United Nations Framework Convention on Climate Change. Mbabane: Government of Swaziland. Available online at http://unfccc.int/resource/docs/natc/swanc1.pdf

http://unfccc.int, 15 September 2011.

IPCC, 2007: Climate Change 2007 Synthesis Report: Summary for policymakers, WMO, Geneva.

Available online at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Matondo, J.I., Peter, G. and K.M. Msibi, 2004: Evaluation of the impact of climate change on hydrology and water resources in Swaziland: part 1, Physics and Chemistry of the Earth parts A/B/C 29(15-18), 1181-1191.

Ministry for Coordination of Environmental Affairs, 2003: Mozambique Initial National Communication to the UNFCCC. Maputo: MICOA. Available online at http://unfccc.int/resource/docs/natc/moznc1.pdf

Ministry for the Coordination of Environmental Affairs, 2007: National Adaptation Programme of Action. Maputo: MICOA. Available online at http://unfccc.int/resource/docs/napa/moz01.pdf

Mpandeli, S., Special Advisor, Adaptation Unit, Department of Environmental Affairs, September 2010.

Schneider, M., Holzer, A., and V.H. Hoffman, 2008: Understanding the CDM's contribution to technology transfer, Energy Policy 36(8), 2930-2938.

Seres, S., Haites, E., and K. Murphy, 2009: Analysis of technology transfer in CDM projects: An update, Energy Policy 37(11), 4919-4926.

Smit, B., Burton, I., Klein, R.J.T. and J. Wandel, 2000: An anatomy of adaptation to climate change and variability, Climatic Change 45(1), 223-251.

Villaneuva, P.S., 2011: Learning to ADAPT: Monitoring and evaluation approaches in climate change adaptation and disaster risk reduction – challenges, gaps, and ways forward. SCR Discussion Paper 9, Strengthening Climate Resilience Alliance.

www.adaptation-fund.org, 15 September 2011.

www.thegef.org, 15 September 2011

Section III: Practical experiences from working with technologies for adaptation

Photo credit: Tin Ponlok

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Community adaptation to climate change in Cambodia: Technology and development aspects for agriculture

Abstract

As a mostly agrarian economy, Cambodia has limited financial resources to adapt to climate change. Agriculture is rainfed, based on household subsistence and characterised by low inputs and yields, which makes it vulnerable to weather variability. In recent years, rural communities have been unable to cope with increasingly frequent and severe floods and droughts. This paper focuses on technological aspects of community adaptation to climate change in agriculture. The first section provides an overview of the expected impacts of climate change on Cambodia's agriculture and its ability to achieve national development objectives. The second section discusses technology aspects of adaptation in agriculture as articulated in Cambodia's National Adaptation Programme of Action to Climate Change and Technology Needs Assessments. The third section provides suggestions for realistic action with practical benefits for Cambodian farming communities. The lack of financial resources is the most significant constraint for community adaptation in agriculture. Technologies and practices for adapting to climate change already exist among Cambodian farmers. The priority is not the transfer of new adaptation technologies to Cambodia, but rather to expand and strengthen existing indigenous capacity and knowledge to adapt to climate change. Communities need to be given greater financial resources and institutional support to implement adaptation activities in the field.

Introduction

For developing countries with large segments of their populations subsisting on agriculture, adaptation to climate change is a major social and economic issue. Cambodia does not have the necessary financial resources to adapt to climate change. Cambodian farmers may not be aware of the stumbling blocks of international climate change negotiations, but they have experienced climate change first hand: their crops, their belongings, their houses, and sometimes their loved ones have been washed away by climate disasters, which primarily consist of flood and drought. The question arises as to whether there exist some silver bullet technologies that could increase the resilience and adaptive capacity of Cambodia's largely rural population. Technology can be defined as a piece of equipment, technique, practical knowledge or skills for performing a particular activity (IPCC, 2001). The field of greenhouse gas mitigation has been dominated by a focus on hard technologies and equipment, such as renewable energies and energy efficiency technologies, the transfer of technologies from developed to developing countries, and issues of intellectual property rights. In contrast, technological approaches to adaptation include hard technologies, equipment or "hardware", as well as soft technologies, such as knowledge of methods and techniques, or "software". A further distinction can be made between hard adaptation measures, soft adaptation measures, and "orgware", which consists of institutional arrangements (Taylor, Thorne & Mqadi, 2006). The traditional understanding of technology in its narrower sense of capital assets and equipment may be too restrictive to be of practical usefulness to climate change adaptation, while broadening the concept of technology to practices, experience, processes and institutions better reflects the breadth of adaptation activities that can be implemented in the field. In this paper, we use the concept of adaptation technology in its broadest sense, as to include not only hard technologies, but also methods, processes, knowledge, and organisational measures and practices.

Cambodia's vulnerability to climate change

Development priorities

Although Cambodia ranks globally as a middle human development country, it lags behind most of its East Asian neighbours on indicators of education, health and wealth (UNDP, 2010). The country's priority is to achieve the Cambodia's Millennium Development Goals (CMDGs), which include the eight goals of the United Nations MDGs by 2015, and a ninth goal of zero impact from landmines and unexploded ordnance (UXO) by 2012. Cambodia's economy achieved an average growth rate of about 10% per year over the 1998-2007 decade, relying on agriculture, construction, industry and tourism. Although poverty has decreased with economic growth, poverty rates remain high at about at third of the population, or 4.7 million people under US $1 a day. The incidence of poverty is disproportionally higher in rural areas. Poverty rates are in excess of 49% among households whose main source of income is agriculture (Komoto & Stone, 2009; World Bank, 2009). The CMDG targets will probably not be met (ODI, 2010). The impact of the global financial crisis has been severe on Cambodia's economy which relies to a large extent on access to foreign markets as well as on foreign direct investment. Cambodia was one of the few low income countries to see its economy contract in 2010 and experienced a significant deterioration in development finance flows (IMF, 2011). The global credit crunch has resulted in a decrease in financial resources available to government.

Even prior to the impact of the global financial crisis, the National Strategic Development Plan had already acknowledged climate change as a threat to economic growth (RBC, 2010). Cambodia has limited financial resources to adapt to climate change or climate-proof its development. The government's priority is to mobilise funding for the implementation of the National Adaptation Programme to Climate Change (NAPA), as it will also contribute to the achievement of broader national development objectives.

Climate trends and vulnerabilities to climate change

Cambodia has been getting warmer. From 1960 to 2006, the mean annual temperature increased by 0.8°C (McSweeny, New & Lizcano, 2008). In 2006, there were 46 more hot days per year than in 1960. The threshold for "hot" is defined as the 10% hottest for the daily maximum temperatures for the reference period 1970-99. These already observable trends are confirmed by projections of future climate using Global Circulations Models (GCMs) under different IPCC Scenarios. Climate projections for Cambodia generally point to more intense wet and dry seasons and higher average temperatures (McSweeny, New & Lizcano, 2008; MOE, 2002 & 2010). According to the more optimistic projections for the lower emission B1 scenarios, the mean annual temperature would increase by at least 1.4°C by the end of the century.

Nationwide surveys show that floods and droughts are the most pressing climate hazards for Cambodian households (MOE, 2005; CCD & BBC, 2011). Cambodia's hydrology is dominated by the Mekong and Tonle Sap Rivers. Traditional livelihoods are dependent on seasonal flooding that bring water, fish, and alluvial deposits to the agricultural plains. Rainy season floods in Cambodia are an impressive spectacle: around 4 million hectares of lowland areas are inundated, the Tonle Sap River reverses its course with the overflow from the Mekong, and the Great Lake swells from 2,700 km^2 to 16,000 km^2. Seasonal flooding is seen as beneficial and is deeply rooted in Khmer culture. Local people are accustomed to traditional patterns of floods, even though they may be extensive and long lasting. Rural communities have been unable to cope with the rapid changes in the severity and frequency of floods in recent years. The worst floods to hit Cambodia in more than seventy years occurred in 2000, and were followed by severe floods in 2001 and 2002. In contrast, the dry season is a prolonged period with little rainfall and is marked by water shortages. Variability in the onset of the rainy season and in seasonal precipitation can spell disaster for farming communities. The 1998 drought was the most significant in two decades and caused the loss of the annual rice harvest. An estimated two million people were affected by droughts in 1995, 1996 and 2002.

Sea level rise will affect the 435-km long coastline. Coastal populations already experience storms, beach erosion and seawater intrusion. Cambodia is also vulnerable to vector-borne diseases, in particular malaria, which may become more widespread under more humid and warmer climate. The malaria fatality rate is among Asia's highest and is associated with a poorly funded public health system (RGC, 2002; CNM, 2003).

Technological aspects of climate change adaptation in agriculture

Cambodia's agriculture

Agriculture employs almost three quarters of the workforce and accounts for approximately a third of GDP (NIS, 2009). Cambodia's agriculture is predominantly rainfed and based on household subsistence. Improvements in agriculture have thus significant potential for reducing poverty and increasing food security.

Cambodia's primary crop and staple is rice. Rice is planted on 90% of crop area and provides 70% of the population's nutritional needs (MOE, 2010). The annual rice harvest is highly dependent on weather conditions. In years of severe floods and droughts, the entire harvest can be lost. Conversely, favourable weather conditions lead to abundant years.

Cambodia is well endowed in natural assets, including abundant land, forests and water resources, and has a relatively small population. Indicators of rice yields, technology and infrastructure show that Cambodia lags behind its Southeast Asian neighbours (Table 1). The growth potential of agriculture is constrained by inadequate fertiliser usage, lack of irrigation, weak research and extension, poor rural infrastructure and rudimentary credit system. This situation has essentially a historical explanation. Indeed, Cambodia was the leading rice exporter in Asia until the late 1960s at the outbreak of the civil war. Two decades of conflicts and the genocide of half of its population

Table 1. Rice yields, technology and infrastructure

	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Philippines	Thailand	Vietnam
Yield (ton/ha) 2000-2008	2.3	4.6	3.3	3.3	2.7	3.5	2.7	4.6
Tractor (unit/ha) 1999-2003	0.6	4.4	1.2	23.9	1.0	2.0	14.2	24.9
Fertiliser (kg/ha) 2002-2004	5.0	144.7	-	805.5	1.2	150.1	132.6	324.4
Irrigation (% arable land) 1998-2002	7.0	23.0	19.0	20.0	20.0	27.0	31.0	45.0

Source: Adapted from Bingxin & Shenggen, 2009.

have left the country deeply scarred. Cambodia has known relative political stability only since the 1990s. Instability in agricultural yields and production is considered higher in Cambodia than in other Asian countries (Goletti et al., 2006; World Bank, 2009 & 2011). Food shortages are common in periods of inclement weather and unexpected variability in flood and drought. Phnom Penh, the capital city, is the only area considered fully food secure (MOP, 2005).

Adaptation technologies for Cambodia's agriculture

Cambodia's NAPA, completed in 2006, lays out a realistically achievable country-driven programme of action addressing the needs for adapting to the adverse impacts of climate change. The climate hazards addressed are flood, drought, windstorm, high tide, salt water intrusion and malaria. The formulation of NAPA relied on extensive consultations from the grassroots level to policy-makers. Nation-wide surveys of local authorities, non-governmental organisations, and more than 700 households were conducted in 17 provinces to identify coping mechanisms to climate hazards and to determine adaptation needs. The NAPA's adaptation projects are prioritised according to a set of 14 criteria, including: improvement of livelihoods, food security, water availability, use of appropriate technology, responsiveness to immediate community needs, and sustainability. Cambodia has selected "no regrets" options that are already justified by current climate conditions. A total of 39 project profiles were developed, amounting to an estimated budget of US $130 million.

Cambodia is in the process of conducting a Technology Needs Assessment (TNA) funded by the Global Environment Facility (GEF) and coordinated by the UNEP Risø Centre (URC). The project, to be completed by 2012, aims to produce Technology Needs Assessment and Technology Action Plans (TAPs) for adaptation and mitigation to climate change (URC, 2010). These will be used as roadmaps for policy making for specific priority sectors, and to access international sources of funding for the implementation of priority activities.

The TNAs and TAPs are developed in support to Cambodia's national sustainable development objectives, and complement national policies in mitigating greenhouse gas emissions and in adapting to climate change. The Adaptation TNA draws from the strategic choices of Cambodia's NAPA, and aims to assess in greater detail specific climate change adaptation technologies. The TNA exercise is of more limited scope than the NAPA which consists of a broader framework for adaptation priorities. A further distinction lies in the fact that the NAPA only provides

Table 2. Priority adaptation for agriculture and water resources in Cambodia's national adaptation programme to climate change

Title	Objectives
Rehabilitation of a Multiple-Use Reservoir in Takeo Province	- To improve water storage capacity for multiple uses including irrigation, water supply for urban areas, recreational uses and enhanced aquatic biodiversity.
Rehabilitation of Multiple-Use Dams in Takeo and Kampong Speu Provinces	- To improve water management for multiple uses including irrigation, water supply rural communities, recreational uses and aquatic biodiversity enhancement.
Development and Rehabilitation of Flood Protection Dikes	- To protect settlements and agricultural fields from flood.
Rehabilitation of Upper Mekong and Provincial Waterways	- To reduce risks caused by Mekong floods - To improve fishery resources - To improve rural livelihoods by supplying sufficient water for irrigation and domestic uses; - To improve provincial water transportation.
Water Gates and Water Culverts Construction	- To regulate flood water around the newly rehabilitated road network; - To minimise road and crop damage caused by flood.
Safer Water Supply for Rural Communities	- To provide safe water in sufficient quantities for rural communities; - To reduce the risk of contracting water-related diseases.
Development and Improvement of Small-Scale Aquaculture Ponds	- To ensure food security in the areas where wild fish stocks are insufficient to meet demand; - To increase the income of people living in these areas.
Promotion of Household Integrated Farming	- To increase agricultural productivity; - To improve farmers' incomes, food security and livelihoods in the areas affected by flood and drought.
Development and Improvement of Community Irrigation Systems	- To provide sufficient water for rice farming; - To reduce the risk of crop failures from water shortage; - To enhance food security and assist in eliminating poverty among rural people.

Source: Adapted from MOE, 2006.

general project profiles for adaptation priorities, while the TNA project focuses on comprehensive Technology Action Plans which consist of concrete steps towards broad diffusion and adoption of selected priority technologies. Because of budgetary and time constraints, it is not possible for the TNA project to cover all of Cambodia's climate change vulnerabilities. The project aims to assess technology needs in two to three sectors, and develop technology action plans for two to three technologies in each sector. The Cambodian TNA focuses on the water sector and the coastal zone. A higher budget would have been needed to fully develop technology action plans for malaria and the health sector where there is a paucity of data in Cambodia. The wide scope of the agriculture sector meant that a comprehensive assessment would have far

Table 3. Technologies for agriculture in Cambodia's national adaptation programme to climate change

Technologies	Type of Technology
Multiple-use reservoirs	Equipment
Multiple-use dams	Equipment
Flood protection dikes	Equipment
Waterways	Equipment
Vegetation planting for windstorm and flood protection	Equipment, Knowledge
Community Disaster Preparedness	Knowledge, Institution
Water gates	Equipment
Water culverts	Equipment
Wells, ponds, reservoirs	Equipment
Integrated farming	Equipment, Knowledge, Institution
Community irrigation	Equipment, Knowledge, Institution

Source: Adapted from MOE, 2006.

exceeded available funding. Although water resources discussed in the TNA report cover the subsector of water use in agriculture, a comprehensive adaptation strategy for agriculture is yet to be articulated.

A list of fifteen technologies for water resources adaptation has been established by the national stakeholders (CCD, 2011). These cover a range of hard technologies, as well as institutional and organisational knowhow, and are of relevance to adaptation in agriculture. These technologies can also be divided into: diversification of water supply, groundwater recharge, preparation for extreme weather events, resilience to water quality degradation, stormwater control and capture, and water conservation (Elliott, Armstrong, Lobuglio, & Bartram, 2011). The national TNA stakeholders have favoured community intervention and technologies applicable by households, with the following considerations:

- Diversification of the resources of water supply reduce Cambodia's vulnerability to precipitation variability;
- Technologies that contribute to groundwater recharge contribute to the sustainable use of Cambodia's water resources;
- The preparation of Cambodia to drought is essential, as local communities are suffering periodically from shortage of water;
- Since the majority of rural Cambodians only have access to unprotected sources of water, resilience to water quality degradation contributes to climate change adaptation;
- Technologies for stormwater control and capture has traditionally been used in Cambodia to prevent flooding in the rainy season, but also to stock water for the dry season;
- Water conservation measures and practices increase resilience to drought and may postpone the need for expansion of water reservoirs and treatment facilities.

The prioritisation of adaptation technologies for the water sector is broadly in line with the priorities identified by the NAPA. The top five technologies are (1) Rainwater harvesting from rooftop, (2) Small reservoirs, small dams and micro-catchments, (3) Wells for domestic water supply, (4) Community irrigation systems, and (5) Household water treatment and safe storage.

Adaptation priorities in agriculture

The Cambodia NAPA recognises awareness raising and capacity building activities as necessary, but these should be supportive of concrete and practical actions in the field. In the final approval stages of NAPA,

Table 4. Adaptation technologies for the Cambodian water sector

Technologies	Type of Technology
Rainwater Harvesting from Rooftops	Equipment
Small Reservoirs, Small Dams and Micro-Catchments	Equipment
Wells for Domestic Water Supply	Equipment
Community Irrigation Systems	Equipment, Knowledge, Institution
Household Water Treatment and Safe Storage	Equipment, Knowledge
Water Use Efficiency	Knowledge
Leakage Management	Equipment, Knowledge, Institution
Water Gates and Water Culverts	Equipment, Knowledge, Institution
Upper Mekong and Provincial Waterways	Equipment
Water Reclamation and Reuse	Equipment
Community Flood Preparedness	Knowledge, Institution
Water User Communities	Knowledge, Institution
Community and Household Flood Safe Areas	Equipment
Drainage for Roads	Equipment
Awareness Raising and Education on Climate Change Issues	Knowledge

Source: Adapted from CCD, 2011.

some donors attempted to influence the outcome of NAPA towards a focus on softer projects (De Lopez & Tin, 2010). This may have stemmed from a lack of understanding of rural livelihoods. Several rounds of consultations had showed that the national stakeholders did not deem generally necessary, for example, to further inform and educate Cambodians about the dangers of severe floods. It was and still is more urgent to give these communities the means to deal with floods and provide them with hard equipment that they think may be useful: water control and drainage infrastructures.

Although the TNA exercise for adaptation technologies in Cambodia is still in its early stages, it may provide useful add-ons to the NAPA through the formulation of Technology Action Plans. As discussed earlier, it is not astonishing that the priorities identified by the TNA are consistent with the priorities of the NAPA: national development objectives and the Cambodian Millennium Development Goals provide the overarching framework in both cases. One could argue that adaptation technologies are not a key feature of the NAPA, while technologies appear as the main focus of the TNA. However, since the concept of climate change technology may consist of hard and soft aspects, practices, experiences and institutional arrangements can all be covered under the TNA. For instance, the TNA for mitigation technologies in Cambodia also prioritises changes in behaviours and practises for transport and energy efficiency, and not just hard equipment and infrastructure. Soft priorities include: vehicle emission standards, eco-driving, traffic management, transport masterplan, education campaigns and energy efficiency building codes. Cambodia's experience shows that practitioners in the fields of climate change mitigation and adaptation are not necessarily biased towards hard or soft technologies. Their bias, if any, arises mainly from national needs and development objectives.

From a national stakeholder point of view, it does not seem to be a practical necessity to sharpen the definition of climate change technologies. The question however arises as to whether the term of technology should be used if it has traditionally a hard equipment connotation. The NAPA does not have a particular focus on the concept of technologies, yet prioritises both hard and soft aspects. The TNA has a specific focus on the concept of technologies, yet also covers both hard and soft aspects. Again, from a national standpoint, this is unlikely to be of practical consequence on the implementation of adaptation and mitigation activities in Cambodia. What is of importance is that national stakeholders understand that both hard and soft technologies will be necessary to Cambodia to adapt to climate change and mitigate its emissions.

A remarkable finding of the nationwide household surveys conducted for the formulation of Cambodia's NAPA was to highlight the breadth of traditional coping mechanisms to climate hazards. Recession rice farming ingeniously takes advantage of annual floods. The silted waters of the Mekong and its tributaries replenish rice fields with nutrients. Farmers start planting as flood waters recede, draining and flooding fields as needed. In areas that are seasonally flooded, houses, barns, shelters, and animal enclosures stand on stilts. In the dry season, access is provided by stairs and ladders, while in the wet season, villagers boat from a structure to another. The height of the stilts matches the expected water level in a given settlement: the higher the flood level, the higher the stilts. In addition, community reservoirs and household ponds have been traditionally used as water storage structures for rainwater and flood. This would usually allow local people to survive long dry spells until the following rainy season. These examples of indigenous coping mechanisms have been developed by generations of Cambodian farmers. However, climate change and higher frequency and intensity of flood and drought may be too rapid for communities to cope with. This may not necessarily stem from a lack of knowledge on practises and equipment to adapt to climate change. Surveys of rural communities show that the overwhelming majority of people know what projects need to be implemented immediately to adapt to drought and flood (MOE, 2005; MOE & BBC 2011). The lack of financial resources is a major constraint and is the main reason why villagers may be left with no choice but organising religious offerings for rain. People are aware of the benefits of wells, ponds, rainwater harvesting, irrigation canals, water locks or dikes, but do not have the means to build and operate these structures.

Thus, our point of view is that technology transfer for adaptation in agriculture may not be a priority for Cambodia. The use of fertilizer, machinery and irrigation is far lower than in other Southeast Asian countries. There are ample opportunities for government and donors to expand and strengthen existing indigenous capacity to adapt to climate change. These traditional adaptation practices have the advantage of being socially accepted, proven, cost-effective and environmentally friendly. In the longer run, more advance technologies such as crop varieties adapted to higher temperatures, and more intense wet and dry seasons, may be introduced to Cambodian farmers if they are socially acceptable and sustainable. Technologies and practices for adapting to climate change already exist among Cambodian farmers. Communities simply need to be given the financial resources and institutional support to more systematically and broadly implement adaptation activities in the field.

Community adaptation and the cambodian farmer

Climate projections for Cambodia broadly point to higher average temperatures, and more intense wet and dry seasons, which concurs with the IPCC AR4 and other regional projections for Asia. In this section, we draw practical implications for community adaptation in agriculture, taking into consideration these general trends in temperatures and seasonality. Our goal has been to suggest principles and guidelines for realistic action with immediate benefits for Cambodian farmers, based on our discussions with the Cambodian Climate Change Department (CCD, 2011), and the Inter-ministerial Technical Working Group on Climate Change Adaptation, which includes representatives of the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of Public Works and Transport (MPWT), the Ministry of Meteorology and Water Resources (MOWRAM), the Royal University of Phnom Penh (RUPP), and the Royal University of Agriculture (RUA).

Adaptation technologies should not be limited to the narrow definition of hardware and equipment, but should also include social and institutional practices that increase the resilience of Cambodia's farming communities to climate change. Technologies for adaptation and technologies for mitigation are concepts that can be understood by senior Cambodian policy-makers who would need to plan for both aspects of climate change activities. To avoid confusion, we propose to use the expression "technologies and practices" rather than the alternatively unwieldy paraphrase "hard technologies and equipment, as well as soft technologies, such as knowledge of methods and techniques, and organisation and institutional arrangements". These technologies and practices for adaptation in Cambodia's agriculture form a basis not only for increased resilience to climate change, but also for the development of agriculture, even in the absence of climate change.

In the context of the global financial crisis, we are aware that funding will not be forthcoming and that some donors may argue that most of our suggestions do not consist of pure adaptation projects or projects that would not be needed under a purely hypothetical scenario of constant climate. We argue that poverty reduction through the development of Cambodia's agriculture addresses the root causes of the climate vulnerability of rural communities. If these causes are not addressed, it is difficult to see how rural communities can successfully adapt to climate change. Our matter-of-fact suggestions are formulated as to be handy and usable for activities to be implemented in the field with local people. We do not presume that a dozen suggestions can constitute a comprehensive adaptation strategy. Our aim is more modestly to provide a basis for further discussions, including the formulation of national plans or guiding directives specifically for community adaptation in Cambodia's agriculture.

Recommendation 1 – No-regret adaptation with immediate development benefits

Cambodia has focused on the need to implement no-regret adaptation activities with immediate development benefits in accordance with its national socio-economic development plans. It makes little sense for countries with pressing social and economic needs, and limited resources such as Cambodia to implement pure adaptation projects, whose development benefits are more uncertain and dependent on climates that may only materialise in the longer term. "No regrets" adaptation options are already justified by current climate conditions and would provide immediate social and economic benefits for local communities if implemented. Under changing climate conditions, including higher frequencies of climate hazards, and more intense wet and dry seasons, these projects would be even more attractive.

Examples of no-regret adaptation include the construction of wells and reservoirs that would help alleviate current water shortages, and at the same time increase the resilience of local people to more frequent and intense drought. Adaptation projects that yield the highest immediate social, economic and environmental benefits for Cambodian farmers should be the priority for agriculture.

Recommendation 2 – Community and grassroots participation in practical adaptation activities

Villagers understand the need to adapt to climate change and have local knowledge necessary for the design of appropriate small scale projects. Cambodia's network of water supply and control infrastructure fell into disrepair during the years of wars of the 1970s and 1980s, and requires extensive rehabilitation. This provides opportunities to increase local resilience to flood and drought by implementing rapidly small projects that necessitate only limited resources, planning and management.

The complementarity between regional scale and household hydrology finds its roots in ancient Khmer cities. Large elevated reservoirs (the famed Angkorian barays), citywide dikes, and extensive irrigation networks were supplemented by a wide range of smaller waterworks at the household and village level. There was a seamless connection from the smallest household ponds (trapeang) and village water gates, to the colossal moats and reservoirs that supplied

Angkor and other Khmer metropolises. Much of this network communicated providing continuity in water management from the household up (Groslier, 1979; Garami & Kertai, 1993; Evans & Fletcher, 2003; Kummu, 2003).

Cambodia's agriculture is household based and has few large commercial exploitations. Farmers cultivate their own family plot. Participatory adaptation to climate change consists in giving local communities a say in designing and implementing practical adaptation measures. Participation ultimately gives local people self-resilience and independence for adapting to climate change.

Recommendation 3 – Community and household water storage and irrigation

Cambodian farmers overwhelmingly rely on rainfall, which makes them vulnerable to weather variability, climate disasters and climate change. Without proper irrigation, rice can be cultivated and harvested only once a year. The annual wet season precipitation and flooding provide abundant water that can be stored for the dry season. Water storage facilities can also buffer farming communities against climate and seasonal variability.

The immediate priority is the rehabilitation and improvement of existing community irrigation networks that consist of multiple use reservoirs and dams, village and household ponds and wells, water gates and locks, culverts and canals. Reliable supplies of water can reduce the vulnerability of agriculture to increased variations in precipitation, flood and drought.

Recommendation 4 – Community information on climate change

Nationwide surveys have shown that Cambodians believe that temperatures have increased, and that seasons are less predictable. Extreme weather events are experienced more frequently and more intensely. However, there is still confusion in public perceptions of climate change, its projected impacts on the lives of Cambodians, and what can be done about it (MOE, 2005; CCD & BBC 2011).

Clear and simple messages conveying useful information need to be developed for the general public, rural communities and farmers. These should avoid technical jargon as well as the complexities of climate science. The consensus among existing projections that point to higher average temperatures, and more intense wet and dry seasons for Cambodia, must be more broadly disseminated.

Recommendation 5 – Agricultural training for farmers to improve technical skills in adaptation to drought, flood and heat stress, and in sustainable agriculture

Technologies and practises specific to adaptation to climate disasters need to be directly transferred to farmers through agricultural extension. There are only about 500 agricultural extension officers in Cambodia. Less than 1% of farmers have benefited from any form of extension services. Even in cases where local people can afford tools, equipment or seeds, they may not have the technical knowledge and experience to successfully use them.

Agricultural training must be expanded significantly in order to improve the technical skills of farmers. Adaptation to drought, flood, and heat stress needs to be included in agricultural extension and support, along with the promotion of the sustainable use of water and land.

Recommendation 6 – Integrated farming of crop, fish and livestock

Integrated farming aims to ensure food security while at the same time diversifying sources of income from a variety of agricultural activities that can be carried out by a single household. Integrated farming provides opportunities for combining traditional agricultural activities together. For example, farmers can use rice straw as feedstock and litter for animals, and medium for mushroom cultivation, minimising the need to burn agricultural residues. In turn, manure fertilises vegetable plots, feeds fishes and produces energy in biodigesters.

The different activities of an integrated farm involve a broader range of skills than single households are accustomed to. A household may be growing rice and raising cattle, but not be familiar with fish farming, pig breeding, biogas digesters or composting. Farmers will require training and support to gradually diversify their activities.

Recommendation 7 – System of Rice Intensification (SRI)

The System of Rice Intensification was introduced to Cambodia at the beginning of the century and has benefited from about a decade of local experimentation. Developed in Madagascar over thirty years ago, SRI consists of a set of principles for low-cost rice cultivation by local communities. Compared with traditional rainfed cultivation, SRI promotes the transplantation of younger seedlings, higher spacing of plants to avoid resource competition, wet and dry periods rather than continuous flooding, Integrated Pest Management, and the use of organic fertilisers. SRI is associated with higher productivity per input of resources used in rice cultivation, and requires less water, and fewer synthetic fertilisers, pesticides and herbicides.

The original principles of SRI are continuously improved upon to suit the specific local needs of farmers. The accumulated practical experiences of farming communities need to be more formally codified and summarised into SRI best management practices that also take into consideration projected climate trends for Cambodia.

Recommendation 8 – Community and household tree planting for watershed protection, carbon sequestration and supply of forest products

Cambodians consider deforestation to be a key social and environmental problem (CCD & BBC, 2011). The population values forests not only as the country's most important natural asset, but also for their roles in groundwater protection, erosion control, and protection against storms and floods. The 1980s and 1990s saw intense commercial logging far exceeding sustainable harvest (ADB, 2000; IFSR 2004). Public opinion that climate change is partially caused by deforestation may not be grounded in scientific understanding, but is technically correct. Deforestation accounts worldwide for about 17% of greenhouse gas emissions, which is slightly less than industry and more than global transport (IPCC, 2007). Reducing Emissions from Deforestation and Forest Degradation (REDD) is a key element of global mitigation strategies.

Forests and trees have traditionally provided Cambodians with timber, food, fuelwood, medicine, fodder, as well as environmental services such as watershed protection, micro-climate control, storm protection, high tide protection, erosion control etc. Community forestry has broad public support and constitutes opportunities for preserving water resources, controlling flood, increasing the supply of forest products, all of which would contribute to higher resilience to climate change. In addition to these adaptation benefits, tree planting activities would enhance sinks for carbon sequestration.

Recommendation 9 – Village rice banks

Farmers do not generally have storage facilities for their crops. In bumper years, farmers are forced to sell their entire harvest at relatively low prices, as production is abundant and largely exceeds demand. Conversely, in times of crop failures or poor harvests, farmers are left without resources to survive until the next season and must rely on relatives and external assistance.

The storage of rice over longer periods requires monitoring of temperature, humidity, and pest. Rice banks with high standard storage facilities would allow farmers to set aside part of their annual harvest, particularly in bountiful years. In leaner years, such as times when crops fail because of flood or drought, households would withdraw from these banks for either personal consumption or to sell crops at more advantageous prices. Cambodian consumers would also benefit from a more steady supply of crops at less volatile prices.

Recommendation 10 – Farmers' cooperatives

Agricultural cooperatives allow farmers to pool their resources together in a more formalised institutional set up. Cooperatives can provide their members with greater resources to produce and market agricultural commodities. Because of economies of scales, cooperatives are able to purchase inputs and sell produce at more advantageous prices than individual farmers. These benefits would improve local livelihoods and allow farmers to better withstand the impacts of climate change. Areas where cooperatives can operate include pooling machinery, procuring inputs, storing and marketing produce, and granting credit.

Recommendation 11 – Improved rural road network

Poverty is more prevalent in unconnected rural areas or areas with unreliable motorised access. Roads allow rural communities to reach markets and essential services (healthcare, education, administration). It is more expensive for villages without motorised access to buy inputs for agriculture and more difficult to sell their production. Perishables may not reach consumers in time, who in turn will have to pay higher prices.

Cambodia's national road network was severely damaged during the wars and has remained in disrepair since the 1970s due to the lack of funds for reconstruction and maintenance (MOP, 2005). The provincial network is usually impassable during the rainy season when floods isolate parts of the country. Partial motorised access, only interrupted by seasonal floods, would lower the logistical costs for agriculture, and improve rural communities' access to essential services and their resilience to climate change.

Recommendation 12 – Improved credit and banking facilities

It is difficult and costly for rural communities to borrow money. The lack of credit and banking services is a bottleneck to the development of Cambodia's agriculture. Transactions are conducted in cash, whether for purchase of inputs and equipment, or for selling crops. The need for cash also forces farmers to sell crops to traders quickly after harvest, when prices are lowest.

About 5% of all outstanding loans of private banks in Cambodia have been disbursed to support agricultural activities (World Bank, 2009). Interest rates commonly exceed 40% per annum, loan amounts are limited to a few thousand dollars, repayments start almost immediately after initial disbursement, and requirements for collaterals very high. Household vulnerability to climate change may be decreased with better access to financial services that allow them to withstand the shock of climate hazards, and to take advantage of economic opportunities. In areas where credit unions operate, other financial institutions have had to lower their lending rates. Small not for profit loans towards tools, equipment, wells, ponds, fertilisers, seeds, seedlings, livestock and a variety of other agricultural inputs would allow farmers to expand their production to better withstand climate variability.

Conclusion

Cambodia has limited resources to adapt to climate change. Agriculture is rainfed, based on household subsistence and characterised by low inputs, which makes it vulnerable to weather variability. For Cambodians, the most pressing climate hazards are flood and drought. Traditional livelihoods are dependent on seasonal flooding and wet season precipitation. However, rural communities have been unable to cope with the higher frequency of severe flooding in recent years. Local people know what adaptation projects need to be implemented immediately to adapt to drought and flood, using traditional coping mechanisms. The lack of financial resources is a major constraint. Thus, the priority is not to transfer new adaptation technologies to Cambodia, but rather to expand and strengthen existing indigenous capacity to adapt to climate change. Communities need to be given greater financial resources and institutional support to implement adaptation activities in the field.

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References

Bingxin, Y., & Shenggen, F. (2009). Rice Production Responses in Cambodia. Development Strategy and Governance Division. Washington: IFPRI.

Climate Change Department. (2011). Synthesis Report on Vulnerability and Adaptation to Climate Change in Cambodia's Agriculture. Phnom Penh: Ministry of Environment.

Climate Change Department & BBC World Services Trust. (2011). Understanding Public Perceptions of Climate Change in Cambodia. Phnom Penh: MOE.

Elliot, M., Armstrong, A., Lobuglio, J., & Bartram, J. (2011). Technologies for Climate Change Adaptation - The Water Sector. (T. De Lopez, Ed.) Roskilde: Unep Risø Centre.

Goletti, F., Purcell, T., Higgins, S., Leng, S., Ouk, P., Sok, M., et al. (2006). Cambodia Agriculture Sector Diagnostic Report. Canberra: AusAID.

Guimbert, S. (2010). Cambodia 1998-2008, An Episode of Rapid Growth. Washington DC: World Bank.

Intergovernmental Panel on Climate Change. (2000). Emission Scenarios. (N. Nakicenovic, & R. Swart, Eds.) Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007). Fourth Assessment Report. Cambridge: Cambridge University Press.

McSweeney, C., New, M., & Lizcano, G. (2008). Cambodia Climate Profile. Oxford: Oxford University.

Ministry of Environment. (2002). Cambodia's Initial National Communication under the UNFCCC. Phnom Penh: MOE.

Ministry of Environment. (2010). Cambodia's Second National Communication under the UNFCCC. Phnom Penh: MOE.

Ministry of Environment. (2003). Declaration on Cambodian Climate Change Office Establishment (CCCO). Phnom Penh: MOE.

Ministry of Environment. (2006). National Adaptation Programme of Action to Climate Change. Phnom Penh: MOE.

Ministry of Environment. (2005). Vulnerability and Adaptation to Climate Hazards and to Climate Change - A Survey of Cambodian Households. Phnom Penh: MOE.

Ministry of Environment. (2009). Vulnerability, Impact and Adaptation Assessment to Climate Change. Phnom Penh: MOE.

Ministry of Planning. (2005). Achieving the Cambodia Millenium Development Goals. Phnom Penh: MOP.

Ministry of Planning. (2002). Second Five Year Socio-Economic Development Plan 2001-2005. Phnom Penh: MOP.

Ministry of Water Resources and Meteorology. (2003). National Sector Review 2003: Water Supply and Sanitation. Phnom Penh: MOWRAM.

National Institute of Statistics. (2009). Cambodia Statistical Yearbook. Phnom Penh: NIS.

Overseas Development Institute. (2010). Cambodia Case Study for the MDG Gap Task Force Report. London: ODI.

Royal Government of Cambodia. (2002). National Poverty Reduction Strategy 2003-2005. Phnom Penh: RGC.

Royal Government of Cambodia. (2010). National Strategic Development Plan Update 2009-2013. Phnom Penh: RGC.

Royal Government of Cambodia. (2010). Statement of the Kingdom of Cambodia United Nations Climate Change Conference, 29 November-10 December 2010, Cancun, Mexico.

Royal Government of Cambodia. (2006). Sub-decree on the National Climate Change Committee Establishment. Phnom Penh: RGC.

Royal Government of Cambodia. (2005). The National Strategic Development Plan (2006-2010). Phnom Penh: RGC.

United Nations Development Programme. (2010). Human Development Report 2010. New York: Palgrave Macmillan.

World Bank. (2011). Global Food Prices Volatility and Implications for Cambodia. Washington DC: World Bank.

World Bank. (2009). Sustaining Rapid Growth in a Challenging Environment. Washington DC: World Bank.

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Adaptation technologies in agriculture: The economics of rice-farming technology in climate-vulnerable areas of Bangladesh

Abstract

The vulnerability of global agriculture to impacts of climate change is one of the major concerns in current adaptation discourses. It is predicted that global agricultural production will be reduced due to variations in temperature and rainfall, the direct and indirect effects of flood, cyclone and storm surge, salinity intrusion, the loss of land caused by sea level rises etc. A recent estimate shows that world agricultural productivity will decline by 3% before 2080 with a high emissions scenario (World Bank, 2010) while another estimate suggests that the aggregated impacts of climate change will cause yield reductions of about 6% by 2080 (ICTSD, 2010). Asia and Africa will suffer most from severe drops in crop yields by 2030. The critical drop in commodity production will include wheat in South Asia, rice in Southeast Asia and maize in southern Africa. It is now a great challenge for the global agriculture community to address climate change and to ensure the sustainable production of crops, especially rice, wheat and maize, to feed billions of people.

Introduction

Climate change is one of the greatest challenges for the future of agricultural development and management all over the world. South Asian countries, particularly Bangladesh, may be the most vulnerable in terms of agriculture and food security due to climate change and climate variability. The climate-related elements that are affecting agricultural production and management include variations in temperature and rainfall, drought, the increased frequency and intensity of flooding and recurrent flooding, frequent cyclones and storm surges, salinity intrusion caused by rises in sea level or low water flows in the river systems etc. For example, the massive flood in Pakistan last year damaged crops over about 0.6 million hectares, while the flooding in China this year caused damage to crops of about 0.4 million hectares (Reuter and Latest China, 2011). The excessive rainfall in 2007 damaged crops over at least 13.3 million hectares in India and 25% of wet-season crops in Bangladesh (IRRI, 2009).

It is predicted that per capita crop production will drop in Africa, Asia, North and Central America, and Oceania by 2030, while it will increase in Europe, South America and the Caribbean (Zhang, 2006). On the other hand, one recent estimate shows that world agricultural productivity may decline by 3% by the 2080s with a high emissions scenario (World Bank, 2010) while another estimate suggests that the aggregated impacts of climate change will cause yield reductions of about 6% by the same period (ICTSD, 2010). Asia and Africa are expected to suffer most from severe drops in yields by 2030. According to one analysis, a 5% decrease in per capita rice production could occur in Africa and Asia by 2030 (Zhang, 2006).

The agriculture sector is vulnerable due to both the primary effects (variations in temperature and rainfall) and secondary effects (drought, flood, cyclone and storm surge, saline intrusion etc.) of climate change. In addition, climate change-related phenomena such as variations in temperature and rainfall may enhance the spread of pest attacks or crop diseases that affect crop production. According to recent reports, about 50 percent of rain-fed crops will be lost by 2020 in some countries in Africa (UNFCCC, 2008), while some areas of Latin America may lose up to 50 percent of agricultural land due to desertification and salinisation by 2050. In Central and South Asia, it is predicted that crop yields may fall by 30 percent due to climate change.

This paper will provide a brief overview of adaptation technologies in agriculture with reference to the specific case of Bangladesh. The Bangladesh case study emphasises the economics of rice-farming technologies for adaptation to climate change in the coastal region of Bangladesh, with a particular focus on the cost of cultivating saline-tolerant varieties as an adaptation option to climate change in vulnerable areas.

Adaptation strategies in agriculture: Technological responses

Based on a clear understanding of the implications of climate change for agriculture, the policy, institutions and technologies need to be changed to reduce vulnerability. Farmers, fishermen, forest-workers and communities are acting spontaneously with their own capacity and resources to adapt to climate change in many countries like Bangladesh. This is now a vibrant issue in the global discussion for a concrete global strategy to develop adaptation technologies for agriculture that are environmentally sustainable, culturally compatible, socially acceptable, economically feasible and technically viable. Such discussions include deciding on a pragmatic mechanism for the transfer and implementation of technology in the affected communities.

A number of policy and institutional initiatives have been taken on sustainable agriculture technologies and management in order to change from traditional to context-specific or climate-resilient practices at the international, regional and national levels. The International Rice Research Institute (IRRI), International Centre for Agriculture in the Dry Land Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Maize and Wheat Improvement Centre

(CIMMYT) and International Institute of Tropical Agriculture (IITA) as a member of the Consultative Group on International Agriculture Research (CGIAR) are actively seeking technological innovations to address climate stresses. Climate Change, Agriculture and Food Security (CCAFS) and the Rice and Climate Change Consortium (RCCC) are also putting efforts into facilitating increases in productivity and resilience in crop agriculture, especially rice, wheat and maize-farming, through technological innovations. Some climate-tolerant varieties have already been discovered and are being grown in a number of different countries, especially in Africa and Asia.

In addition, the Food and Agriculture Organization (FAO), Climate Change, Agriculture and Food Security (CCAFS), Rice and Climate Change Consortium (RCCC), International Food Policy Research Institute (IFPRI) and other organisations are also active in conducting agricultural and food security-related research, policy and implementation activities. It is now essential to initiate a smooth mechanism through either existing inter-governmental systems or a new system to consolidate all agricultural success stories regarding adaptation technologies in government, non-government and private initiatives for wider promotion and implementation in vulnerable communities.

Agricultural (crops) technology to address climate change and climate variability at the global level

Different countries, institutions and communities have either modified or newly developed agricultural (mainly crops) technologies and introduced them at the local level based on considerations of climate and ecosystem. The available technologies in crop agriculture are likely to address current climate variability. To address the long-term impacts and vulnerability, technologies in crop agriculture have to be consistent with the predicted changes in climate system. For example, the varieties of crops need to be resilient to higher temperatures, have low or no water requirement during the life-cycle of the crops, be tolerant of high salinity etc. Currently, the adaptation technologies in crop agriculture are being implemented in two forms: i) hard technologies that engage hardware or equipment and associated constructions such as flood control, irrigation systems, climate-resistant crop varieties etc.; and ii) soft technologies, which are more related to the management of knowledge and behavior. Examples of soft technologies include crop-insurance schemes, crop-rotation patterns, capacity-building programs etc. In addition, there is another type of technology which refers to the institutional framework, or organisation (orgware), involved in the process of the adoption and diffusion of a new technology to address climate change (Climents et al., 2011). The following sections provide brief overviews of technologies in crop agriculture.

Hard adaptation technology in crop agriculture (with institutional framework)

Under the category of hard adaptation technologies, some specific options or varieties are being attempted in crop agriculture in different countries in Africa and Asia, including Bangladesh, to address climate change-related hazards or disasters. Drought- and flood (submergence)-tolerant rice varieties have already shown quite positive results in terms of yields and productivity in Bangladesh, India, the Philippines and Nepal (IRRI, 2011). In Africa, drought-tolerant rice, wheat, sorghum and maize varieties are successfully being planted and harvested. New Rice for Africa (NERICA) has demonstrated substantial advances in crop adaptation in drought environments in Africa (CGIAR, 2010). This has been made possible by active research undertaken by some dedicated governmental and non-governmental organisations.

Soft adaptation technology in agriculture (crops)

These technologies are mainly being practiced according to climate-related elements, access and availability of the options and the existing capacity, knowledge and skills of communities in particular locations, countries or regions. It is to be noted that the climatic elements affect the different stages of the life-cycle of all crops through multiple direct and indirect pathways, such as the direct impacts of climate stress, climate-induced pest attacks, the lack of water supplies or irrigation, the lack of knowledge and skills for crop management under stress conditions, the availability of technology, the inefficient management and implementation of early warnings, crop calendar etc. Under the soft category of technology, training or capacity-building and crop-rotation patterns could be effective options in addressing climate change or climate variability. Mass awareness or training and capacity-building in relation to climate change would help farmers improve their skills in crop management. Alternative cropping patterns may be tested for better results in the affected areas. Authentic information, early warning, technical training etc., may help farmers modify their own crop calendars or develop alternative crop-management strategies to reduce the risks of a changing condition that may affect any stage of the life-cycle of a particular crop. An appropriate adaptation strategy for crop agriculture may be a package of multiple options consisting of hard, organisational and soft technologies that can effectively address the vulnerability of specific climate elements or sub-elements at all stages, from the sprouted seeds or seedlings to the ripening or harvesting stage in the case of rice. Table 1 lists a set of technologies that are being practiced or may be practiced to address particular climatic elements to reduce the impacts and vulnerabilities of rice and wheat crops. For example, rice farmers could adapt better to increased temperatures with improvements to early warning systems, heat-tolerant varieties, improvements to irrigation systems and the enhancement of skills in crop management through awareness, training etc. These technological options have to be environmentally sound, socially acceptable and economically feasible, as mentioned above.

It is necessary to measure the economic aspects of any of these technological options (e.g., heat-tolerant varieties) or the package (hard and soft technologies) of technology as a whole to take them on the ground for farmer's wider practice and sustainability. Realising the importance of climate-resilient technological options, practice and sustainability, a study was undertaken to explore the economics of adaptation in rice-farming in the coastal zone of Bangladesh. Some of the findings and insights of the study are given below.

Case study of the 'economics of rice-farming technology from climate-prone areas (coastal zone) in Bangladesh'

Background: Coastal zone and agriculture perspectives

The coastal zone of Bangladesh covers 32 percent of the country in terms of land area and accommodates about 30 percent of the total population of the country (Islam, 2004). The coast offers a diversity of natural resources such as marine fisheries and shrimps, forest, salt, minerals and a location for the high-potential exploitation of both onshore and offshore natural gas. The coast of Bangladesh is prone to both climate and non-climatic hazards. The major climate-induced hazards for the coast include cyclones, droughts, tidal floods (rapid onset) salinity intrusions and rises in sea level (slow onset). The key non-climatic factors may include high poverty (about 50 %), increased population growth, different types of pollution, low-lying characters of the land ecosystem etc. All these climate and non-climate factors critically affect different sectors, including agriculture.

Agriculture is economically the most important sector of the country. A recent report shows that the contribution of the broad agriculture sector was 20.48 percent in FY 2008-2009 (MoF, 2009). Within the broad agriculture sector, the agriculture and forestry sector contributed 15.91 percent of GDP in FY 2008-2009. In 1999-2000, the national contribution of the agriculture sector to GDP was 26 percent, 29 percent from the coastal zone. In addition, the agriculture sector currently employs 43.6 percent of the total labour force in the country. Although the exact figure for the current contribution of the agriculture sector from the coastal zone to GDP is not known, it is reported that crop production, especially rice production, in some vulnerable districts in the coastal zone has decreased in the recent past. For example, the total production of Aus (local and HYV) decreased from 3,606 tons in 2007 to 2,955 tons in 2008 in Satkhira District (BBS, 2009). Similar findings were reported in the total production of Aman and Boro rice varieties in Satkhira. Perhaps this has mainly happened due to Cyclone Sidr, which on 15 November 2007 hit most of the coastal districts,

Table 1. Climate change key elements, impacts on crops (mainly rice and wheat) and adaptation technologies being practiced or with the potential to be practiced

Climate change key elements		**Impacts/possible on crops** (e.g. rice)	**Current adaptation technologies for crop agriculture (e.g. rice and wheat)**	
Elements	***Sub-elements***		***Hard Technology***	***Soft Technology***
Temperature variations	High temperature	✓ Injury during anthesis or flowering stage ✓ Increase sterility ✓ Reduce seed size	✓ Heat-tolerant variety ✓ Improve moisture capacity ✓ Early morning flowering variety ✓ Improve irrigation system	✓ Training/capacity building ✓ Irrigation efficiency
	Low temperature	✓ Slow growth of seedlings and early vegetative stage ✓ Reproductive phase of early established crops	✓ Changing cultivars and crop varieties ✓ Cropping pattern change	✓ Crop rotation patterns ✓ Awarenessraising ✓ Capacity building
Erratic rainfall	Excess rainfall	✓ Submergence ✓ Poor plant population	✓ Submergence tolerant varieties ✓ Early warning system ✓ Crop insurance	✓ Awareness raising ✓ Capacity building
	Late rainfall	✓ Late seed-bed preparation ✓ Late crop establishment	✓ Change of cropping pattern ✓ Short-term variety	
Drought	Scarcity of water	✓ Poor growth ✓ Sterility ✓ Low yield	✓ Drought-tolerant variety ✓ Rainwater harvesting for lean period ✓ Excavation and re-excavation of water channels, mini-ponds for irrigation ✓ Improve irrigation system ✓ Moisture improvement ✓ Change tilling practices ✓ Drip irrigation system	✓ Awareness raising ✓ Capacity building ✓ Irrigation efficiency
Flood	Flash flood	Crop damage during maturity	✓ Flood-tolerant variety ✓ Infrastructure, e.g. flood control ✓ Seed preservation ✓ Early warning and crop forecasting	✓ Awareness raising ✓ Capacity building
Salinity	Salinity in soil and surface water	✓ Growth stunted ✓ Drastic yield reduction	✓ Saline-tolerant variety ✓ Infrastructure	✓ Awareness raising ✓ Capacity building

Source: IUCN, 2010; Zelli, 2010; CIDSE and Caritas, 2009; UNFCCC, 2006.

including Satkhira. The storm surge, heavy rainfall and salinity intrusion caused by Cyclone Sidr affected all types of crops, including rice. The other reasons may include changes in rainfall and temperature patterns, mean shifts in flood hydrographs, tidal surges, waterlogging etc. However, the 18% reduction in Aus rice production in Satkhira in 2008 indicates a threat to rice production if the frequency and magnitude of cyclonic events increases in the future. This might be exacerbated under conditions of SLR, as the cultivable land along the coast would be occupied and saline water pushed further inland (Rahman, et al., 2007).

The Government of Bangladesh has taken a number of initiatives to address climate change. Following the development of a National Adaptation Programme of Action (NAPA), the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) has been drawn up. It identifies agriculture as the prime sector for adaptation in the country and for ensuring food production and security. Currently, the government is supporting several research and implementation projects for adaptation in agriculture sector under the Climate Trust Fund. The Ministry of Agriculture and associated departments and institutes are implementing these adaptation projects.

The Bangladesh Rice Research Institute (BRRI) and other associated departments such as the Bangladesh Agricultural Research Council (BARC) under the Ministry of Agriculture have introduced a number of varieties that are tolerant to flood, drought and salinity (see Table 2). Farmers in different parts of the country, including coastal areas, are cultivating these varieties as adaptation options in rice-farming to address climate change and climate variability.

The rice varieties in the country are grown in three different seasons, locally called Aus, Aman and Boro. The Boro season refers to the cultivation that takes place from December to May. The Aus season starts in April and continues till August. June to December is agriculturally known as the Amon season. This is the time when most natural climate-related hazards hit the country.

Farmers in Bangladesh are growing the following climate-related stress-tolerant rice varieties to adapt to

Table 2. Climate-related stress-tolerant rice varieties in the coastal regions of Bangladesh

Climate-Related Stress	Climate-Tolerant Rice Variety	Growing Season	Growth Duration (days)	Average Yield (Ton/Ha)
Flood (submergence)	BRRI dhan 51	Aman	142-154	4
	BRRI dhan 52	Aman	145-155	4.5
Salinity in soil, surface and ground water	BRRI dhan 40	Aman	145	4.5
	BRRI dhan 41	Aman	148	4.5
	BR 10	Aman	150	5.5
	BR 23	Aman	150	5.5
	BRRI dhan 27	Aus	115	4
	BR 47	Boro	152	6.0
Drought	BRRI dhan 42	Aus	100	3.5
	BRRI dhan 43	Aus	100	3.5
	BRRI dhan 33	Aman	118	4.5
	BRRI dhan 39	Aman	122	4.5

Source: BRRI, 2011; Mazumdar, 2011; Financial Express, 2011; Salam, et al., 2011; Daily Star, 18 July 2010.

the changing conditions. Some of the varieties that are growing in popularity among the farmers show higher production levels and higher net profit (see section 4.2. for details). The following table shows a number of climate stress-tolerant varieties being grown in different vulnerable regions of Bangladesh.

It appears that growing these rice varieties in different vulnerable areas, including the coastal zone, improves resistance to some specific climate stresses and are economically feasible. The following sections provide a brief overview and insights into the economic aspects of rice-farming for adaptation to climate change in coastal regions of Bangladesh. It mainly emphasises the costs of cultivation for saline-tolerant varieties as an adaptation option to climate change in the villages in the study sites.

Brief approach and methodology

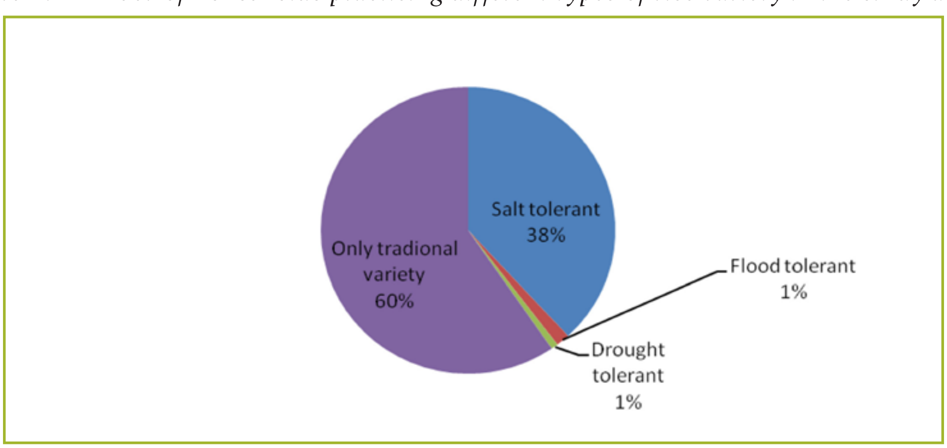
The study was conducted in twenty villages in Khulna and Bagerhut Districts. A questionnaire was developed to conduct household surveys targeting 401 households in the villages in both these coastal districts. The total of surveyed households in Bagerhut was 224 and in Khulna 177. A set of structured and some open-ended questions were included to cover the local demographic profile, including socio-economic status, knowledge and understanding of climate change, perceptions of current and potential impacts and vulnerabilities to climate change, and adaptation strategies, especially regarding rice-farming in the villages.

Key results and discussion

The study indicates that fisheries and crop agriculture are the main sources of income in both Khulna and Bagerhut Districts. In Khulna, the agriculture sector (40 percent) was found to be dominant for income, while in Bagerhut it was fisheries (59 percent). About 25 percent of people spend more than they earn in a year. Forty percent of the people in Bagerhut face the greater deficits, although their average incomes are comparatively much higher than in Khulna. In fact, the lowest income groups in both districts suffer from the deficit. The study also indicates that those who suffer from deficits coped by taking loans (68 percent) from banks, NGOs, cooperatives, relatives etc.

It was found that farmers are trying their best to adapt to changing conditions and extreme climatic events in terms of the cultivation of rice crops in the study areas. In both districts they have started growing the different rice varieties which are resistant to salinity, flood and drought in different seasons. Saline-tolerant varieties were found to be grown more in both study locations. This indicates that 40 percent of people are adapting with climate-resistant crops, while the rest are still struggling to cultivate only traditional varieties in all three main seasons when rice is grown (see Figure 1). About 38 percent of households produce saline-tolerant rice crops, while 2 percent grow flood- and drought-tolerant varieties.

Figure 1. Number of households practicing different types of rice variety in the study areas



Figures 2 and 3 represent the total production of different Aman and Boro rice varieties per acre based on the available field data and information. In fact, Figure 2 gives a comparative picture of traditional (all except BR 23) and salt-tolerant aman varieties (BR-23). It appears that the total yield per acre of the salt-tolerant variety (BR-23) is higher than three (BR-30, Morisail, and Balam) and lower than one (BR-33) of the current traditional aman varieties. However, the average production of the four traditional aman varieties shown in Figure 2 is 6 percent lower than that of the salt-tolerant variety. It is to be noted that the yield of the BR-33 (traditional variety) is higher than any variety but is very sensitive to pest and heavy rainfall.

Regarding the Boro category, the yields per acre of the salt-tolerant variety is more than double compared to BR-14, which is a current traditional variety. Again, the average yields of Boro varieties is

Figure 2. Total production of different types of traditional and salt tolerant Aman variety (kg/acre)

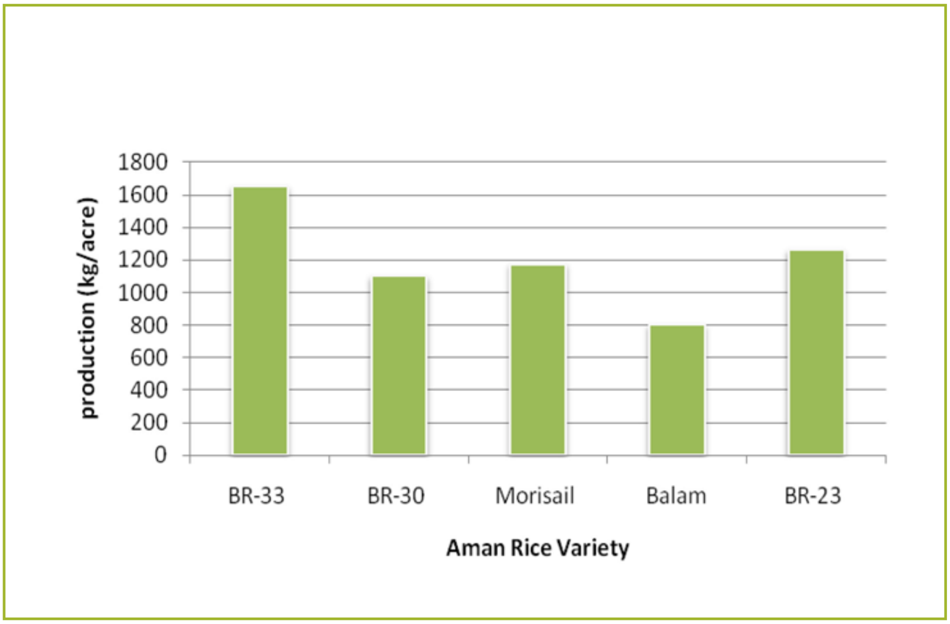
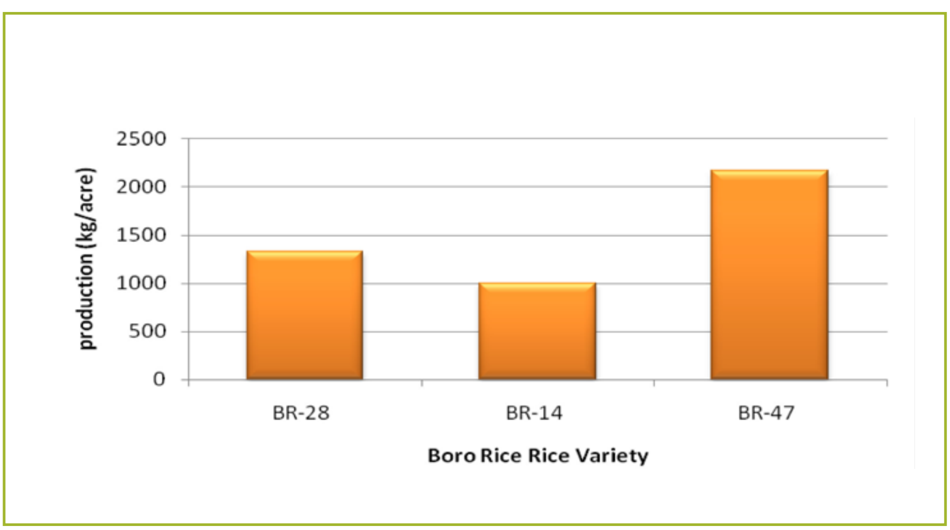


Figure 3. Total production of different types of traditional and salt tolerant (BR-47) Boro variety (kg/acre)



54 percent lower than the salt-tolerant variety (BR-47). The total production of the salt-tolerant Boro variety is more than two tons per acre, while it is less than one and half tons in each of the traditional varieties (see Figure 3). Salinity most severely affects the crops of the Boro season (December-May) in the coastal zone. This might be the main reason for the low production of traditional Boro varieties, as these are not resistant to salinity, while BR-47 can resist salinity intrusion.

Regarding the costs of production and profits for the traditional and salt-tolerant aman varieties, the study reveals that the cost of production of the salt-tolerant variety (BR 23) is much lower than the average for the traditional varieties, being 26 percent lower than the average cost of traditional aman varieties per acre, while the profit from the salt-tolerant variety per acre is again 25 percent higher than the average range of traditional varieties. However, the traditional aman variety, especially BR-33, is the most profitable of the aman rice crops in the study areas. The net profit per acre from BR-33 is 319 USD (equivalent to 22,330 BDT), while it is 206 USD per acre from salt-tolerant aman crops (see Figure 4). But again it should be stressed that BR-33 is very sensitive to pest and heavy

Figure 4. Estimates of cost of production and profit of traditional and salt tolerant Aman variety (USD)

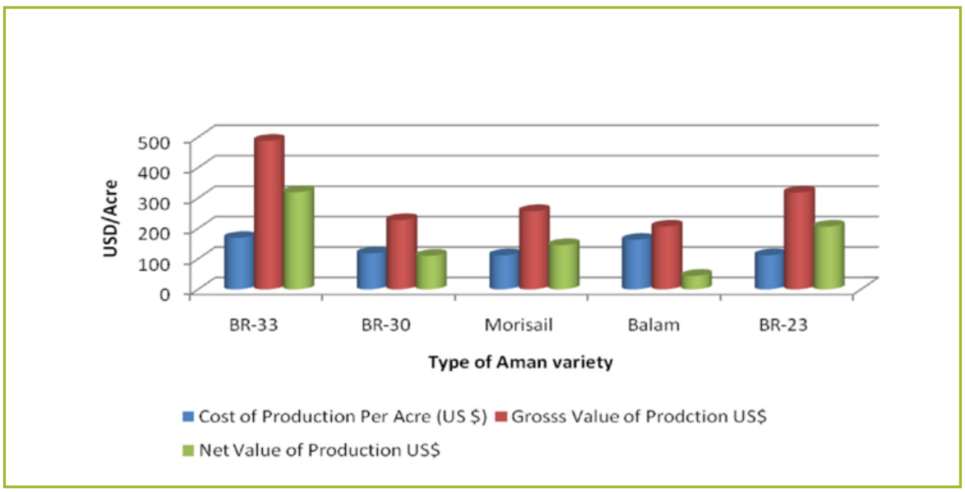
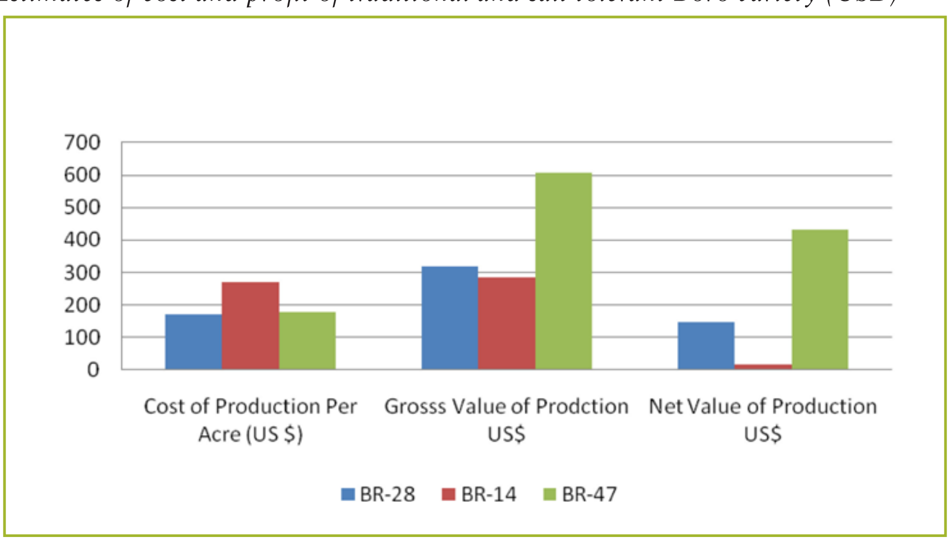


Figure 5. Estimates of cost and profit of traditional and salt tolerant Boro variety (USD)



rainfall. On the other hand, since rainfall in the coastal zone is slightly increasing, some farmers are reluctant to cultivate this variety, as the risk of production is also high.

The respective costs of traditional and salt-tolerant Boro varieties are also different. Here the costs of production for traditional varieties range from 171 to 270 USD per acre, while it is more than 177 USD per acre for the salt-tolerant variety. This indicates that per acre the salt-tolerant variety requires 20 percent fewer resources than the average cost of production for the traditional varieties. And the net profit from the salt-tolerant variety reaches more than 81 percent compared to the average profit from the traditional varieties (see Figure 5).

It appears that the lower middle-income group of households earning 1428-2124 USD (equivalent to 0.1 to 0.15 million BDT) per year is the main cluster of the study population growing saline-tolerant varieties. In fact, this group represents 46 percent of total households practicing this salt-resistant variety. The highest income group comes far behind (only 17%) in its use of these resistant varieties in the study areas. On the other hand, higher education is somewhat correlated with higher the number of households growing salt-tolerant varieties. About 32 percent of those growing salt-tolerant varieties have a secondary level of education (see Table 3 for details).

Despite the frequent climate-induced hazards, pollution of surface and ground water and increases in cultivation costs (e.g., irrigation, price of seeds, fertilizers), the production of rice in the country has increased. However, in coastal areas total rice production went down in 2008. As mentioned above, about 18% of Aus rice production was lost in 2008, probably mainly due to Cyclone Sidr and heavy rainfall in late 2007. In addition, it is evident that salinity is increasing along the coast and that farmers are already suffering from low yields as a consequence. The study reported that over 30% of respondents identified salinity as the obstacle to rice-farming in the study area. On the other hand, many farmers are already producing climate-resistant crops to adapt to changing conditions and reduce the adverse impacts of climate change. Saline-tolerant varieties were found to be economically viable adaptation options in rice-farming practices in coastal zones in Bangladesh. It is to be noted that the cost of fertilizers, including pesticides, manure, seeds and plants, are lower for the saline-tolerant Boro variety (e.g., BR-47) than the traditional Boro variety (e.g., BR-28, Br-14), while the labour costs of traditional Aman varieties are higher than for the saline-tolerant Aman variety. The study indicates that families with

Figure 6. Percentage of households practicing salt tolerant rice varieties (by income group) in the study areas

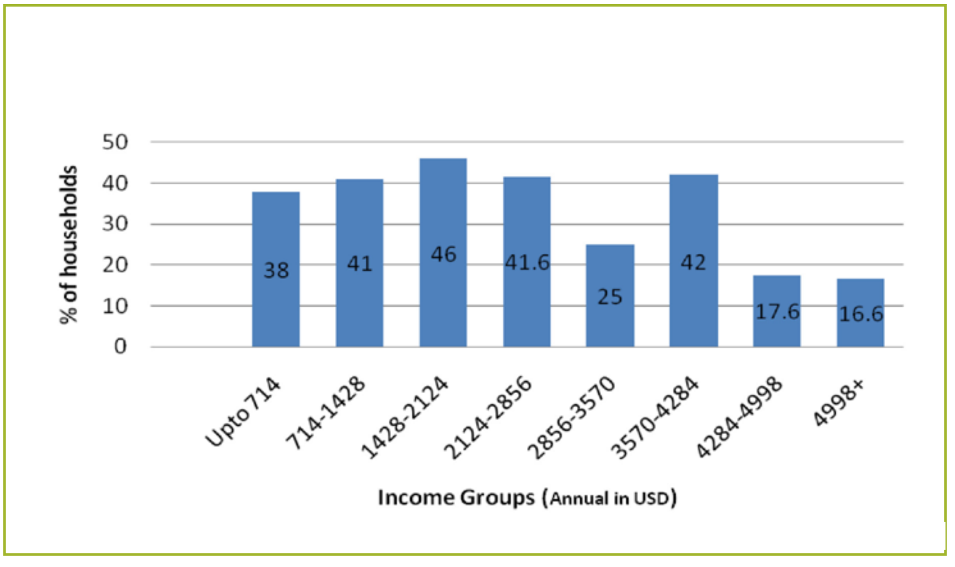


Table 3. Percentage of households producing salt-tolerant variety by education

Educational Status	No. of Households	No. of Households Producing Salt-Tolerant Rice	Percentage of Household Producing Salt-Tolerant Rice
Illiterate	36	9	25
Can sign only	78	29	37
Primary education	97	42	43.2
Secondary education	118	48	40.7
Higher secondary education and above	72	23	32

middle incomes are the beneficiaries from adaptive agriculture. It is to be understood that families with higher incomes are not necessarily inclined to farming, since there are other professions they can adhere to. It is also recognised that the higher the rate of education the more a household is liable to be adaptive in rice-farming. It is necessary to disseminate best practices and experiences in rice-farming to wider communities for scaling up or replication. Methods of cultivation may be further investigated to reduce costs while increasing production.

Conclusions

To meet the challenge of climate change, there is strong need to strengthen existing adaptation-technology practices in agriculture to avoid any crisis in food security. Communities might need improved technologies which would be resilient to changes in climate. The government and non-governmental organisations have introduced some adaptation technologies which are being practiced at the community level in many parts of the world, including Bangladesh. These mainly include climate-resilient crop varieties, irrigation systems and efficiency, cropping patterns, capacity-building and institutional frameworks to expedite the technological process. Farmers and practitioners must have easy access to all the necessary hard and soft technologies, including policy and institutional support in the implementation process. Capacity, knowledge and skills in relation to agricultural technology have to be strengthened at all policy and user levels, especially in vulnerable locations, countries or regions, to ensure appropriate adaptation practices.

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References

BBS (2009). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of Bangladesh. 2010.

BCAS., 2010. Economics of Adaptation to Climate Change in Bangladesh (draft report) prepared by Bangladesh Centre for Advanced Studies (BCAS), Dhaka, Bangladesh.

BRRI., 2011. Achievement of Bangladesh Rice Research Institute-Modern Varieties. Accessed on 14 February 2011. Available at http://www.knowledgebank-brri.org/

CBC News., 2011. The toll of Australia's flood. Accessed on 30 August 2011 and available at http://www.cbc.ca/news/world/story/2011/01/11/f-australia-queensland-floods-by-the-numbers.html

CGIAR., 2011 a. Who we are? Accessed on 25 August 2011 and available at http://www.cgiar.org/who/index.html

CGIAR., 2011 b. Adapting agricultural systems to climate change: a synthesis paper prepared by Consultative Group on International Agricultural Research.

CIDSE and Caritas., 2009. Reducing vulnerability, enhancing resilience: the importance of adaptation technologies for the post-2012 climate agreement. A report prepared by CIDSE and Caritas Internationalis

CIMMYT., 2011. Our mission. Accessed on 25 August 2011 and available at http://www.cimmyt.org/

Clements, R., J. Haggar, A. Quezada, and J. Torres., 2011. Technologies for Climate Change Adaptation : Agriculture Sector. X. Zhu (Ed.). UNEP Risø Centre, Roskilde, 2011.

Daily Star ., 2011. Two salinity tolerant varieties of T-Aman paddy soon. 18 July 2010. Accessed on 29 August 2011 and available at http://www.thedailystar.net/newDesign/news-details.php?nid=147255

The Financial Express., 2011. BRRI releases 2 new stress-tolerant rice varieties. Accessed on 28 August 2011. Available athttp://www.thefinancialexpress-bd.com/more.php?news_id=132106&date=2011-04-10

ICARDA., 2011. About us: our mission. Accessed on 25 August 2011 and available at http://www.icarda.org/Facelift.htm

ICRISAT., 2011. About us. Accessed on 25 August 2011 and available at http://www.icrisat.org/Icrisat-aboutus.htm

ICTSD., 2010. Agricultural technologies for climate change mitigation and adaptation in developing countries: policy options for innovation and technology diffusion. Published by International Centre for Trade and Sustainable Development (ICTSD), Switzerland.

IITA., 2011. About us. Accessed on 25 August 2011 and available at http://www.iita.org/about;jsessionid=F35E56E2C72E87478A7576F1C2952C4A

IRRI., 2009. Managing rice and rice systems in a changing climate: the Rice and Climate Change Consortium (RCCC). International Rice Research Institute. Manilla, Philippines.

IRRI., 2011 a. About IRRI. Accessed on 25 August 2011 and available at http://irri.org/about

IRRI., 2011 b. Our science-better varieties-climate change ready rice. Accessed on 20 August and 5 September 2011 and available at the website of International Rice Research Institute http://irri.org/our-science/better-varieties/climate-change-ready-rice

Islam, M. R., 2004. Where land meets the sea: A Profile of the Coastal Zone of Bangladesh. The University Press Limited, Dhaka, Bangladesh.

IUCN., 2010; Protocol for monitoring of impacts of climate change and climate variability in Bangladesh. Project Report prepared by International Union for Conservation of Nature, Bangladesh Country Office

Latest China., 2011. China flood claim victims, crops. Accessed on 3 September 2011. Available at http://latestchina.com/article/?rid=39500

Mazumdar, M.L.H. ,2011. Adapting agriculture to climate change. Daily Star, 1 January 2011. Accessed on 14 February 2011

http://www.thedailystar.net/newDesign/news-details.php?nid=168249

MoF., 2010. Bangladesh Economic Review 2010. Economic Division, Ministry of Finance, Government of Bangladesh, 2010.

Reuter., 2011. Fact box-facts about Pakistan's key crops after floods. Accessed on 2 September 2011 and available at http://in.reuters.com/article/2010/08/17/idINIndia-50885020100817

Salam, M.A. , Rahman, M.A. , Bhuiyan, M.A.R. , Uddin, K. Sarker, M.R.A. , 2011. BRRI dhan 47: a salt-tolerant variety for the boro season. Plant Breeding Division; and R. Yasmeen and M.S. Rahman, Plant Physiology Division, Bangladesh Rice Research Institute, Gazipur 1701, Bangladesh. Accessed on 3 September 2011 and available at http://dspace.irri.org:8080/dspace/bitstream/10269/112/1/v.32%281%29Soil.pdf

UNFCCC., 2006. Technologies for adaptation to climate change. United Nations Framework Convention on Climate Change. Bonn, Germany.

UNFCCC., 2008. Climate change: impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change. Bonn, Germany.

World Bank., 2010. The World Development Report 2010. Development and Climate Change. Washington, USA.

Zelli, F., 2010. Technologies for Adaptation to Climate Change: A Stepchild of International Climate Negotiations. Paper presented at the ECPR-SGIR Conference, Stockholm, 9-11 September 2010.

Photo credit: Peter Fries

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Adaptation technologies to climate change impacts on coastal zones in Thailand

Abstract

Thailand's coastline is economically important in terms of tourism. Coastal areas are currently under threat due to severe erosion and sea water intrusion. This paper presents two case studies of coastal adaptation technologies and draws lessons from how a successful enabling environment for coastal adaptation technologies was created in Thailand.

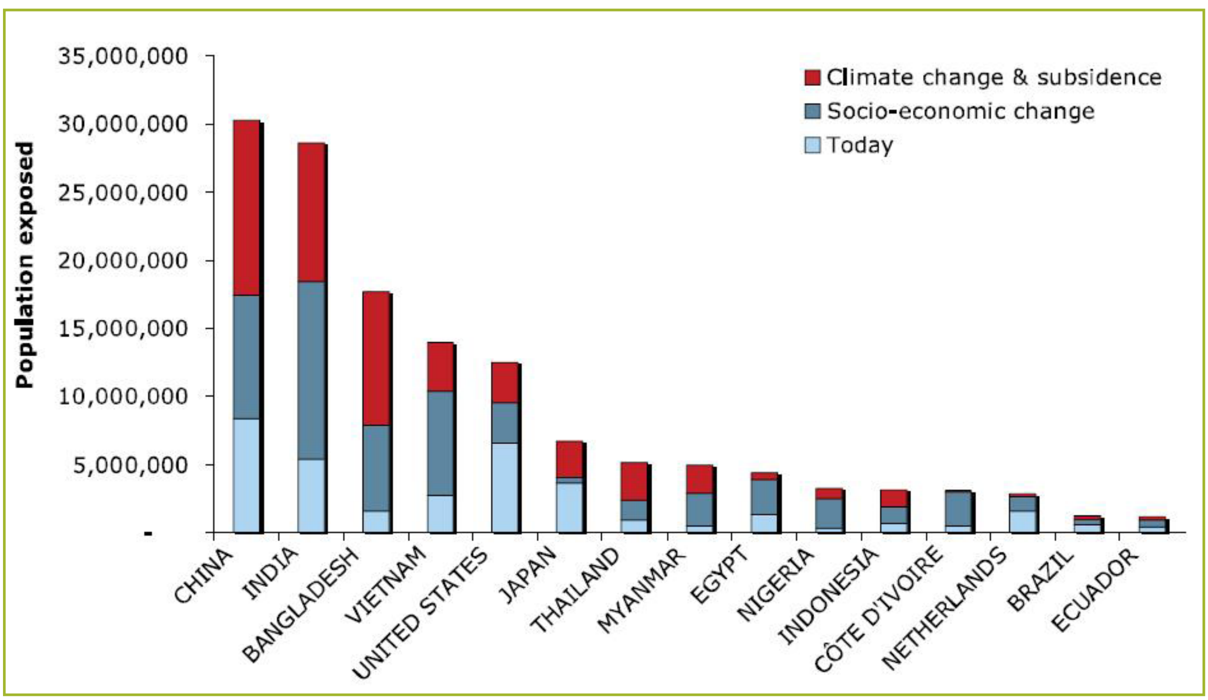
Introduction

Thailand has a long coastline of about 2,600 kilometres, covering an area of about 513,000 square kilometres within 24 provinces (Sudara, 1999). These areas are economically important in terms of economy, human settlement and habitats for many coastal flora and fauna that live in mangrove and other coastal ecosystems. Thailand's long coastline makes it especially vulnerable to the effects of climate change. There is expected to be a significant rise in sea level due to land subsidence as a result of excessive groundwater extraction in the low-lying areas of the Gulf of Thailand (Rawadee Jarungrattanapong and Areeya Manasboonphempool, 2008). According to a Chulalongkorn University study (World Bank, 2006), eleven and two percent of the coastlines along the Gulf of Thailand and the Andaman Sea respectively are eroding at a rate of over five metres annually. A recent study by the OECD (2007) ranking the cities of the world that are most exposed to coastal flooding today and in the future provides interesting insights into this vulnerability. The analysis indicates that by the 2070s almost all (90 per cent) of the total asset exposure of large port cities will be concentrated in only eight countries, one of which is Thailand (see Figure 1). Thailand ranks seventh in terms of the severity of the projected effects. The same study also assessed the impact on the population of countries exposed to coastal flooding. Figure 2 shows that 90 per cent of the exposure of people in the 2070s will be in ten countries and that Thailand will rank sixth in terms of the negative impacts projected.

Past efforts to cope with coastal erosion in Thailand include a project to grow permanent mangroves in celebration of H.M. Queen Sirikit's 72nd birthday so as to preserve and restore the coastal ecosystem (ONEP, 2008). In addition, the Ministry of Natural Resources and Environment has issued a strategic plan, including guidelines on sustainable wetland management with public participation in different areas.

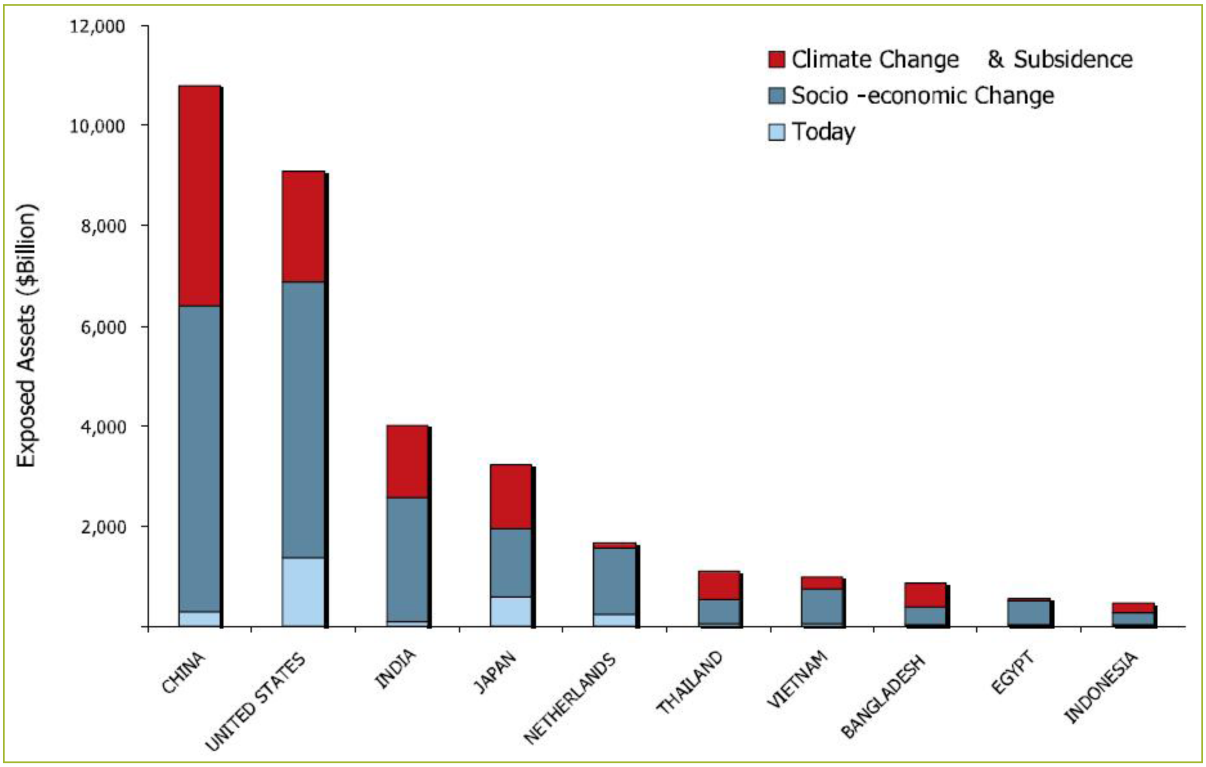
The objective of this paper is to present case studies of coastal adaptation and to draw lessons from how a successful enabling environment for coastal adaptation technologies was created in Thailand. The paper focuses on existing climate adaptation technologies applied to

Figure 1. Top fifteen countries vulnerable to climate change



Source: OECD, 2007: Figure 1 p.6

Figure 2. Top ten countries by assets exposed today and in the 2070s, showing the influence of future climate change versus socioeconomic change



Source: OECD, 2007: 8, Figure 4

coastal zones in Thailand. It is based on a review of existing work on expected climate change impacts on Thailand's coastlines.

Climate change and its impacts on Thailand's coastal areas

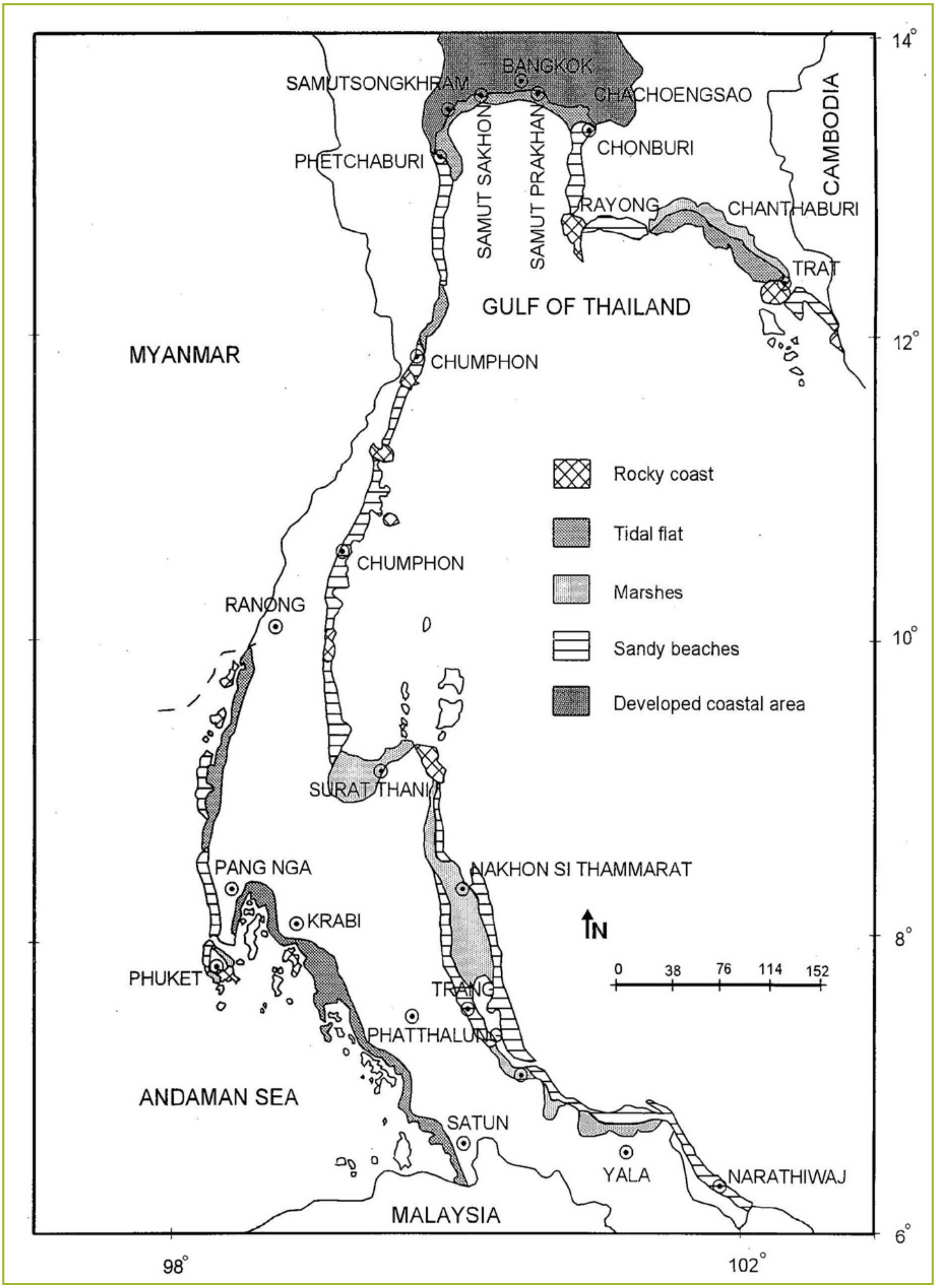
Sea-level rise will have many impacts such as inundation of low-lying coastal areas and accelerated coastal erosion. Coastal erosion will further damage the ecosystem and man-made structures, resulting in severe impacts on the livelihoods of coastal communities. Thanawat Jarupongsakul (2006) identifies thirty coastal areas in Thailand as having been prioritised as being severely eroded. There are several types of coast in Thailand (see Figure 3): rocky coasts, tidal flats, marshes and sandy beaches.

The coastline in Samut Sakhon and Samut Prakan provinces and in Bang Khun Thian district of Bangkok are included among the hot spots. Among the worst affected areas are Bang Khun Thian district and its neighbouring district, Phra Samut Chedi in Samut Prakan province. These two districts are greater risk than other coastal areas owing to land subsidence caused by excessive extraction of groundwater over decades, which has resulted in the surface of the ground sinking to a point lower than the mean sea level.[1]

Besides the land subsidence that is occurring, currently there is a relatively slow process of inundation from rising sea levels, with the waters in the Gulf of Thailand rising at a rate of about 25 mm per year (Bangkok Assessment Report on Climate Change, 2009).

1 According to a study by Thammasat University (Sombat Raksakul 2008), the rise in sea levels is small when compared to the subsidence rate. Sea levels are predicted to rise in the long term, but the analysis of fifty years of data reveals that the effect of land subsidence in the upper Gulf of Thailand is a major factor.

Figure 3. Types of coast in Thailand



Source: Department of Coastal and Marine Resources, 2011.

Policies addressing climate change in Thailand

Currently, the Office of Natural Resources and Environmental Policy and Planning, under the Ministry of Natural Resources and Environment, is in the process of drafting a strategy to address climate change issues as they relate to Thailand. The draft of the country's five-year plans has been out for public consultation since September of 2007. The plan discusses the impact of climate change on Thailand's natural resources such as forests, soils, water and fisheries. Moreover, it discussed the impacts on the critical industries of seaside tourism and agriculture. The plan suggested a number of mitigation measures such as energy efficiency, a less-polluting transport sector and new land-use policies in response to expected rises in sea level. In general, the measures also call for promoting the awareness of the general public about climate change and the need for community action to implement them. Efforts to build or strengthen capacity will also be undertaken, especially in the area of research and development (NESDB, 2011). Presently, the plan's principal action items focus on increased training of government officials regarding climate change and encouraging them to incorporate this knowledge into future policies and projects.

The analysis of the vulnerability and adaptation of coastal resources in Thailand suggests the following adaptation options (MOSTE, 2000):

- Establishing a coastal hazard management sub-committee to develop policies, strategies and guidelines for coastal hazard management and to provide guidelines on the management and development of coastal areas
- Improving drainage and flood control facilities
- Improving cropping systems suitable for this sort of environmental change and using organic matter to improve salty soil conditions
- Improving crop cultural practices.

Many different technologies exist for adapting to natural coastal hazards. In the literature, these technologies are often categorised as 'hardware', 'software' and 'orgware' (UNFCCC, 2006). Hard structures (i.e., 'hardware' technology solutions to coastal hazards, such as groins, breakwaters, etc.), will rarely solve coastal erosion problems permanently and may also have significant negative side effects on the local ecosystem. A better approach may therefore be to live with, not against, nature. Indigenous knowledge among local people often contains a deep understanding of how coastal communities and ecosystems can coexist harmoniously, and how the conscious preservation of healthy coastal wetlands can help mitigate natural coastal hazards and thus be a more effective way of dealing with climate-induced coastal erosion in the upper Gulf of Thailand than modern 'hardware' technologies. Indigenous knowledge among local people is thus a form of information, or 'software', which can also be defined as a coastal adaptation technology. There is also a growing recognition in the academic literature that a combination of local indigenous and scientific knowledge has the potential to contribute to conservation efforts (Berkes and Folke, 2002). The following case studies highlight the growing recognition of the benefits of 'soft' approaches that can be employed to reduce vulnerability to climate change in coastal zones and enhance awareness of the need for coastal adaptation to be suited to local natural and socio-economic conditions.

Case studies of technologies for adaptation

Faced with the effects of climate change, communities in coastal zones have a choice of three basic adaptation strategies: protect, retreat or accommodate (UNFCCC, 2006). This section presents two practical experiences of adaptation technologies for the coastal zones in the upper Gulf of Thailand. These case studies, summarised in Table 1, give examples of a soft technology, and a mix of soft and hard technology, respectively. The first case study shows how indigenous knowledge has been used to fight against coastal erosion in Kohok Karm sub-district of Samut Sakhon province. The second case study describes the success of an experiment with a permeable breakwater to battle coastal erosion in Ban Khun Samutchine village of Samut Prakhan province.

Table 1. Summary of case studies reviewed

Case study	Type of technology
1. Bamboo poles technology	Soft
2. Khun Samutchine breakwater	Soft and hard

Bamboo poles technology

The Khok Karm project describes a unique bottom-up development project initiated by the villagers to fight coastal erosion. The project uses bamboo to reduce wave forces and increase sedimentation along the coastline, allowing replanted mangroves behind the fence to grow. The planted mangroves are expected to be large enough to continue trapping sediment and maintaining the coastal ecosystem on their own. The bamboo fences represent the indigenous knowledge of a Khok Karm resident, Vorapol Dounglomchan (see Figure 4), who was motivated to look for a solution after his home was submerged. Building on his experiences in mussel farming, he uses bamboo poles to create barriers that trap sediment from the seawater and stop the silt being washed away. Later, the scheme was replicated in Bang Khun Thian by local authorities as an ecological solution to restore the costal ecosystem.

An initial community network was formed in 2003 by a small group of villagers led by Voraphol[2] in response to a direct threat to their local livelihoods. Vorapol's house was damaged by a series of storms (Chatchawassa Katipipatporn, 2011). At first he tried to repair the damage after each storm, but after four years he finally abandoned the house. And he has seen many households in neighbouring coastal communities having been forced to relocate further inland. The initial, informal network had no funding from outside at all. All activities were conducted at the grassroots, being carried out by the villagers themselves, and any costs for items such as bamboos or mangrove saplings were absorbed and shared by those in the village who were participating in these activities. They set aside an area for conservation and gradually replanted mangroves behind bamboo fences from the shore out to the sea. The formal Khok Karm project started in 2007 with funding from Department of Marine and Coastal Resources (DMCR) and the Samut Sakhon provincial office (Chatchawassa Katipipatporn, 2011; Mangroves for the Future, 2010).

The DMCR decided to grant Vorapol and the community network financial and technical support, enabling him to extend the bamboo fences to three rows stretching more than a kilometre along the shore.

In groups of triangular shape, 55 bamboos to each group, they form the first line of defence less than two hundred metres from the shore. They are not supposed to stop the waves from reaching the shore the way other devices are designed to do. Rather, their purpose is to weaken the force of the waves and allow a more natural exchange between the marine and freshwater environments. Behind the first line of defence stands another line about ten metres from the shore through which the now weakened waves go. Behind this line the sea water becomes calm enough to allow sedimentation to accumulate, forming a mud flat on which mangrove seedlings can be planted.

In Bang Khun Thian, families, businesses and government offices have been forced to move to higher ground over the past twenty years. The erosion is taking place at the rate of 20-25 metres of coastal land annually (Thanawat Jarupongsakul, 2006). A Bangkok

2 He was a former village head of Khok Karm and now serves as a coordinator of the Upper Gulf of Thailand Conservation Network (Gawin Chutima, 2010), established in 2009 to promote the conservation of marine and costal resources in the upper Gulf of Thailand. Its coordinating centre is in Khok Karm.

A model replica of bamboo breakwater.

Photo: Rudklao Ruangkhanab, 2011.

Bamboo fences protecting the coast at the village of Khok Karm.

Photo: Rudklao Ruangkhanab, 2011.

Mangrove replanting behind bamboo fences at the village of Khok Karm.

Photo: Rudklao Ruangkhanab, 2011.

Metropolitan Administration study (2006) found that two villages have been directly affected by coastal erosion. In 2005, the total numbers of houses in these villages were 382 and 327 respectively. Coastal erosion is most severe in village number 9, where the stakes marking the Bangkok boundary are already submerged (see Figure 8). Local residents with land next to the sea have been forced to retreat away from the advancing sea water that has eroded their land.

In response to the problem, Bangkok Metropolitan Administration officials proposed a USD 10.5 million[3] project to build breakwaters and groins. Local residents disagreed with the plan. Earning their living from the sensitive coastal ecology, Bang Khun Thian residents have learned from the mistakes of other coastal communities, and they believe that the groins would do more harm than good.

Having learned from the success of the Khok Karm project, villagers in Bang Khun Thian replicated the bamboo fence technology. Today behind the bamboo walls at Bang Khun Thian shore put down some years ago, a 65-centimetre mud flat has formed where there was once sea water. It has drawn weekend visitors, some just to take in the sea view, while others dig for mussels in the mud to supplement their incomes. For residents along this coast, rising sea water as a result of global warming is still too remote a threat. Their immediate concern is how to ensure they can maintain this nature-friendly line of defence. In addition to the bamboo breakwater, residents in Bang Khun Thian are planning social and ecological conservation projects. Now the International Union for the Conservation of Nature and United Nations Development Programme are working on a project to replant mangrove forests at Bang Khun Thian.

This case study shows a successful example of project that was initiated and accepted by the locals. It has shown that local people are best placed to prepare

3 USD 1 = 30 Baht as of 6 September 2011.

for and respond to these problems. One of the key elements which contributed to the success of the Khok Karm project was the involvement of the DMCR. This government agency was important in assisting the villagers with financial and technical support. The DMCR is now keen to monitor and promote this project as an example of ecosystem-based adaptation to address coastal erosion problems (Mangroves for the Future, 2010).

Khun Samutchine breakwater

The coastal Ban Khun Samutchine community in Samut Prakhan province has been relocated five times in the past two decades. Around sixty families have already been forced away from this once idyllic fishing community (Spender, 2009). Analysis of the Thammasat University research shows that Ban Khun Samutchine is hit by strong waves all year round and loses approximately 28 metres of coast a year (Sombat Raksakul, 2008).

Severe erosion has encroached about a kilometre deep into the mainland in the Ban Khun Samutchine community. Khun Samutrawat temple used to be in the village but now is surrounded by sea (Barrow, 2007). Today the ordination hall is a metre underwater. The compound of the Buddhist temple used to cover an area of over 112,000 square metres, but only 8,000-9,000 square metres remain (Wudhichai Assawinchaichote and Thanawat Jarupongsakul, 2007). It does not have a footpath anymore, so monks and local people visiting the temple used to walk on a line of water jars. Later a wooden walkway was built, but it could not withstand the strong waves. It was finally replaced with an elevated concrete footpath. Also elevated was the floor of the ordination hall, lifted one metre to escape flooding. A line of electricity poles that once lined the village streets are now standing in the water. Without effective solutions, coastal erosion may reach 1.3 km into Samut Prakhan province in the next two decades (Wudhichai Assawinchaichote and Thanawat Jarupongsakul, 2007).

With a slow response from government agencies, residents have had to try to fight the erosion themselves. They have built small seawalls of soil, and some residents have tried strengthening their seawalls with rocks and old tyres. But as the erosion becomes worse and is more publicised, officials have instigated large and expensive shore protection schemes,[4] such as placing submerged off-shore breakwaters in ecologically sensitive areas, which created conflict with local residents. Moreover, such hard structures are not suitable for muddy beaches. This is why the residents of Khun Samutchine community opposed the sandbag seawall project proposed by Samut Prakhan's administrators, which tends to concentrate on just one very specific objective, that is, to prevent coastal erosion. It creates conflicts with the interests of the local community. These kinds of top-down projects tend to have limited success, as they are designed and initiated by higher levels of government agencies and then implemented in local communities without community participation.

To help the residents cope with the problem, Thanawat Jarupongsakul and his associates from a unit studying disasters and area-oriented information in the Faculty of Science, Chulalongkorn University, have studied coastal erosion in Ban Khun Samutchine village. This experimental project was sponsored by the Thailand Research Fund (TRF).[5] The project has drawn experts in many fields, including meteorology, hydrology, coastal ecology, geological disasters, economics, coastal engineering, sociology, landscape architecture and land legislation. In order to reduce the conflict with the local community, the team hired ten local researchers from the community to help with gathering information and monitoring the accumulation of sediments. By this means, the latter can simultaneously learn about and understand the natural processes in their locality and thus build critical local capacity for the potential development of innovative local solutions to coastal erosion. This kind of cooperation between the local population and academics in the development and implementation of the adaptation technology can

4 The cost is estimated at USD 2 million per kilometre, while that of bamboo fence is estimated at half that (Sakhon Online 15 May 2010).

5 The TRF was established by the national government to provide funding for research.

Wat Khun Samuttrawat during a storm.

Photo: Barrow, 2007.

be considered integrative since it is designed to deal with several problems which villagers are facing.

The project has been built on research into coastal erosion during two monsoon seasons: the southern monsoon between March and April, and the south-western monsoon between May and September. Sediment resulting from coastal erosion is deposited near the shore, but not for long. Between November and February, north-east winds blow the sediment into the sea. The information collected from the research has led to the invention of the 'Khun Samutchine 49 A2' permeable breakwater.

This kind of breakwater consists of two parts. The first part comprises three rows of concrete columns in the shape of equilateral triangles. The columns in the first row, which faces the sea, are ten metres high, those in the second row eight metres high, and those in the third row, facing the shore, six metres high. The rows are placed 1.5 metres apart from one another, and the columns in the three rows are placed in a zigzag pattern. Waves break repeatedly when they hit the rows of triangular columns. As waves are dissipating inshore, they deposit sediment behind the breakwater.

The second part will be made of rows of boomerang-shaped concrete columns that will close both sides of the three rows parallel to the shore. The boomerang-shaped columns are intended to trap sediment and protect it from northeast winds. Thus, the breakwater will reduce coastal erosion and trap sediment. When there is enough sediment, the research team will plant mangroves to help trap more sediment and accelerate the reclamation of land in these areas.

Thanawat told us that the three rows of concrete columns had been installed for a distance of 250 metres parallel to the shore. During the installation of the columns, the researchers measure the amount of sediment, the force of the currents, and the direction and speed of the winds. This information will help them improve the final version of the Khun Samutchine 49

A2 breakwater. This is the world's first initiative to cope with the erosion of a muddy coast. There are similar projects overseas, but they are designed only for sandy shores. The installation of the three rows of concrete columns has so far produced satisfactory results; the depth of the deposited sediment has reached 30 centimetres. The experiment has succeeded in stopping coastal erosion in these areas. The breakwater not only protects existing areas, it also brings more mud to the beach for aquaculture, which many locals can use to earn money farming prawns and mussels. This can last for many years if residents understand how it works and participate in its maintenance.

The Khun Samutchine 49 A2 breakwater project has received international attention. Representatives of international news agencies such as the BBC, AFP, Reuters and NHK, as well as foreign experts on coastal erosion, have visited the project site. They are interested in the new and patent-pending technology designed to cope with the erosion of muddy coasts in particular. It will take some time to complete a study of the new technology, but the findings are expected to create an international solution to help other nations facing similar problems.

Conclusions

This paper presents case studies on coastal adaptation technology in Thailand. Four lessons can be learned from this paper. First, how should we define technologies for adaptation to coastal problems? The conventional thinking among experts in Thailand is that technologies for adaptation must be in the form of hard structures such as cement breakwaters, groins, etc. Not many think of indigenous climate management practices at the local level. In this paper, two case studies were selected to show how indigenous knowledge of bamboo fences can be used to trap sediments, forming a mud flat on which mangroves can

Khun Samutchine 49 A2 breakwater.

Photo: Thanawat Jarupongsakul, 2006.

be replanted, which will accelerate land reclamation. The principle of the bamboo fences is based on co-existence with nature. Secondly, traditional top-down projects have limited success, as they are designed and initiated by higher levels of government agencies and then implemented in local communities without community participation. Bottom-up approaches are more successful because they tend to deal with many problems which the community concerned may be facing. The approach is participatory in nature. Thirdly, the strong leadership of the Khok Karm village head was critical initiating this project, since he has been instrumental in expanding conservation efforts and is very active in networking. Finally, capacity building can be informal through the participation of villagers in the project, where villagers learned skills in data collection and analysis, as well as skills relating the documentation of research. This model of local and academic cooperation in the development, installation and management of adaptation technology provides an example of a successful strategy for the implementation of adaptation technology locally.

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References

Bangkok Metropolitan Administration, 2006. The project on coastal erosion protection: a case study of Bang Khun Thian district, Bangkok, Interim report. Bangkok (in Thai).

Bangkok Assessment Report on Climate Change, 2009. BMA, GLF and UNEP, Bangkok.

Berkes, F., Folke, C., 2002. Back to the future: ecosystem dynamics and local knowledge, in: Gunderson, L. H., Holling, C. S. (eds.), Panarchy: understanding transformations in human and natural systems. Island Press, Washington DC, pp. 121-146.

Barrow, R., 2007. Thai temple in the sea. Retrieved July 25, 2011 from http://www.khunsamut.com/thai-temple-in-the-sea.html.

Chatchawassa Katipipatporn, 2011. The man who reclaims the land, in: Peeyanee Rungratthawatchai, Chatchawassa Katipipatporn, Wannawanut Soodchinda. The vanishing land. Manager 360 Degree Magazine, 28 (March 2011) (in Thai).

Department of Coastal and Marine Resources, 2011. Retrieved July 26, 2011 from http://www.dmr.go.th/ewtadmin/ewt/dmr_web/main.php?filename=coastal_En

Gawin Chutima, 2010. Upper Gulf of Thailand Conservation Network after One Year. Retrieved September 5, 2011 from http://www.bcst.or.th/index.php?option=com_content&view=article&id=278%3A2010-09-18-14-18-43&catid=67%3Abcst-act-network&Itemid=1&lang=en.

Mangroves for the Future, 2010. Newsletter, 8 (November-December), 1-13.

MOSTE, 2000. Thailand's initial national communication under the United Nations framework convention on climate change. Ministry of Science, Technology and Environment, Bangkok.

NESDB, 2011. Office of the National Economic and Social Development Board, Thailand. Retrieved July 29, 2011 from http://www.nesdb.go.th/Default.aspx?tabid=95.

OECD, 2007. Ranking of the World's Cities Most Exposed to Coastal Flooding Today and in the Future. Retrieved July 25, 2011 from http://www.oecd.org/dataoecd/16/10/39721444.pdf.

ONEP, 2008. National strategy on climate change management 2008-2012. Office of Natural Resources and Environmental Policy and Planning, Bangkok.

Rawadee Jarungrattanapong and Areeya Manasboonphempool, 2008. Adaptation Strategies for Coastal Erosion/Flooding: A Case Study of the Communities in Bang Khun Thian District, Bangkok, Final report. Economy and Environment Program for Southeast Asia, Singapore.

Rudklao Ruangkhanab, 2011. Retrieved September 8, 2011 from http://www.facebook.com/Ruangk?ref=ts#!/media/set/?set=a.263741113649473.65438.100000407584509&type=1.

Sakhon Online, 2010. Retrieved August 5, 2011 from http://www.sakhononline.com/news/?p=790.

Sombat Raksakul, 2008. Coastal protection in the Gulf of Thailand: swimming against the tide. Bangkok Post 16 November 2008 Retrieved July 25, 2011 from http://wildsingaporenews.blogspot.com/search?q=

coastal+protection+in+the+Gulf+of+Thailand&updated-max=2010-03-24T08%3A20%3A00%2B08%3A00&max-results=20.

Spender, T., 2009. Thai villagers battle rising sea levels. Retrieved July 26, 2011 from http://www.demotix.com/photo/384767/Thai-villagers-battle-rising-sea-levels.

Sudara, S., 1999. Who and what is to be involved in successful coastal zone management: Thailand example. Ocean and Coastal Management, 42, 39-47.

Thanawat Jarupongsakul, 2006. Coastal Erosion in Thailand: Causes and Management. Bangkok: Chulalongkorn University (in Thai).

UNFCCC, 2006. Technology for adaptation to climate change. Bonn, Germany.

United Nations Development Programme, 2009. Thailand cooling down the planet with both hands: making friends with nature again.

Retrieved July 27, 2011 from http://www.undp.or.th/resources/documents/Part3Minus2degrees.pdf.

World Bank, 2006. Thailand Environment Monitor 2006. Bangkok, Thailand.

Wudhichai Assawinchaichote and Thanawat Jarupongsakul, 2007. Reversing the erosion of muddy coasts: a breakthrough by Thai experts. Thailand illustrated magazine, 24(4). Retrieved July 27, 2011 from http://thailand.prd.go.th/thailand_illustrated/content.php?s_id=313.

This edition of UNEP Risø Centre's Technology Transfer Perspectives series collects 10 articles from a number of adaptation experts and practitioners around the globe. Each article presented discusses issues related to the definition and application of the concept of 'technologies for adaptation'. The selected articles are divided into three broad themes: 'The Concept and Context of Technologies for Adaptation', 'Assessments of Adaptation Technology Needs', and 'Practical Experiences from Working with Technologies for Adaptation'. It is hoped that the insights, experiences and recommendations shared in this collection of articles will inspire a broader international debate on the concept and practical application of technologies for adaptation.

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