Chapter 15. Adaptation Planning and Implementation

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Executive Summary

[to be developed]

15.1. Introduction

As impacts of climate change have been becoming apparent around the world, adaptation has attracted increasing attention. The impacts are expected to be severe particularly in the developing world and among marginalized communities because their adaptive capacity is limited. Therefore, there is a strong need to develop and strengthen capacities effective for adaptation planning and implementation in the developing countries. To respond to their urgent needs, least developed countries (LDCs) have developed National Adaptation Programmes of Action (NAPAs). The NAPA focuses on existing coping strategies and actions at the grassroots level, and builds upon that to identify priority activities, recognizing that local communities are the main stakeholders. At the same time, the movement to introduce climate change adaptation policies into national policies has been accelerated in the developed countries as well.

Regarding the assessment of adaptation, Chapter 17 of the IPCC Fourth Assessment Report (AR4) (Adger et al., 2007) presented the following major findings:

- Adaptation to climate change is already taking place, but on a limited basis.
- Adaptation measures are seldom undertaken in response to climate change alone.
- Many adaptations can be implemented at low cost, but comprehensive estimates of adaptation costs and benefits are currently lacking.
- Adaptive capacity is uneven across and within societies.
- There are substantial limits and barriers to adaptation

This chapter will review the literature on climate change adaptation to assess the progress and limitations of the adaptation planning and implementation focusing on those occurred after AR4, characteristics of adaptation in different settings, and barriers and lessons drawn from actual adaptation implementation and practice.. As the Fifth Assessment Report of the IPCC Working Group II has 4 interrelated chapters for adaptation, this chapter focuses on the assessment of cases at different levels, from international to local, to identify how progress was made after IPCC AR4. To this end, this chapter consists of the following six sections.

The research-based information necessary to support such practices include rigorous methodologies to assess and reliable knowledge about: (McKinsey Group)

- The impacts already posed to society from today’s climate extremes and variability and where improved early warning and preparedness will provide both immediate and future benefit
- Climate-sensitive paths and asset development that might put greater population, ecosystem services, and economies at risk
- The potentially high-impact additional risks presented by climate change and the opportunities for improving management efficiency and outcomes in fisheries, water resources, and coastal regions and across sectors

Key drivers of adaptation, such as technological innovation and change, are difficult to predict with great accuracy on scales that matter for regional and local decisions. In addition for periods of rapid transitions, the combined physical and social system may change faster than the models can be recalibrated. Research to inform early adaptation efforts have impact on decisions: (i) that are sensitive to present-day extremes and climate variability and will provide immediate and future benefits for reducing vulnerability to climate change; and (ii) that will have long-lasting consequences, including decisions about long-lived assets such as dams, urban development.

15.2. Assessment of Local, National, Regional, and Global Strategies and Policies for Adaptation Planning and Implementation

The international literature (peer-reviewed and gray) reports a significant growth of publications reporting adaptation to climate change during the last 5 years. Tompkins et al. (2010) document over 300 adaptation actions in the UK in 2005. Berrang-Ford et al. (2011) document a sharp increase in the peer review literature addressing adaptation to climate change during the last years (1741 articles published between 2006 and 2009). Preston et al. (2009) identify at least 62 different adaptation plans publicly released in the United States, Canada, United Kingdom and Australia, and they expected that number would double by the end of 2009.

Despite the fast growth of the adaptation literature, only few articles in the peer-reviewed literature have study national adaptation strategies. At a regional level, only Europe has a regional effort to encourage adaptation to climate change. The European Commission provides a structure supporting the creation of national adaptation strategies (Commission of the European Communities 2009). Biesbroek et al. (2010) study of 7 national adaptation strategies in Europe considers these strategies represent a new political commitment to adaptation at national political levels. But they also recognize there are many institutional challenges which can act as considerable barriers in future policy implementation. The review of national adaptation strategies in other countries in the gray literature (Australia, Brazil, Mexico, ..) shows the national level enhances the importance of adaptation in the political agenda and creates a coordination framework for subnational actions or by economic sectors. It also shows different approaches in the national strategies. For example, Australia Climate Change Adaptation Framework (2007) has two practical objectives: building understanding and adaptive capacity and reducing vulnerability in key sectors and regions; support decision makers during the next 5 to 7 years. In contrast, Mexico (SEMARNAT 2010) seeks to create a comprehensive framework for subnational and sectorial actions.

Adaptation planning is reported by the peer-reviewed and gray literature at the local level. Urban areas are the locus of a number of those planning initiatives (Blanco and Alberti 2009, Coffe et al. 2010, Hamin and Gurran 2009, Lowe et al. 2009, Parzen 2008, Roberts 2008, Sanchez-Rodriguez et al 2009), including special issues in some academic journals (Habitat International vol 33 2009, Current Opinion in Environmental Sustainability vol. 3 2011). But the gray literature documents a larger number of adaptation plans to climate change (New York[1], Chicago[2], King County in Washington State, London[3], Toronto[4], Rotterdam[5], Mexico City[6], Cartagena and San Andres de Tumaco[7] in Colombia, Durban[8] and Cape Town[9] in South Africa provide interesting early lessons potentially useful to other cities.[10]

[INSERT FOOTNOTES 1-10 HERE:

1) http://www.nyc.gov/html/planyc2030/html/home/home.shtml
2) http://www.chicagoclimateaction.org/
3) http://www.cityoflondon.gov.uk/Corporation/LGNL_Services/Environment_and_planning/Sustainability/Climate_change
4) http://www.toronto.ca/teo/pdf/ahead_of_the_storm_highlights.pdf
5) http://www.rotterdamclimateinitiative.nl/NL/Home/?cid=1
6) http://www.sma.df.gob.mx/sma/links/download/archivos/paccm_summary.pdf
7) http://www.nlcap.net/fileadmin/NCAP/Countries/Colombia/ColombiaTechnicalProgressReport2_01Jan06.pdf
8) http://www.durban.gov.za/durban/services/environment
9) http://www.erc.uct.ac.za/Research/publications/06Mukheibir-Ziervoge%20-%20Adaptation%20to%20CC%20in%20Cape%20Town.pdf

10) This list of urban areas is intended for illustrative purposes in this review. It is difficult to determine how many urban areas have created adaptation to climate change.]

One of the most interesting aspects of recent contributions of adaptation to climate change in urban areas is the growing attention to the situation of middle and low-income countries. Blanco (2007), Moser and Satterthwaite (2008), UN-Habitat (2007), Agrawala and van Aalst (2008), Ayers (2008), Bartlett (2008), Caney (2008), Revi (2008), Roberts (2008), Stren (2008), Tanner et al. (2008), , O'Demsey (2009), Hardoy and Pandiella (2009), Wong (2009) study different dimensions of climate change and adaptation in those countries.

15.2.1. Responding to Present and Future Climate Impacts

The literature review identifies a number of issues frequently cited as important element relevant to planning and implementing adaptation in order to respond to present and future climate impacts. There is growing recognition that adaptation to climate change should be considered a process (..). This coincides with the notion of the planning process requiring frequent evaluation and adjustments to incorporate change in conditions and needs. The research supports the contention that adaptation takes place as a response to multiple stimuli not just climate (Adger et al. 2009, Tompkins et al. 2010). This facilitates connecting adaptation with the development process of societies. The importance of climate adaptation also is influenced by how the issue is framed. For example, to the extent that it is viewed as a public safety issue or a development issue, it may have greater resonance within local government (Measham et al. 2010).

Despite the growing attention to adaptation to climate change, the peer reviewed literature reports concerns about the contributions to a better understanding of adaptation. Berrang-Ford and co-authors (2011) study of the English peered-reviewed literature on adaptation highlight the limited understanding of if and how adaptation is taking place. They report that despite considerable research on adaptation has been conducted yet the majority of studies report on vulnerability assessments and natural systems (or intentions to act), not adaptation actions. Arnell (2010) characterizes what we know about adaptation by reviewing all adaptation related articles in the journal Climatic Change. His conclusions indicate there are very few published examples of case studies of how adaptation to climate change is actually being delivered, or on the barriers that will influence how adaptation takes place. Tompkins et al. (2010) question weather the observed adjustments and changes to perceived climate risks represent evidence of a societal shift towards a well-adapting society, or are merely unconnected actions of individuals motivated by different stimuli. They suggest that in the context of adaptation planning, there is no evidence to show that adaptation planners are working towards transitions. Mozumder et al. (2011) survey responses reveal that experts and decision makers in the Florida Keys are currently operating with limited information and they lack a formal institutional framework necessary to shape and execute adaptation measures on an urgent basis. Despite the recognition of the importance of climate change impacts, very few experts and decision makers report that their respective agencies have developed formal adaptation plans.

This discussion is important to a better understanding how adaptation responds to present and future climate and builds resilience in societies. A relevant issue in this discussion is the fact that research supports the contention that adaptation takes place as a response to multiple stimuli not just climate, reinforcing the importance of mainstreaming no-regrets adaptation (Berrang-Ford et al. 2011, Dovers 2009, Hallegate 2009, Mozumder et al. 2011, Preston et al. 2010). Tompkins et al. (2010) highlight the need to understand those triggers in order to introduce policy to direct effective adaptation. Mozumder et al. (2011) stress the importance of cognitive and behavioral changes, at the individual and institutional level, involving the general public and experts and decision makers in various sectors, in order to moving from risk assessments to pragmatic adaptation measures. Other authors focus on the limits to adaptation beyond current ecological, physical, economic or technical narrower standpoints (Adger et al. 2009). Their focus on ethics, knowledge, risk, and culture places the social construction of adaptation limits inside society rather than outside it. This approach is particularly useful placing adaptation to climate change within the process of development or within the context of sustainable development suggested by a number of studies as an important step to mainstream adaptation to climate change (Dovers 2009, Tompkins 2010). The approach is instrumental addressing the perception of risk as an important factor at the individual and society level in determining whether and how adaptation takes place (Adger et al 2009, Wolf et al. 2009).

Recent contributions extend this discussion calling attention to the interpretation of key concepts in adaptation like adaptive capacity (Engle 2011) and vulnerability (Hinkel 2010). Engel calls attention to the limited effort to evaluate adaptive capacity across vulnerability and resilience frameworks, and to improve understand adaptive capacity dynamics. For him, it is important to identify what builds adaptive capacity and what functions as limits and barriers to adaptation. Hinkel questions the use of vulnerability as a concept to identify mitigations targets of vulnerability, raising awareness about the importance of adaptation, to guide the allocation of adaptation funds, monitoring of adaptation policy, and conducting scientific research. He finds misleading speaking of measuring of vulnerability as it raises false expectations. These and other recent contributions on the literature (Adger et al. 2009, Preston et al. 2010, Tompkins et al. 2010, Wolf et al. 2010) move the discussion of adaptation to climate change to better understanding of those elements needed to operationalize this concept building responses to present and future climate impacts.

15.2.2. Adaptation Indicators

How to evaluate successful adaptation is under researched and requires significant work to go beyond the simple evaluation criteria that have been developed to date (Doria et al., 2009). Preston et al. (2009) suggest the institutional arrangements for the evaluation of adaptation processes, policies and measures are still in their developmental infancy. For them, evaluation and monitoring are often advocated within adaptation decision making frameworks, but methods for undertaking such work are rarely articulated and adaptation plans frequently fail to acknowledge the importance of core design principles for adaptation policies and measures such as efficacy, efficiency and equity. Reidsma et at. (2010) consider that in order to assess the effectiveness of adaptation strategies, frameworks should not start from the modeling perspective, but from the stakeholders perspective. They suggest three steps: (1) assess current vulnerability to climatic variability (including aspects that cannot be simulated with quantitative models), (2), assess climate risks (considering climate scenarios), and (3) develop adaptation strategies (based on integrated assessments and stakeholder involvement), either relevant at farming system level or at policy level.

Adger and Barnett (2009) argue that the metrics that may be used to determine the goals of adaptation, the measures of its success, and the trade-offs that may be involved can be understood only in terms of the social context in which adaptation takes places. Communities value things differently and these must be take into account if adaptation is to be effective, efficient, legitimate, and equitable (Barnett and Campbell, 2009). By the same token, Arnell (2010) highlights the importance of context in the analysis and evaluation of adaptation. The case studies and the assessment of potential adaptation measures in his review show that local circumstances significantly affects what adaptation options are considered feasible, what information is likely to be used, what assessment technics are adopted, and, crucially, how adaptation decisions are actually made. For him, this implies that it will be difficult to make generalized assessments of the potential contributions of adaptation to managing the risks posed by climate change and to construct generalized models of the adaptation process.

15.3. Approaches for Climate Change Adaptation Planning Being Used – Adaptation as a Dynamic Process

15.3.1. Incorporating Adaptation into Current Development Efforts

It is reported above that growing emphasis to consider adaptation to climate change a continuous learning process (not a single outcome) (Hinkel et al. 2009, Hofmann et al. 2010) likely to require regular revisiting of development policies, plans and projects as climate and socioeconomic in conditions change. Most strategies can be regarded as just the start of a policy process rather than its culmination (Hulme et al. 2009). International organizations emphasize the important relation between adaptation to climate change and development in that process (OECD 2009, UN HABITAT 2011, UNEP 2010, UNDP 2005, World Bank 2010). Unfortunately, not enough attention has been provided in the literature (peer-reviewed and gray) to the common elements between development and adaptation and how they can be combined in adaptation strategies, plans and actions.

Some literatures are concerned that a disproportionate focus on the impacts of climate change could obscure opportunities for connecting development pressures, poverty, social inequality and climate change, particularly for the reduction of social vulnerability (Hardee and Mutunga 2010, Lemos et al. 2007, Sietz et al. 2011). Thomas and Twyman (2005) highlight the fact that climate change does not occur independently of other social processes. They call attention to how the interface between climate change and development processes can enhance existing inequalities. Boyde and Juhola (2009) express also concern how the debate of climate change is dominated by impacts-led approaches that focus on climate risks rather than on human vulnerability. Knowledge on impacts and vulnerabilities does not necessarily lead to the most cost-effective and efficient adaptation policy decisions, partly due to the context specificity of adaptation which makes detailed planning at national level challenging (Hulme et al. 2009). Linking development and adaptation reduces the risk of unintended consequences of adaptation and facilitates its acceptance by decision-makers at the subnational and national level. Dovers (2009) highlights the importance of connecting climate adaptation more closely to existing policy and management understanding in communities, professions, and agencies, and to their existing agendas, knowledge, risks, and issues they already face.

It is worth noting that despite the fact that social change is a central element of development, there is perhaps not enough attention to livelihoods in development studies to connect adaptation, vulnerability, and development (Paavola 2008, Sanchez-Rodriguez 2009). Other authors consider a critical task integrating that knowledge and experiences into multidimensional and multi-scale approaches that can better guide the construction of adaptation responses to climate change and integrate them to development strategies (Erwin et al. 2008, Hodson and Marvin 2009). Moser and Satterthwaite (2008) propose considering the roles of not only different levels of government but also individuals, households, and civil society organizations. They suggest a framework of pro-poor asset adaptation for climate change as a conceptual and operational framework. Moser (2008) proposes a second-generation asset based policy as an effort to sustain current poverty reduction policies focusing on the provision housing, urban services and infrastructure, health, education and microfinance.

The bottom-up approaches can be particularly useful in efforts seeking to reduce social and urban vulnerability and addressing adaptation to climate change as a process. However, adaptation to climate change requires also complementary top-down strategies through urban institutions (Raschky 2008). Blanco and Alberti (2009) suggest adaptation planning for climate change will need to rely on an emerging interdisciplinary scientific field, which couples human and natural systems and their interactions. Norman (2009) highlights the importance of intergovernmental and multidisciplinary approaches integrating science and spatial planning as an efficient approach to address those conflicts between adaptation and mitigation. However, the ADAM project in Europe considers most barriers to actual adaptation appear to be related to policy co-ordination and implementation (Hulme et al. 2009). Particularly challenging is multi-level coordination within the public sector, between the public sector and other sectors in society, and multi-level governance in developed and developing countries.

The experience of UNFCCC’s NAPAs (National Adaptation Programmes of Action) illustrates some of those challenges in developing countries. NAPAs are required to engage local stakeholders in the NAPA process, and take into account existing coping strategies at the local level, building upon them to identify priority activities for which further delay could increase vulnerability or lead to higher adaptation costs at later stages. Stringer et al (2010) study of NAPAs in four African countries illustrates how they are attracting the support of a greater range of actors. But they find the linkages between development and adaptation should be made more explicit. For them, adaptations like livelihood diversification to reduce vulnerability have long been taking place at local and policy levels in each of their case study countries. Their results show people do not adapt only to climate change but they aggregate result of multiple drivers, needs and aspirations operating over myriad time and spatial scales. They also find the enthusiasm for broader participation in the rhetoric of international politics does not yet match the realities of its enactment on the ground. Agrawal (2008) study of NAPAs identified only 20% of projects described in the NAPA documents incorporate local institutions as the focus of adaptation projects; even fewer identify local institutions as agents or partners in facilitating adaptation.

The optimal design of such participative processes is underexplored in current social science research (Lovbrand et al. 2010) and needs to become a stronger focus (Lahasen et al. 2010).

15.3.2. Science Supporting Adaptation Planning and Implementation

Adaptation planning and practices have included developing infrastructure and assets, technological process optimization such as introducing efficiencies, institutional and behavioral changes to reduce risks or reinforce existing beneficial practices and learning and redesign after crises. Massey (2007) has developed a framework for this purpose (9), which categorises adaptation measures from three main dimensions (1) the level or stage of adaptation planning (i.e. whether a programme is in place or whether a country is contemplating a specific action), (2) the objective of the actions (i.e. why adaptation is taking place, e.g. building adaptation capacity, reducing risk and sensitivity) and (3) the issue or problem that adaptation aims to address (e.g. coastal zone management and disaster risk reduction).

Which adaptation actions make are most appropriate depends on context: the nature of the impact, the geographical scale and location, and the sector(s) affected. As a result, generalized conclusions about effects of particular options are often difficult to transfer to other locations. Very little research has been carried out on climate change adaptation actions to date (as distinguished from determinants of adaptation capacity (NRC, 2011).

Adaptation measures now being considered include both extensions of past practices and novel strategies for addressing uncertainty and change (Rojas Blanco, 2006). For example, newer efforts incorporate the necessity of anticipating a different climate and potential threshold events and conditions that will be outside the range of past experience. The goals of adaption efforts, however, remain the same as those in the past: to minimize harm and to take advantage of opportunities while sustaining human welfare and ecological integrity in the face of a changing environment.

Some attention to adaptation to climate change is already under way in sectors most likely to be affected, from agriculture to tourism, although information about such voluntary actions is limited and their effects will have to be evaluated over time. Most of the explicit adaptation planning is occurring now at national or local levels. For instance the UK has started to build capacity for adaptation, with evidence of growing awareness of the risks and appropriate responses, particularly in public sector organisations. This compares favourably with progress in other countries, with some examples of good practice in adaptation decision-making. However, from the evidence reviewed, capacity building is not yet systematically translating into tangible action on the ground to reduce the UK's vulnerability to climate change (Biesbroek et al, 2010).

Climate scenarios involving several timescales including longer term change are now being widely advocated for use (see Brekke et al, 2009; Wilby et al, 2009). To date climate risk assessment models have focused almost exclusively on climate model uncertainty and have been limited in addressing uncertainties in impacts and data. While interannual and decadal-scale information can be more resource intensive they provide critical information on the interaction between variability and change needed for successful implementation.

The availability of scenarios and tools have been shown to be a necessary but insufficient requirement for adaptation. Their provision has been accompanied by ongoing guidance and support to ensure widespread, tested, and appropriate uptake. The multiple pathways of dialogue between those providing scenarios and improved risk assessments together with communities using them has been shown to be necessary for meeting challenges especially regarding adaptation to emergent events (Gawith et al, 2009; Pulwarty et al, 2009). Part of the overall approach has been the development of regional scenarios related to medium- and long-term prospects, starting from existing global scenarios that address global environment change in general terms

Research shows that even in countries with high economic, institutional and technical capacity, it is not currently feasible to prioritize national-level adaptation options based on social cost-benefit analysis because of methodological difficulties and insufficient quantitative data. Multi-criteria analysis based on qualitative indicators can help prioritizing adaptation options but the analysis show gaps between priority and feasibility criteria. The 5 priority indicators (importance, urgency, no regret, co-benefits, and mitigation effect) agree well with criteria for prioritizing adaptation (Fussel, 2009; de Bruin et al 2009).

Highly rated adaptation options that are being implemented adds climate change to already existing activities for managing climate-related and other risks. These include:: integrated ecosystem and water management; integrated coastal zone management; r; risk-based allocation policy; risk management as basic strategy; and new institutional alliances (Fussel, 2009). Fairness in adaptation requires considering the distribution of adaptation benefits, costs, and residual climate impacts across regions, sectors, and population groups (Adger et al., 2006).

Market based arrangements have shown immense potential. Where available, households and individuals take advantage of the financial products offered by insurance companies and banks. Throughout the world, crop insurance has allowed national economies to develop the full potential of their agricultural sector by transferring weather-related risks away from the farmer. Informal arrangements have existed for a long time and still constitute the main source of risk management for the majority of the world's population. In the absence of (or with incomplete) market institutions and public support, individual households respond to risk by protecting themselves through informal and personal arrangements.

Index insurance is one mechanism that has been recently introduced to overcome obstacles to traditional agricultural and disaster insurance markets. If the rainfall amount is below the threshold, then the insurance pays out. Of particular note is the CCRIF, the world's first index-based parametric insurance mechanism. It is a new (2007) partnership among 16 Caribbean countries and the World Bank with support from several countries, and will be tested over the coming years. Increasingly the good practices of planning and implementing coastal and watershed management measures have been shown to apply equally to climate change adaptation (Tobey et al, 2010). These linked approaches highlight the need for greater emphases on nature-based protection strategies or buffers.

Integration of climate change into other policy areas aims at protecting citizens and nature, and making economic activities less vulnerable by appropriate and proportionate adaptation measures. Examples of such measures include: developing early warning information systems health/heat action plans, vaccination, health system planning, flood risk planning, drought and water scarcity risk management, water demand management, coastal and flood defences, economic diversification, natural hazard monitoring, reinforcing the built environment (e.g. roads, bridges, electric wires), land-use management, and greening of cities.

Linkages between adaptation and mitigation also have to be considered (Swart and Raes, 2007), particularly when mainstreaming and coordinating future actions.

Another emerging emphasis has been on low costs behavioural actions that provide benefits within a short time. One such example, the Humbo Project, assists communities affected by ecosystem degradation including loss of biodiversity, erosion, and flooding with an opportunity to benefit from carbon markets. The Farmer Managed natural regeneration has been involved in the regeneration of 2728 ha of degraded native forests in Humbo, Ethiopia (Brown et al, 2010). Benefits have included fodder and firewood in the first year and fruit and non-timber products within three years. Indigenous communities have been using such low cost actions for generations.

Several have tried to incorporate climate concerns such as into Environmental Impacts Statements.

Natural systems often have a lower adaptive capacity than human systems, especially when certain thresholds — which are poorly but increasingly understood — are exceeded. More diverse systems are likely to adapt to climate change better. But even for human systems (i.e. all economic sectors) there will be limits, influenced by social, technological, economic, environmental, political and institutional constraints. With increasing impacts of climate change, adaptation costs will increase and response options may decrease.

Ecosystem dynamics can often be altered by non-linear events such as fires, pest outbreaks, or storm events. Current climate change trends are resulting in a number of thresholds affecting ecosystems in marine, freshwater, and terrestrial systems in challenging ways. Analyses climate related ecological thresholds associated with increased seasonal warming, altered precipitation patterns, and acidification of the oceans suggest that ecosystem have exceeded natural thresholds producing for instance forest die off and that ecosystems are less able to cope with these changes with attendant loss of environmental and physical capital.

There is a lack of information across most countries on impacts and vulnerability assessment at regional and local levels, and on adaptation activities and measures planned or currently being implemented.

15.3.3. Stakeholder Participatory Approaches

To address vulnerabilities to climate change, stakeholder participation is essential so that local impacts can be addressed and coping mechanisms identified. Stakeholder participation is also an important tool for recognizing social and cultural barriers to adaptation. Lyytimaki (2011) examined the role of national-level media coverage in Finland in relation to communicating climate policies. Their work showed that the majority of news that mentioned climate change actually focused on additional issues of culture, economy, and lifestyle issues. Marshall et al. (2010) examined the reasons behind sub-optimal adoption of seasonal forecasts by livestock owners in Queensland Australia, and found that environmental awareness as well as social factors significantly influenced their willingness to adopt new grazing practices.

Community participation in adaptation planning appears to be more common in developing countries where community level planning is more common (Ford et al., 2011). Because climate change impacts occur locally, the scale of community engagement in the approaches used have been critical to the success or failure of adaptation programs. Patt and Schroter (2008) document barriers to implementing climate change adaptation strategies in Mozambique that resulted from differing perceptions of climate risk between farmers and policy makers, and the perceived potential for negative consequences of the proposed adaptation plans. Without broader stakeholder agreement at the local level, successful implementation was not possible. However, in case other studies of community-based participatory adaptation projects, local farmers such as those in Sri Lanka needed no additional incentives to participate in adaptation programs that they recognized as an opportunity to improve their harvests and income. The creation of community organizations can provide an avenue for local participation, and provides a mechanism that helps to sustain adaptation efforts. Community-based adaptation in Bangladesh has included participatory action plan development, an approach that combines consensus building and participatory rural appraisal. Using this approach, the needs, skills and assets of the communities were assessed by conducting household surveys and consultation meetings (Ensor and Berger, 2009).

Stakeholder participation takes many forms, including integration of downscaled climate change scenarios based on IPCC projections that have been used to integrate climate change impact scenarios in local decision-making processes (Scmit-Thome and Kaulbarsz, 2011; Gawith et al., 2009; Romanenko et al., 2007). One such example, in the Baltic Sea Region, included two projects referred to as the ‘Sea level change affecting the spatial development of the Baltic Sea Region’ (SEAREG), and ‘Developing policies and adaptation strategies to climate change in the Baltic Sea Region’(ASTRA) that focused on integration of potential climate change impacts in local decision-making. The communication process that resulted, produced a set of tools referred to as the ‘Decision Support Frame’ (DSF). The DSF addresses uncertainty in climate change model results, but also includes a vulnerability assessment and a discussion platform to help identify stakeholders, and to clarify climate change impacts and downscaled model uncertainty (Scmit-Thome and Kaulbarsz, 2011). Initially, it was difficult for the project to make meaningful contacts with stakeholders from the focus area, in part because of the long time-range of climate change scenarios. However, a winter storm struck the region in January 2005 that led to record sea-level and storm-surge heights. The SEAREG project team consisted of natural scientists (geologists and meteorologists) social scientists and planners. Challenges addressed in the project included the explanation of the creation, application and uncertainty of complex climate models, as well as the inclusion of social scientists into applicable communication and application frameworks for climate change adaptation strategies. The ASTRA project followed, and was tasked with identifying what stakeholders perceive as the biggest potential impacts from climate change. ASTRA work is the sustained result of SEAREG by continuing awareness-raising efforts and the development of adaptation strategies based on SEAREG scenarios (Scmit-Thome and Kaulbarsz, 2011).

15.3.4. Decision Support Tools and Processes

Global climate change imposes new stresses on natural and socio-economic systems. Because these systems are subject to complex human-nature interactions, decision makers face challenges on deciding among multiple possibilities which adaptive option(s) are most suitable for the systems concerned. To assist the decision making, numerous decision support tools have been deployed. Predominantly depending on computers or networks of computers or internet to establish a link among scientific information, analytical tools and mechanisms governing the behavior of human-nature coupled systems, a large number of the tools have been shown capable of presenting quantitative perspectives on climate change impact and feasible adaptive measures in a more direct and more robust means (Shim et al., 2002; Pyke et al., 2007). Meanwhile, synthesis reports, though largely qualitative and yet gaining gradual improvement, have been continuously deployed as a reliable tool for considering adaptive options to climate change (Mahoney et al., 2001).

15.3.4.1. Monitoring, Modeling, and Spatially Integrated Tools

Monitoring and modeling systems are the essential forms of computer-aided decision support tools for assessing climate change impact and adaptive options. Using data extraction and retrieval functions, monitoring systems provided an effective means for issuing early warnings to potential environmental hazards resulted from climate change (e.g. Alter, 2004). In addition, the complex, multi-scale, interdisciplinary nature of climate change impact on human-nature coupled systems has made the computer-based modeling approach a robust tool for understanding the evolving processes and the future conditions of the systems (Pyke et al., 2007). With the widespread application of cellular automata and the multi-agent techniques since the 1980s, modeling of the behavior of physical, socio-economic or coupled systems has gained a new dynamic pace, and the role of modeling approach in decision support tools has been enhanced to a much higher level (e.g., Epstein and Axtell, 1996; Wolfram, 2002)

Recent years have seen integration of monitoring systems and/or modeling systems with the techniques of geographical information system, remote sensing and global positioning system. As a result, much more powerful, process-visual and spatially implicit decision support systems have been developed. A typical example of this kind is the development of the Invasive Species Forecasting System (ISFS) (1999), which, through combining USGS science and NASA Earth observations with software engineering and high-performance computing expertise, is capable of providing regional-scale assessments of invasive species patterns and vulnerable habitats. In the Yellow River, the second largest drainage basin in China, the drying up of the channel near the mouth of the river in low-flow seasons forced governments to develop a basin-scale decision support system (Li and Li, 2009). This system provides not only an instant monitoring of the spatial-temporal variation of river channel flow across the whole drainage basin, but also choices for regulating the use of water resources when river channel flow reaches a critical state of drying up. Numerous such applications have also been made in the management of water quality, air quality, land use, crop production, and more (e.g., Jamiesona, and Fedra, 1996a,b; Huang et al., 1998; Gimblett, 2002; Qin, 2008).

15.3.4.2.Synthesis Reports

Extensive interdisciplinary syntheses of technical information on climate change impacts and adaptive options are able to yield convincing assessment reports (Pyke et al., 2007). This is reflected with the most well known assessment reports of the Intergovernmental Panel on Climate Change (IPCC, 2006), the first U.S. National Assessment of the Potential Consequences of Climate Variability and Change, and the U.S. Climate Change Science Program Synthesis and Assessment products. These reports are explicitly designed as decision support resources for policy makers (Mahoney et al., 2001).

To assist the syntheses, a variety of rule- or matrix-based methods has been applied for screening adaptation options. For example, the Adaptation Decision Matrix uses subjective scoring to compare the relative cost-effectiveness of alternative adaptation measures (Benioff and Warren, 1996), while the RamCo system uses a series of structured questions to a decision matrix to illustrate adaptive opportunities for coastal zone management. For generating visualizations and customized reports, greater emphasis on user interaction, sensitivity analysis, and capabilities has been placed in recent years (Sarewitz et al., 2000; Sarewitz, 2004). Furthermore, multi-criterion and multi-actor participatory approaches that allow users to consider alternative adaptation strategies and evaluate tradeoffs have also been deployed, typically in the development of the tool for environmental assessment and management (TEAM) (Julius and Scheraga, 2000).

15.3.4.3. Feedbacks and Adjustment Mechanism

Through creating information products (reports, maps, diagrams, figures, visualizations, etc.), decision support systems provide knowledge for better choices about how the human-nature coupled systems can achieve efficient, effective and equitable adaptation to global climate change. However, climate change occurs at long time-scales and is a dynamic process with a considerable degree of uncertainties (IPCC, 2006). In response, adaptation needs to take place in a wide range both temporally and spatially and adaptation measures do not always represent discrete and well-defined options. In order to make adaptation follow a right pathway, a chain of appraisal and adjustment and complex management and governess processes need to be implemented (Moser, 2009).

To appraise if adaptation measures taken by a human-nature coupled system are properly selected, it needs to assess the degree of feedbacks of the system to climate change for the measures taken. If the feedbacks are direct and strong, significant adjustments in adaptation measures need to be given. In contrast, indirect and weak feedbacks provide a justification for the measures selected (e.g. Berkhout et al., 2006). By doing so from time to time, desired adaptation measures for complex human-nature coupled systems under concern will be selected. However, recent studies have demonstrated that there are a large number of potential limits and barriers to adaptation, including lack of leadership, lack of funding for research and planning, political opposition, ignorance about climate change impacts and the need for adaptation, lack of intra- and interagency coordination, competing priorities, lack of adaptation mandates, legal constraints, mismatch of between the lack of, and the need for, scientific capacity, technical expertise and widespread, scale-relevant climate change and vulnerability information, etc. (Moser, 2009). To overcome these barriers so as to make the process of adaptation undergo more effectively, it needs to carry out the Earth System Governance Project that interfaces with other scientific research projects focused on global change, typically GLP, UGEC, GECAFS, GCP, GWSP, etc. (Adger et al., 2009a,b).

15.3.5. Differential Characteristics and Conditions between High-Income Countries/Communities and Middle- and Low-Income Countries/Communities

15.3.5.1. High-Income Countries

15.3.5.1.1. Current Status

As there are very few peer-reviewed literatures analyzing the current status of adaptation strategies and practices, the following assessment was performed mainly using reports and documents published by governments and other organizations including the national communications submitted to the UNFCCC. Most developed countries repeatedly carried out assessment of impacts of and vulnerability to climate change. Through the past assessments, it was recognized that impacts of climate change have been appearing in their countries and the effects would be more severe in the future. Based on such recognition, a systematic development of national adaptation policies have started since mid 2000s.

For example, 17 countries have adopted or are expect to adopt national adaptation strategies in the member countries the European Environment Agency (EEA, 2011). The US Government established an inter agency task force in 2009 to assess the present federal actions and to provide recommendations for additional actions to support a national adaptation strategy. The task force published a progress report in 2010 (The White House Council on Environmental Quality, 2010). This report identified the Federal Government's role to promote and implement best practices for adaptation, build public awareness and understanding of the importance of adaptation, and maintain dialogue and partnerships with stakeholders and decision makers. The importance to enhance services that enable informed decisions based on the best available science, and to work with the international community to improve knowledge sharing is also pointed out (The White House Council on Environmental Quality, 2010). The Ministry of the Environment, Japan, also made an approach to climate change adaptation under a concept of wise adaptation to climate change (Committee on Climate Change Impacts and Adaptation Research, 2008; Committee on Approaches to Climate Change Adaptation, 2010). “Wise adaptation” means effective, efficient and flexible approach to adaptation by incorporating adaptation policy into existing policy areas and related plans. furthermore, as today’s society faces various challenges including an ageing trend, adaptation to climate change is widened to a comprehensive approach is discussed to lead transformation of the local society to resolve these problems simultaneously. Australia also implement an approach to develop scientific basis and strategies for adaptation. In 2007 the National Climate Change Adaptation Framework was endorsed to guide practical activities (Council of Australian Governments, 2007). The efforts focuses on building the information needed to support sound decision-making in the governments, vulnerable sectors and communities to manage the risks of climate change impacts; for example, the National Climate Change Adaptation Research Facility was established in 2007.

These trends indicate that climate change adaptation has gained significant importance in formulating national policies, and its measures are embedded in existing policy structure, which may mean that mainstreaming adaptation policies has been realizing in some countries. These trends are driven by increased political leadership. A variety of policy tools were also developed in the approaches to adaptation. They include a national strategy, individual policies for vulnerable sectors, guideline and tools for policy development and assessment. New agencies or committees were established to plan, coordinate, and implement adaptation strategy and plans. In this way, climate change adaptation is integrated into the institutional structure, and has been occupying an important position in the policies, though the current situation is still at a preliminary stage in many countries.

An example of systematic approaches at national level is seen in UK’s National Communication (Department of Energy and Climate Change, 2009). The UK Climate Change Act 2008 was legislated in 2008, which set out a legally binding long-term framework to cut carbon emissions. It also creates a framework for building the UK's ability to adapt to climate change, by establishing that:

- A UK-wide Climate Change Risk Assessment must take place every five years
- A National Adaptation Programme must be put in place and reviewed every five years
- The Government has the power to require public authorities and statutory undertakers (companies like water and energy utilities) to report on how they have assessed the risks of climate change to their work, and what they are doing to address these risks
- The Government is required to publish a strategy outlining how this new power will be used, and to provide guidance on what reporting authorities need to do
- An Adaptation Sub-Committee of the independent Committee on Climate Change should be created in order to oversee progress on the Adapting to Climate Change Programme and advise on the Risk Assessment.

Introduction of five-year periodical review of national risks and progress of national adaptation programme can be a framework to make the adaptation plan effective and flexible. As the climate change and its projections must change with time, this is a way to incorporate the latest scientific knowledge to respond to the uncertainties in an institutionalized way.

15.3.5.1.2. Features and Gaps

Most strategies developed so far in developed countries aimed at mainstreaming adaptation policy. As impacts of climate change affects a wide areas of natural environment and socio-economic activities of human society, adaptation is inevitably related to wide areas as well; common areas of many countries are interested in are biodiversity and ecosystem, water, agriculture, coastal zones, human health and settlement and infrastructure. Some countries prioritize specific sectors depending on their threats and vulnerability. For example, the first priority of the Netherlands is put on water sector aiming at ensuring safety from water-related hazards and safe and sufficient water supply, as the effects of climate change are particularly felt in the risk of flooding or breaching of water-retaining structures (Ministry of Housing, Spatial Planning and the Environment, 2009). The Delta Committee appointed in

2007 has formulated a vision and policy advice on the long-term protection of the Dutch coast and its hinterland. In many cases, each country already has a set of policies for each sector. The first stage of mainstreaming is embedding adaptation aspects into the existing sectoral policies, and adjusting them.

Second common feature is putting focus on the local-scale approaches. Impacts of climate change vary with places, because they reflect the local vulnerability which in turn is determined by the geographic, historical, socio-economic characteristics. To respond to these impacts in the form of adaptive policies and measures, approaches of the local level are most important. There is a gap of this necessity and the current status of scientific understanding of climate change and its impacts. To support the local efforts, climate projections and impact assessment should be done in a local scale, which requires higher spatial resolution particularly in climate change projection. Although significant progress has been made in downscaling and more precise projection of climate change, uncertainties are still large particularly in the local scale projection. Therefore, most developed countries plan to accelerate developing climate models with higher resolution, in order that they go into a phase where concrete adaptation strategies and options are planned.

Adaptation strategies and options are planned and implemented under uncertainties which are involved in climate projections and impacts assessment as mentioned above. It is also uncertain how the society will change in the future, and what kinds of other stresses will occur. Therefore, development of adaptation strategy is an attempt to develop a strategy under uncertainties. Some countries use no-regret and/or win-win approaches as a concepts to make decisions under uncertainties. Another way is to introduce a flexible approach, so that flexible adjustment of adaptation strategy can be done when new situation or new scientific knowledge are presented. One of the concrete examples of this approach is regular review of scientific knowledge and adaptation strategy such as five-year review system brought in by the Clime Change Act in UK (Department of Energy and Climate Change, 2009). At the same time developing countries already developed a set of policies for risk management and those for other individual sectors. An incremental adaptation policy is also used, which add or strengthen a part of existing policies as climate change proceeds. This may be away to introduce a flexible approach. However, a basic question related to this is whether incremental adaptation is enough to avoid long-term impacts of climate change. This question is important particularly for the spatial planning and long-life structures. Some countries focus on this issue, stressing that long-term strategic perspective is important for such planning (Ministry of Housing, Spatial Planning and the Environment, 2009).

An evidence-based approach is also a common feature in the developed countries. In general, because of its comprehensive nature, climate policy should be based on a range of scientific bases. Countries need up-to-date knowledge and results of physical understanding of the climate change phenomena, advanced climate models, impact assessment, technological development for adaptation measures, socioeconomic tools to reduce uncertainties involved in the decision making and implementation of adaptation policies. Therefore, adaptation planning and implementation are closely connected with the agenda of science and technology development. In this regard, it is often planned to build a clearing house function at a national level to store, distribute and analyze the scientific information. Through these activities, society can share the information to raise awareness of the public about climate change and adaptation to it. These capacities ranging from scientific research and technological development to the public awareness are important components of adaptive capacities of the society. Therefore, promoting these activities means strengthening the adaptive capacity of the society.

Biesbroek (2010) reviewed the national adaptation strategies (NASs) of the European countries to deliver an observation of the relationship of scientific knowledge and adaptation governance. It is pointed out that the NASs show great resemblance in terms of topics, methods and approaches addressed, which is partly caused by our current limited scientific and political understanding of adaptation practice. Due to the uncertainty of climate change combined with the long-term time frame, little guidance for short-term action is provide to policy makers. The strategies therefore remain abstract rather than particular solutions. Based on such observation, they delivered the following knowledge gaps, which are mostly related to the adaptation governance:

- Carefully design a flexible mechanism for science-policy interactions.
- Connect research to local, regional and national policy needs.
- Analyze the role of institutions in climate change adaptation.
- Exploit different options to share knowledge internationally.

- Develop systematic ways to analyze, manage and communicate relevant scientific uncertainties
- Analyze options to address mechanisms and responsibilities involved in effective multi-level governance.
- Develop frameworks for evaluating adaptation policies, with a supporting toolbox of methods and metrics.
- Analyze the applicability of different types of policy instruments for adaptation policy.
- Perform comparative analyses of sectoral and cross-sectoral adaptation in vulnerable regional hotspots.
- Analyze national adaptation in the context of European and global developments.

One of further gaps exists in the economic assessment of adaptation. It is rational to compare of costs of impacts with and without adaptation, when decision-makers plan adaptation. However, the current knowledge about adaptation cost is limited: particularly this is the case for local level. Therefore, development of tools to evaluate the adaptation costs is very important. This point can be project into a larger framework of the economics of climate change countermeasures. Comparison of the cost of mitigation and adaptation, and cost of no-action is needed when a overall climate change policy is planned. Therefore, the development of the economic tools for adaptation costs will contribute to the comprehensive assessment of climate policies.

15.3.5.2. Middle- and Low-Income Countries

Adaptation to climate change is more urgent for developing counties, as they are expected to receive severe impacts in many sectors. However, in general, developing countries have limitations in capacity making adaptation difficult. The IPCC Fourth Assessment report (Adger et al., 2007) analyzed that adaptation to climate change is already taking place, but on a limited basis for both developed and developing countries. Though some progress has been made in developing countries as well as developed countries, nationally and internationally, this analysis is still effective. Adger et al. (2007) also pointed out that adaptation measures are seldom undertaken in response to climate change alone. Many actions that facilitate adaptation to climate change are undertaken to deal with current extreme events. Often, planned adaptation initiatives are also not undertaken as stand-alone measures, but embedded within broader sectoral initiatives such as water resource planning, coastal protection and disaster management planning. Therefore, the adaptation approaches for developing countries have links with efforts aimed at poverty alleviation, food security, water availability, land management and biological diversity and ecosystem management.

National Adaptation Programmes for Actions (NAPA) is a major driving force for planning adaptation in developing countries. As many countries submitted their NAPAs, there are lessons and constraints to formulate them. Balgis and Downing (2007) analyses these focusing on developing countries in eastern and southern Africa. NAPA process played an important role in creating a wide awareness and a sense of ownership among the different stakeholders at different levels, from policy makers to the general public at the village level. This was largely attributed to the emphasis on participatory processes, bottom-up approach and capacity building and awareness raising. At the same time, they also pointed out that the NAPA process has weaknesses including lack of free flow of information, communications problems within and between different levels of government, lack of local technical capacity to participate effectively in the NAPA process and insufficient financial resources.

Analysis on the barriers to adaptation planning and implementation is also made in US-AID Asia (2010), which assessed nineteen countries in the Asia and Pacific region. They observed that countries in the region have made limited progress in carrying out adaptation planning and virtually no progress in implementing adaptations. In part, this reflects the nascent nature of adaptation planning and an initial focus on the preparation of NAPA for the least developed countries. It also found two categories of barriers for adaptation planning and implementation: one is barriers related to the process of adaptation, and the other barriers related to governance issues.

15.3.5.2.1. Barriers of adaptation process

[to be developed]

- Poor understanding of adaptation concepts
- Weak capacity

  - Access to climate information and climate scenarios relevant to the scale of vulnerability assessments, compounded by weak local capacity to conduct climate research. Data sharing within and between countries emerged as a constraint in a number of consultations.
  - Knowledge of adaptation including: adaptation options, their effectiveness, costs, and potential benefits; lessons learned from adaptation projects in the region which have addressed similar climate impacts; and research on new adaptations (e.g., climate-resilient crops, best practices).
  - Understanding of donor project cycles, and application procedures for accessing financing for adaptation projects; guidance and capacity building to design, implement, and monitor adaptation projects.
- Lack of coordination on adaptation planning
- Limitations of the assessment toolkit

15.3.5.2.2. Barriers of Governance
[to be developed]

- Weak governance structures
- Poor transboundary coordination

15.5. Capabilities for Adaptation Planning and Implementation

15.5.1. Institutional Arrangements: Public- and Private-Sector Stakeholders and Priorities

The peer-reviewed literature recognizes institutions are central to understanding and responding to global environmental challenges. Though adaptation was first considered a matter of relevance only to the environmental sector, it is now considered a challenge that will require the participation and cooperation of a multitude of sectors to avoid potential conflicts (Juhola and Westerhoff 2011). Institutions embody rules that encapsulate values, norms and views of the world, including rules that define roles and the 'game' of politics (Lahasen et al. 2010). Anguelovski and Carmin (2011) study on institutions on urban climate governance highlights the ways in which public, private, and civil society actors and institutions articulate climate goals, exercise influence and authority, and manage urban climate planning and implementation processes. They document urban areas tend to formalize and institutionalize their work through the establishment of dedicated climate units, either within a relevant department or as separate and cross- cutting office. However, few local governments have had the resources and know-how to institutionalize adaptation to climate change.

Juhola and Westerhoff (2011) study of the challenges of adaptation across multiple scales in Italy and Finland documents that governance of adaptation is developing through various different processes, including vertical and horizontal scales of decision-making. Adaptation at the national level in Finland has been undertaken almost exclusively by state actors. However, the lack of vertical interaction below the national level has, to some extent, slowed down adaptation actions at lower scales of governance. Similarly, the lack of formal adaptation institutions in Italy has hindered action at the national level but has still allowed for sub-national initiatives based on networks that extend across national boundaries. The local nature of climate-related risk management and planning activities means that adaptation will also require coordination at regional and national levels in order to ensure the ability of local actors to adapt is not constrained by national or regional processes (Urwin and Jordan 2008). Although the complex interaction between the supra-national, national and regional decision-making levels has become a particularly European phenomenon (Pahl-Wostl 2009), they create useful insight to the challenge of multi-scale adaptation governance. The experience of Italy and Finland illustrate how efforts that serve to engage regional and local actors in adaptation, do not receive the same attention when unsupported by formal institutional arrangements. As such, they are not a perfect substitute for hierarchical governance and the incentives that may flow from top-down arrangements (Juhola and Westerhoff 2011). They find that the absence of steering and designated resources for the design and implementation of adaptation measures at sub-national scales allows only those municipalities that have the capacity to move ahead on adaptation. The coordination of efforts across administrative and geographic scales remains an important factor and may speak to the continuing role of national governments. They conclude that although the experience in those two countries represent a first wave of attempts to plan for ongoing and future changes in climate, and mark a growing interest in such activities at various scales across Europe, adaptation has not yet led either to a reframing of problems or to a structural transformation of governance structures that would enable a system to move towards more successful governance outcomes.

The role of formal institutions to guide and balance the adaptation process is also a matter of concern in the literature. Adger et al. (2005) highlight the key role of underlying distributions of power within the institutions that manage resources and often create vulnerabilities to climate change. Moser and Satterthwaite (2008) assert that addressing the social development dimensions of climate change adaptation in urban areas requires considering the roles of not only different levels of government but also individuals, households, and civil society organizations. One common element of new urban governance that affects the path of local adaptation throughout regions is the effort from national, state, and provincial governments to transfer management responsibilities for public services to local governments without transferring adequate financial resources to take over those responsibilities (Seto et al. 2010). These new arrangements have fundamentally changed the process of urbanization by reducing the effectiveness of local planning aggravating the obstacles for adaptation to climate change.

Conditions in developing countries are particularly challenging. Koch et al. (2007) stress the gap in understanding and evaluating how institutional networks operate. Their research results in South Africa show that few institutions fully understand the implications of adaptation and their roles and responsibilities have not yet been properly defined. Constraints relating to capacity, lack of awareness and poor information flow need to be addressed. They also demonstrate how adaptation challenges the hierarchical manner in which government works and a more collaborative approach to climate change adaptation is needed. For them, adaptation needs to be mainstreamed and institutional networks need to be strengthened in order for adaptation mechanisms to be effectively implemented.

A final important role of institutions in the adaptation process to climate change is their to carry out the monitoring and evaluation of that process (Berrang-Ford 2011, Engel 2011, Preston et al. 2010).

15.5.2. Knowledge Development and Sharing

Adaptation to climate change is considered as a complicated dynamic process. Scientists and managers across agencies and management systems would benefit from greater sharing of data, models, and experiences (West et al. 2009). However the number of documents published about this issue is still limited. The available documents deal mainly with general principles rather than practical applications. The current section outlines the main relevant issues of knowledge development and sharing in adaptation to climate change.

15.5.2.1. Science and Technologies for Observation, Monitoring, and Prediction

Development and diffusion of new technologies and management practices will be critical to many adaptation efforts. The role of technology is not so much to make adaptation possible—a wide range of adaptations are possible with current technologies and management practices—but to expand the range of adaptation possibilities by expanding opportunities or reducing costs (Smith et al., 2009). Unfortunately, the status quo generally requires no new capital costs and may be more profitable in the short term than developing more climate resilient technologies (Yang et al., 2007). Several researches indicated self adaptation to climate change of many animals and plants (Mastrandrea et al., 2010, Tingley et al., 2009). The integration into a common platform of an economic optimization model and a hydrology model WEAP (Water Evaluation And Planning system) is used to analyze the spatial and temporal effects of different water and agricultural policies under different climate scenarios. It permits the prediction of different climate and policy outcomes across farm types (water stress impacts and adaptation) at basin's level (aquifer recovery), and along the policies' implementation horizon (short and long run) (Varela-Ortega et al., 2010).

15.5.2.2. Early Warning Information Systems

Monitoring and early warning systems (EWS) play important role in helping to adjust adaptation implementation, especially at local scale. However the current science and technology do not resolve the uncertainties in modeling and in the response of ecosystems to climate change and to management interventions. Precise information on some concerning questions of adaptation may be impossible (or prohibitively expensive or time consuming) to acquire. If this is the case and if the information is needed for a specific adaptation action, then it may be that the action is not practical or is at a high risk for failure with implementation (West et al. 2009). Climate information at the scale decisions are made is too uncertain to support adaptation, based on this, they often fall back to a "wait and see" approach (Smith et al, 2009).

The EWSs are often utilized for disaster management by traditional media (radio, TV). However, to ensure the collection and dissemination of information and delivery of early warnings, the EWSs need new Information and Communication Technologies (ICT) for analysing and processing information and providing automated alerts to vulnerable populations (Karanasios, 2011). Local coping strategies are an important element of planning for adaptation and ICTs can be used in a number of productive ways, particularly by leveraging existing ICT successes in developing countries such as telecentres and mobile phones, as well as introducing emergent ICTs in conjunction with existing sectoral policies, planning and budgeting (UNFCCC, 2007). EWSs are also set up by FAO, USAID providing realtime updates on global weather hazards, food security and remote sensing data for a number of developing countries which are available at their websites.

15.5.2.3. Science and Technologies for VA and Adaptation Planning and Implementation

Effective collaboration and linkages among managers and resource scientists offer a variety of opportunities for adaptation implementation. First, resource scientists have monitoring data and research results that are often underused. Second, monitoring efforts could be conducted with specific objectives in mind to increase usefulness for managers. Finally, scientists can support management by targeting their research. All of these are opportunities for interactions among scientists and managers that provide information relevant to major management challenges (Fussel, 2007).

Adaptation action, such as changes in crops and crop varieties, improved water management and irrigation systems, and changes in planting schedules and tillage practices can limit negative effects and taking advantage of beneficial changes in climate (Yang et al., 2007). The adaptation part of which is based on a science-policy collaborative exchange that has operated in various forms for about a decade and has successfully co-produced scientific assessments (Corfee-Morlot et al., 2011). In term of CCA, geoengineering is not currently part of the policy discourse, but interest in it may grow in the medium term as climate change becomes a more mainstream concern, especially to prevent dangerous climate change. It would be preferable to begin exploring geoengineering options today, ideally with international partners, to maximize the chances for an informed, measured and inclusive decision if the time comes (Virgoe, 2009).

Visualization of sea level rise and climate change damage in Delta, British Columbia, and subsequent illustrations of options for adaptation, has led to increased awareness of long term risks and response challenges among practitioners in this community, as well as local government and the public (Shaw et al. 2009). ICTs can help strengthen the physical preparedness of livelihood systems for climate change related events. These can contribute to design of defences and determination of their optimal location, make the livelihood system more robust. In remote areas of the Philippines, participatory 3-dimensional modelling, a communitybased tool which merges GIS generated data and local peoples' knowledge to produce relief models – is being used to establish visual relations between resources, tenure, their use and jurisdiction, thus contributing to the ability of the community to deal with climate change hazards and trends (IAPAD, 2010). GIS was utilized to form modelling processes of climate change adaptation which are repeatable, justifiable and have involved critical input from regional stakeholders supports the development of convincing arguments for better protection of key spaces in the landscape (Bardsley and Sweeney, 2010). By sharing observations and reflections through ICT tools, users foster new ways of assimilating or translating information, which can be shared through wider networks, and then influence action, enabling new experiences/practices to take place. This generation of new and broader learning cycles will in turn strengthen systemic resilience (Ospina and Heeks, 2010). Karanasios (2011) outlines the range of new and emergent ICTs (e.g. wireless broadband and wireless sensor networks, geographic information systems and Webbased tools) being applied to climate change issues and investigates their use in developing countries. It also gives people who work on climate change an understanding of the technologies that will increasingly be used in their field, not just the identity of the technologies but their potential benefits and application areas.

15.5.2.4. Science and Technologies for Individual Sectors

The adoption of advanced technologies greatly facilitated agricultural development. New varieties and new fertilizers, pesticides, and agricultural techniques have been actively adopted (Yang et al., 2007). In the sector of logistics, on a global scale, most ports are in the beginning stages of considering adaptation to climate change. There is an opportunity for the scientific community to engage with this sector to create the knowledge base needed to understand and improve the resilience and efficiency in the coming century (Becker et al., 2011). The European Spatial Planning Adapting to Climate Events Project (ESPACE) assert that while adaptation presents a variety of new issues for urban planning, it can be an opportunity for good planning to thrive. It is further argued that good planning can positively contribute to adaptive efforts if it works within its means and correctly uses the tools available to it such as adaptation through infrastructure and design (porous surfacing, green roofs, etc) (ESPACE, 2010). The linkage between disaster risk reduction (DRR) and adaptation can help communities to build resilience and live with change. DRR goals, strategies and measures have to be revised, and in part modified, to meet the goals of CCA more effectively. DRR and resilience-building are not only important options to support adaptation to hazards modified and influenced by climate change, but also to prevent societies from being set back in their efforts to develop (Birkmann and Von Teichman, 2010).

15.5.2.5. Education and Training

The farmers in the Northeast China are the main actors of climate change adaptation. They learn through experience and self-judgment, but also, and importantly, from neighbors' practices and scientific demonstrations. Scientists played a supporting role by discerning long term climate trends, predicting future scenarios and recommending development blueprints and technologies (Yang et al., 2007).

Developing general guidance on the likely climate change impacts, vulnerability, and adaptation helps promoting of flexible approaches to adaptation planning and implementation. It means investing in ''climate science translators'' who could work in partnership with managers and planners to translate the projections of climate models, understand likely impacts, and help design adaptation responses. These individuals would also function as outreach staff who could explain to the public what climate change might mean to long-standing recreational opportunities or management goals (West et al. 2009). Tschakert and Dietrich (2010) emphasizes that the facilitating anticipatory learning as an iterative socioinstitutional process is a key element for adaptation and resilience in the context of climate change.

In the built environment sector, there were some important issues raised that relate to the form and content of education about and for climate change adaptation in accredited courses and other professional development initiatives. Lyth et al., 2007 recommends that education about and for climate change adaptation in accredited courses be addressed in an integrated way with education about and for climate change mitigation in Australia.

15.5.2.6. Local and Traditional Knowledge

Local and traditional knowledge is formed by longtime recognition and adjustment to adverse events. It is normally utilized for disaster risk reduction. However it can sometimes be effective to CCA – a long term process. The value of local knowledge was given primacy, be it to complement scientific climate data, to provide insights about and for climate change adaptation or as a source of community-based environmental monitoring (Newsham and Thomas, 2011).

The adaptation of farmers in eastern Oklahoma in 1930s has shown that rural populations may have an impressive capacity to adapt to a range of climatic and non-climatic risks. However, this capacity does have limits that can be exceeded, especially when climate-related stresses are superimposed on other forces that give rise to vulnerability. Whether that threshold is exceeded is strongly influenced by the role that higher-level actors such as governments choose to play in providing adaptation assistance and capacity building (McLeman et al., 2008). Agro-ecological local knowledge in North Central Namibia has provided farmers with resilience in the face of a highly variable, and hence uncertain, climate for perhaps hundreds of years. It constitutes and enhances adaptive capacity to climate change impacts (Newsham and Thomas, 2011). Most of the farmers in the Mekong river delta had applied them personally during major flood events in the past such as lifting the ground floor level, moving important items to upper floors, sending the children to day care centers, and selling livestock in case of very large floods. Elderly persons mentioned that their coping strategy would be to simply stay at home and wait for the flood to retreat. The strategy is effective for relatively slow processes such sea level rise, slow rising flood. However it shows severe constraints in major floods, especially in term of children fatality (Birkmann, 2011). The integration of indigenous peoples' knowledge and observations of environmental processes in developing collective responses to climate change is outlined in Africa, Australia, small islands in the Asia Pacific, and Artic in a special volume of "Climatic Change" (Green, Raygorodetsky, 2010). They concluded that a knowledge co-creation that brings together local indigenous and conventional scientific paradigms helps to get the purpose of developing climate change mitigation, adaptation strategies and actions.

15.5.3. Technology Development, Transfer, and Diffusion

As technologies development and their sharing are already widely discussed in 15.5.2, this section describes some supplementary aspects for technology development, transfer and diffusion. Technology is an essential part for adaptation to climate change, and the capability to access to necessary technologies is an important component of adaptive capacity of the society. In some setting, new technologies need to be developed to make adaptation more effective and efficient, such as local climate prediction models, new varieties tolerant of high temperature and low water availability, and efficient water treatment. The development and innovation of technologies are driven by necessities to meet the new conditions caused by climate change. At the same time, as the impacts of climate change vary with locations and local settings, there are many cases where traditional and existing technologies are more relevant for adaptation.

One of the important technologies for adaptation is those related to information collection and diffusion, including technologies to observe and project climate changes, to communicate with people during extreme events and emergencies, and to disseminate information including emergency alerts. Climate projections and downscaling of their results are a basis for adaptation planning and implementation providing profiles of possible impacts and vulnerability of the target places. Though advanced climate models have been developed in recent decades, its spatial resolution is not yet sufficient for local adaptation, and their results inevitably include uncertainties of the extent and timing of climate change. Many developing countries still lack capacities to access to the climate models and to apply their results to their countries or localities. Though large practices have been enhanced to transfer the technologies of this kind to developing countries, there is a gap in this area.

In the disaster risk management, it is pointed out that technology choices can contribute to both risk reduction and risk enhancement (Jonkman *et al.*, 2010). Technologies are often used to strengthen physical infrastructure, such as bridges, buildings, or river channels, so that they can withstand higher levels of external forces of hazards. At the same time, it has been suggested that relatively centralized high-technology systems are tenacious, which offer efficiencies under normal conditions but subject to cascading effects in the event of emergencies. In some circumstances, technologies to reduce short term risk and vulnerability can increase future vulnerability to larger extreme events.

Physical facilities are constructed for climate change adaptation, which have long lifetimes of several decades or longer. The gradual changes in social conditions, such as land use, transport, water and sanitation infrastructure, and housing stock, also takes many decades. If the planning is maladaptive rather than adaptive, the consequences can be serious. This induces another aspect of technology development and transfer that might promote more flexible solutions, for example multiple, smaller dams that can resolve local as well as more distant needs. This has been expressed in part of Thailand's Sufficiency Economy approach, where local development is judged against its contribution to local, national and international wealth generation (UNDP, 2007).

15.5.4. Learning and Capacity Building

15.5.4.1. Perception of Climate Change and Adaptation

There is a significant rise in awareness about climate change (reference?). But, there have been very few changes in forecasts, plans, design criteria, investment decisions, budgets or staffing patterns in response to climate risks ((Berrang-Ford et al. 2011; Repetto, 2008). Because there is uncertainty about the future climate, new decision-making tools need to be developed to cope with the impacts (Frommer, 2009). Infrastructure projects could be better adapted in the future, and climate change impacts would remain lower and more manageable if uncertainty is taken into account in long-term planning decisions (Hallegate 2009). Adaptive management is thought to be an effective strategy because it emphasizes managing based on observation and continuous learning, and it provides a means for addressing varying degrees of uncertainty in current and future climate change impacts (West et al., 2009). Even if mitigation plans are implemented properly, warming of the planet is already underway, and there is additional inertia from emissions already released. Because of there is a growing awareness that mitigation efforts will not be widespread enough to stave off changing climatic conditions, there is a strong consensus that adaptation efforts are needed (Nath and Behera, 2010). Adaptation in addition to mitigation is growing in mainstream policy efforts in response to climate change (Preston et al. 2009). However, there is a significant gap between adaptation recommendations and planning, and actual implementation efforts (Berrang-Ford et al., 2011; Repetto, 2008).

Building capacity to respond to change, whether expected or unexpected, builds resilience in communities to cope in the face of uncertainties in climate change projections. Because there are difficulties in providing information about the variability of the specific changes that are likely to occur at the local scale and the timing of extreme events, local communities require the tools to cope with a variety of challenges. However, in both developed and developing countries, climate change adaptation is not viewed as a high priority because of more immediate needs that are based on short-term economic welfare (Coles and Scott, 2009). In developing countries there are also additional challenges in obtaining basic human requirements, such as potable water, and for programs to increase education and to address human health. Yet people in developing countries are particularly vulnerable to climate change and more directly impacted by climatic hazards, in part because their economies tend to be more natural resource dependent (Nath and Behera, 2010; Reid et al, 2010; Handmer, 2009). Moreover, many of the least developed countries are located in geographically vulnerable regions, such as cyclone and sea-level rise impacted small island states, and drought prone regions including those in northern Africa. There are poor and low income communities within countries and other marginalized populations that are also more vulnerable because they tend to settle in more hazardous physical environments and regions deemed less desirable by more powerful sectors of society (McBean and Ajibade, 2009). Greater exposure to vulnerability is often accompanied by a deficit of adaptive capacity, because poorer less educated populations tend to have less access to information about climate risks, and fewer economic and technical resources available (Sissoko et al., 2011; Reid et al., 2010).

Adaptation plans in developing countries tend to be stakeholder driven, and implemented at the local level, where there is ample opportunity to include capacity building as part of the adaptation plan (Berrang-Ford et al. 2011; Ford et al. 2011). Some recent climate community-scale adaptation plans as well as local adaptation methods have increased adaptive capacity by reintroducing indigenous varieties of crops that are selected by local farmers to be more resilient to changing conditions, and by initiating subsistence farming of a broad variety of vegetables in regions where local economies are dependent on the success of a few to sometimes one cereal crop (Deressa et al. 2009; Ensor and Berger, 2009).

15.5.4.2. Balancing Mitigation and Adaptation Responses to Climate Change

Three major themes where adaptation and mitigation issues are expected to coincide are agriculture, built environment and carbon sequestration through revegetation. In north central Victoria, Australia, Jones et al., (2007) describe adaptation and mitigation efforts that are jointly managed by a greenhouse consortium and a catchment management authority. They conclude that when managing climate change risks, there are many instances where adaptation and mitigation can be integrated at the operational level. However, significant gaps in understanding the benefits of adaptation and mitigation between local and global scales remain. Some of these may be addressed by matching demands for mitigation (for activities and locations where adaptive capacity will be exceeded) with the ability to supply that demand through localized mitigative capacity by means of globally integrated mechanisms.

Strengthening the links between adaptation and mitigation through the reduction of emission from deforestation and forest degradation can provide benefits for both mitigation and adaptation, as they contribute to conserving and restoring ecosystem services. However, to avoid the potential negative impacts on resilience of indigenous populations, and local development and biodiversity, policymakers should try to foster synergies between mitigation and adaptation, by developing guidelines or standards for mitigation projects (Van Aalst et al., 2008).

The Klima-Werkstatt project (Germany) has invested in climate change mitigation and adaptation by communicating the added value of climate gentle products and services. It provides demand-oriented knowledge transfer, develops opportunities for stakeholder participation. A long-term goal is to develop a stakeholder network that is a self-supporting structure (Frommer, 2009).

15.5.4.3. Opportunities to Improve the Communication between Science and Practice in the Creation of Decisionmaking Supporting Information and Tools

Decision analysis tools are more valuable as a means of informing decision makers than as a formulaic means of prescribing decisions. Whether it is multicriteria analysis, benefit-cost analysis, or any number of other tools, part of the analytical process will always be difficult and challenging primarily because of underlying uncertainties and differing local conditions (Smith et al., 2009). Decision support systems for climate adaptation have been set up for various sectors such as water (Stakhiv and Stewart, 2010), ecosystem (Munang et al, 2010), and tourism (Scott and Lemieux, 2010). Several efforts at defining frameworks to guide decision makers dealing explicitly with climate adaptation are a valuable start, but more practice-oriented evaluation of such tools is merited (Smith et al., 2009). Networks are useful tool to develop individual adaptation options at local and regional scales, e.g. the KLARA-Net builds on four fields of action that are as follows: ‘spatial planning + building industry + water resources management’, ‘agriculture, viniculture + forestry’, ‘tourism’ and ‘health’. Each of these fields of action is operationalized by a working group (Frommer, 2009).

15.5.4.4. Developing Localized Information for Adaptation Planning and Implementation

Community-based climate change adaptation plans have included strategies for communicating information on climate change and raising awareness using novel and creative methods, including art and essay writing contests, public information posters, and signs on rickshaws. Community engagement offers additional opportunities to discuss climate change impacts in plans by including baseline surveys of community members, public discussions at existing village level social platforms, demonstration projects and festivals (Mekong River Commission, 2010; Ensor and Berger, 2009).

15.5.5. Preparing for Surprises: Adaptive Supporting Systems/Networks and Buffers

The above cases suggest that under transitional climate change, due to climate variability and extreme events appear thresholds may be breached more frequently. In the face of mounting evidence of the biological and ecological consequences of climate change, and of the possibility that changes to ecosystems may in fact be rapid, large, and sometimes irreversible (i.e. there may be thresholds that, once crossed, will exacerbate coping challenges to humans), policy makers and resource managers are confronted with the need to develop ways to proceed with decision-making in the realms of both mitigation and adaptation, despite the many uncertainties associated with thresholds (Ojima et al 2009).

A protected area is defined as: “A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (Dudley, 2008). Forest protected areas help conserve ecosystems that provide habitat, shelter, food, raw materials, genetic materials, a barrier against disasters, a stable source of resources and many other ecosystem goods and services – and thus can have an important role in helping species, people and countries adapt to climate change. Such systems continue to serve as a natural storehouse of goods and services into the future. The REDD is a major effort to produce co-benefits of reducing GHGs and ensuring livelihoods (Ezzine-de-Blas et al, 2011). Protected areas have been recognized for several decades as an essential tool for conserving biodiversity. The impacts of climate change now give them a renewed role as adaptation tools for a changing climate. Their importance in this respect is threefold:

1) In supporting species to adapt to changing climate patterns and sudden climate events by providing refuges and migration corridors
2) In protecting people from sudden climatic events and reducing vulnerability to floods, droughts and other weather-induced problems
3) Indirectly, in supporting economies to adapt to climate change by reducing the costs of climate-related negative impacts.

In helping to protect natural habitat, protected areas indirectly help to protect the national economy. In addition, protected areas provide a direct means of enhancing revenue, notably through tourism, but also through the valuable products they harbour and the services they provide. For example, Guatemala’s Mayan Biosphere Reserve provides employment for over 7 000 people and generates an annual income of approximately US$47 million (PCLG, 2002). In Madagascar, a study of 41 reserves found that the economic rate of return of the protected area system was 54 percent, essentially from watershed protection and to a lesser extent from ecotourism (Naughton-Treves, Buck Holland and Brandon, 2005). Thus, protected areas provide a safety net which can be valuable in times of stress, such as extreme climate events.

15.6. Conclusions

Three broad categories of low-regret options may be drawn from the empirical information on planning and implementation to date:

1) Measures that reduce current climate vulnerability. These provide immediate benefits by protecting against current weather damage, while increasing resilience to future climate change. For example, setting back flood defenses in sparsely populated estuaries can help to reduce current flood risk while providing room for estuaries to adapt to increased sea level.
2) Measures with co-benefits or measures to manage non-climate risks. Some measures, as well as being effective forms of adaptation, can also yield benefits with respect to other objectives. For example, water conservation can reduce the amount of energy used in water treatment and domestic water heating.
3) A portfolio of options that broaden the coping range/choice and flexibility to respond to emergent events and critical transitions. For example, where the capacity of a water storage system is increased in anticipation of drier conditions.

Successful adaptation efforts bridge the disaster risk reduction to adaptation to long-term trends. At present, decision support and risk management efforts to support adaptation are hampered by a lack of solid information about the benefits, costs, and effectiveness of various adaptation options, and by uncertainty about future climate impacts at scales necessary for decision-making. Although adaptation has to be implemented at the local and regional scale, some climate change impacts such as sea-level rise will exceed the adaptive capacity available at those scales. Scales of impacts and resource management are often mismatched. Many U.S. institutions at virtually every scale lack the mandate, the resources, and/or the professional capacity to select and implement climate change adaptations that will reduce risk sufficiently, even when these adaptation actions are urgently needed (Poyar and Beller-Simms, 2009). New institutions and bridging organizations will be required to facilitate the communication and integrated planning efforts needed to address complex problems. Successful adaptation planning and implementation practices provide for exploration of innovative partnerships, techniques, and technologies that could support adaptation action, communication, and trust building between the United States and other countries:

- Focusing on climate-resilient systems in all public and private sectors, including land-use planning, energy, water and wastewater systems, transportation systems and infrastructure, stormwater systems, utilities, solid waste management systems, public facilities, coastal hazard planning, public safety services, and health and social services
- Planning a flexible framework for setting priorities and coordinating implementation, including regional partnerships, and ensuring strong public participation and nongovernmental and private sector
- Building adaptation and mitigation objectives into the operations, budgets, and planning processes and programs of cities and other local governments
- Including a financial assessment of potential adaptation-related infrastructure needs and operating costs and evaluation of the potential impact of adaptation investments on revenues
- Designing adaptations to reduce vulnerability to climate change impacts as well as to promote sustainability at a regional level
- Establishing ongoing monitoring and assessment processes as well as goals and principles for future decision-making with respect to adapting to the impacts of climate change
- Including public education and engagement.

Knowledge gaps include the development of tested methodologies and measurement of progress in reducing vulnerability and enhancing community capacity – e.g., risk management cost-effectiveness methodologies and analyses, investigation of societal impacts of catastrophic events, research on decision making and risk perceptions, and research on implementation of risk management and mitigation programs.

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