

# Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security

Asian Development Bank



# **Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security**

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Asian Development Bank

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# Foreword

Climate change is already a concern in Asia and the Pacific and its impacts are projected to intensify in the decades to come, threatening the development and security of the region. Countries in Asia and the Pacific are among the most vulnerable globally to the adverse impacts of climate change, with poor and marginalized communities likely to suffer the most heavily.

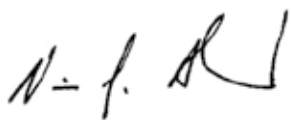
The long-term strategic framework of ADB, Strategy 2020, and its climate change strategy, *Addressing Climate Change in Asia and the Pacific: Priorities for Action*, confirm our commitment to help developing member countries (DMCs) in Asia and the Pacific address the increasing challenges posed by climate change and to build a climate-resilient region. Adjusting to the need for climate-resilient development will mean integrating actions and responses to the physical, social, and economic impacts of climate change into all aspects of development planning and investment. Particularly, ADB is seeking to assist its DMCs to enhance the climate resilience of vulnerable sectors—such as transport, agriculture, energy, water, and health—by “climate proofing” investments in these sectors to ensure their intended outcomes are not compromised by climate change.

However, due to the complexity and uncertainty of the factors that define climate risks and vulnerability, particularly at a project scale and in specific socioeconomic contexts, climate proofing can be a challenging activity. There are gaps in the guidance materials and information resources currently available to facilitate the climate proofing of investment projects within the region. In response, ADB is developing a technical resource package to assist both its own operational staff and those of DMC partners to manage climate-related risks throughout the project cycle. This package will encompass preliminary risk-screening tools, climate projections, and guidance in their interpretation and use. It also includes technical notes for climate proofing vulnerable investments in critical development sectors. The package reflects the growing experience of ADB and its partners in pilot testing a wide range of climate-proofing approaches, methods, and tools on diverse projects in various settings.



This publication is the second in a series of technical notes covering various sectors. It is intended to guide project teams as they integrate climate change adaptation and risk management into each step of project processing, design, and implementation. The technical note encompasses lessons learned and good practices identified through several completed and ongoing ADB agriculture, rural development, and food security investment projects. We hope that it improves—and simplifies—the work of development professionals in their efforts to enhance the climate resilience of such investment projects. We welcome comments and feedback, which will improve subsequent versions of this note.

This report was prepared by Benoit Laplante (consultant) and Lorie Rufo (environment officer [climate adaptation], Regional and Sustainable Development Department) under the regional technical assistance project Promoting Climate Change Adaptation in Asia and the Pacific (RETA 6420), financed by the Japan Special Fund and the Government of the United Kingdom. Valuable inputs were also provided by David Corderi and Liza Leclerc (consultants). Jay Roop (formerly environment specialist, Regional and Sustainable Development Department) provided overall guidance in the initial preparation of the report. Charles Rodgers (senior environment specialist [climate change adaptation], Regional and Sustainable Development Department) provided technical and overall guidance in the finalization of the report. The report also benefited from valuable inputs of Katsuji Matsunami and ADB's Agriculture, Rural Development, and Food Security Community of Practice.



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# Abbreviations

ADB	Asian Development Bank
cm	centimeters
DMC	developing member country
GIS	geographic information system
GCM	general circulation model
IPCC	Intergovernmental Panel on Climate Change
LDCF	Least Developed Countries Fund
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
PRC	People's Republic of China
PPTA	project preparation technical assistance
RCM	regional climate models
UNFCCC	United Nations Framework Convention on Climate Change

# Glossary<sup>1</sup>

**Adaptation.** Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. There may be various types of adaptation:

*Anticipatory adaptation.* Adaptation that takes place before specific impacts of climate change are observed; occasionally referred as proactive adaptation.

*Autonomous adaptation.* Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.

*Planned adaptation.* Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

**Adaptation assessment.** An adaptation assessment is the process of identifying options to adapt to climate change and of evaluating these options using criteria such as feasibility, gender equality, costs, and benefits.

**Agroecological zone.** A land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use. This unit provides an ecology-based division of space as opposed to reporting based solely on administrative boundaries (FAO 1996).

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<sup>1</sup> Unless explicitly indicated otherwise, this glossary is a subset of the definitions presented in the glossaries of the Intergovernmental Panel on Climate Change (2007) report and the contributions of its various working groups, as well as from the United Nations Framework Convention on Climate Change.

**Climate.** Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

**Climate change.** Climate change refers to a change in climate over time, whether due to natural variability or as a result of human activity. The United Nations Framework Convention on Climate Change, in its Article 1, defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”

**Climate change impacts.** The effects of climate change on natural and human systems. Depending on the state of adaptation, one can distinguish between potential impacts and residual impacts:

*Potential impacts.* All impacts that may occur given a projected change in climate, without considering adaptation.

*Residual impacts.* The impacts of climate change that would occur after adaptation has taken place.

**Climate prediction.** A climate prediction (or climate forecast) is the result of an attempt to estimate the actual evolution of the climate in the future at seasonal, interannual, or long-term timescales.

**Climate projection.** A climate projection is the simulated response of the climate system to a scenario of emissions or concentration of greenhouse gases, generally based upon numerical simulations by climate models. Climate projections critically depend on the emissions scenarios used and therefore on highly uncertain assumptions of future socioeconomic and technological development.

**Climate proofing:** A shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning (Asian Development Bank [ADB] 2005).

**Climate variability.** Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).

**Downscaling.** Downscaling is a method that derives local- to regional-scale information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution, or high-resolution global models. The empirical/statistical methods develop statistical relationships that link large-scale atmospheric variables with local and regional climate variables.

**Extreme weather event.** Event that is rare at a particular place and time of year. Definitions of “rare” vary, but an extreme weather event would normally be as rare or rarer than the 10th or 90th percentile of the observed probability density function estimated from observations.

**Food security.** Food security at the individual, household, national, regional, and global levels is achieved when all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. (FAO 1996a).

**General circulation models.** A general circulation model (GCM) is a mathematical model of the general circulation of a planetary atmosphere or ocean. Equations of the model are the basis for complex computer programs commonly used for simulating the earth’s atmosphere or ocean. Atmospheric–ocean general circulation models are key components of global climate models along with sea ice and land surface components. GCMs and global climate models are widely applied for projecting future climatic conditions.

**Impact assessment.** An impact assessment is the practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of climate change on natural and human systems.

**Maladaptation.** Outcome of efforts to adapt that either result in increased vulnerability to climate change or undermine the ability to adapt in the future.

**Resilience.** The ability of a social or ecological system to absorb, accommodate, or recover from disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

**Scenario.** A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a ‘narrative storyline’.

**Sensitivity.** Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

**Special Report on Emissions Scenarios.** The *Special Report on Emissions Scenarios* was a report prepared by the Intergovernmental Panel on Climate Change for the third assessment report in 2001 on future emissions

scenarios to be used for driving global circulation models to develop climate change scenarios. There exist four broad families of emissions scenarios (A1, A2, B1, and B2) that depend on different assumptions pertaining to economic growth, population growth, the adoption of new technologies, and the degree of integration among nations of the world.

**Stationarity.** Stationarity assumes that natural systems fluctuate within an unchanging envelope of variability. It implies that any variable (e.g., annual stream flow or annual flood peak) has a time-invariant (or 1-year-periodic) probability density function; the properties of this function (such as mean and variance) can be estimated from records. (Milly et al. 2008).

**Threshold.** The level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

**Uncertainty.** An expression of the degree to which the exact value of a parameter is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty can be represented by quantitative measures (for example, a probability density function) or by qualitative statements (for example, reflecting the judgment of a team of experts).

**Vulnerability.** Refers to the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed; its sensitivity; and its adaptive capacity.

**Vulnerability assessment.** A vulnerability assessment attempts to identify the root causes for a system's vulnerability to climate changes.



# Executive Summary

This publication, *Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security* (henceforth *Guidelines*) aims to present a step-by-step methodological approach to assist project teams to assess and incorporate climate change adaptation measures into agriculture, rural development, and food security investment projects. While the *Guidelines* focus on the project level, an improved understanding of climate change impacts should also be used to incorporate climate change considerations into agriculture planning and policy at the country level. Though rural development projects include irrigation, rural infrastructure, agriculture production, and natural resource management, this report focuses mainly on irrigation infrastructure projects and agriculture production projects. These were selected because they represent 55% of the ADB's planned and approved investments in the agriculture sector in 2011.

## Climate change impacts and agriculture

Climate change may have positive impacts on agricultural productivity by extending the geographical suitability of agriculture in some cold or high altitude areas of the world, or by increasing carbon fertilization. However, most analyses suggest that both agricultural productivity (crop production

per unit area) and the area of arable land will fall in tropical and most temperate regions. Empirical evidence shows that changes in temperature and precipitation over the period 1980–2008 have resulted in a global net loss of 3.8% of maize and 5.5% of wheat relative to what would have been achieved without the climate trends observed over that period of time (Lobell 2011). Cline (2007) suggests a 9% decrease in agricultural production in developing countries by 2080. Rice production in Asia could decline by 3.8% by the end of the 21st century (Murdiyarso 2000). Nelson et al. (2009) indicate that for almost all crops, South Asia will be the region with the largest yield decline. Under the most pessimistic scenario, rice yield potential by 2100 may decline by approximately 50% from 1990 levels in Indonesia, the Philippines, Thailand, and Viet Nam without adaptation (ADB 2009).

The agriculture sector is vulnerable to changes in temperature, rainfall, sea level, and the frequency and intensity of extreme weather events. Here are a few examples:

- Changes in either mean or variability of climate will have an impact on crop growing conditions, affecting agricultural productivity and the suitability of crops in different agroecological zones (if not the nature of the agroecological

zones themselves), potentially creating challenges and opportunities in both socioeconomic and food security terms.

- High temperatures can lead to negative impacts such as added heat stress and increased water demand, especially in low- and mid-latitude areas already at risk.
- Climate change may trigger the proliferation of weeds, pests, and diseases, which have the potential to severely limit crop production.
- Changes in precipitation can result in a reduction of water availability for rainfed crops, and alterations of discharge in river systems may lower the reliability of irrigation water supply for irrigated crops.
- An increased frequency and intensity of droughts can disrupt agriculture production and may also increase salinity in soils and water, increasing the possibility of irreversible desertification.
- Sea level rise can increase salinity in water and land in coastal areas, severely disrupting agricultural production.

## Adaptation to climate change

Adaptation options in the sector can generally be divided into engineering options (e.g., changes in drainage, irrigation systems, rural roads, storage buildings), non-engineering options (e.g., changes in cropping patterns, soil, landscape, water), and biophysical options (e.g., development of new cultivars). In addition, it is important to recognize that in a number of circumstances, a “do nothing” response to climate change—for example, allowing an infrastructure to deteriorate and be decommissioned instead of investing in climate proofing the infrastructure—may be a preferred course of action.

## Developing an adaptation methodological approach

The methodological approach presented in this report for building adaptation into agriculture, rural development, and food security investment projects is divided into six different sets of activities (Figure E1). The process begins with scoping the project and defining the assessment and its objectives. The core activities related to project design fall under impact assessment, vulnerability assessment, and adaptation assessment. Finally, the process ends with defining implementation arrangements and monitoring frameworks. To facilitate the implementation of the methodological approach, these six sets of activities are subdivided into 20 steps (Figure E2).

A climate change assessment is best integrated into the activities of the project preparation technical assistance, following the identification of climate change as a potential risk and/or opportunity factor to the project at the concept stage. For this purpose, a risk screening tool has been developed and is currently being tested by the ADB.

The outcome of the adaptation assessment activity may result in three different types of decisions:

**Decision of Type 1:** Invest in climate proofing the project at the time the project is being designed or implemented.

A decision of Type 1 may result from circumstances where

- (1) the costs of climate proofing now are estimated to be relatively small while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large. This is occasionally referred as a **low-regret** approach; and/or

- (2) the costs of climate proofing at a later point in time are expected to be prohibitive or climate proofing at a later point in time is technically not possible; and/or
- (3) among the set of climate-proofing options, there is at least one option that delivers net positive economic benefits regardless of the nature and extent of climate change, including the current climate conditions. Such options are occasionally referred to as **no-regret** climate-proofing options; and/or
- (4) the set of climate-proofing options includes options that not only reduce climate risks to the project, but also have other social, environmental or economic benefits. Such options are occasionally referred to as win-win climate-proofing options.

**Decision of Type 2:** Do not invest now in climate proofing but ensure that the project is designed in such a way as to be amenable to be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing.

For example, while current sea level rise and storm surge scenarios may not warrant the construction today of sea dykes suitable to projected higher sea level and stronger storm surges in a distant future, the base of the sea dyke may nonetheless be built large enough today to accommodate a heightening of the sea dyke at a later point in time.

A decision of Type 2 aims to ensure that the project is “ready” to be climate proofed if required. As such, the concept of **climate readiness** is often referred to. This concept is akin to the **real options** approach to risk management.

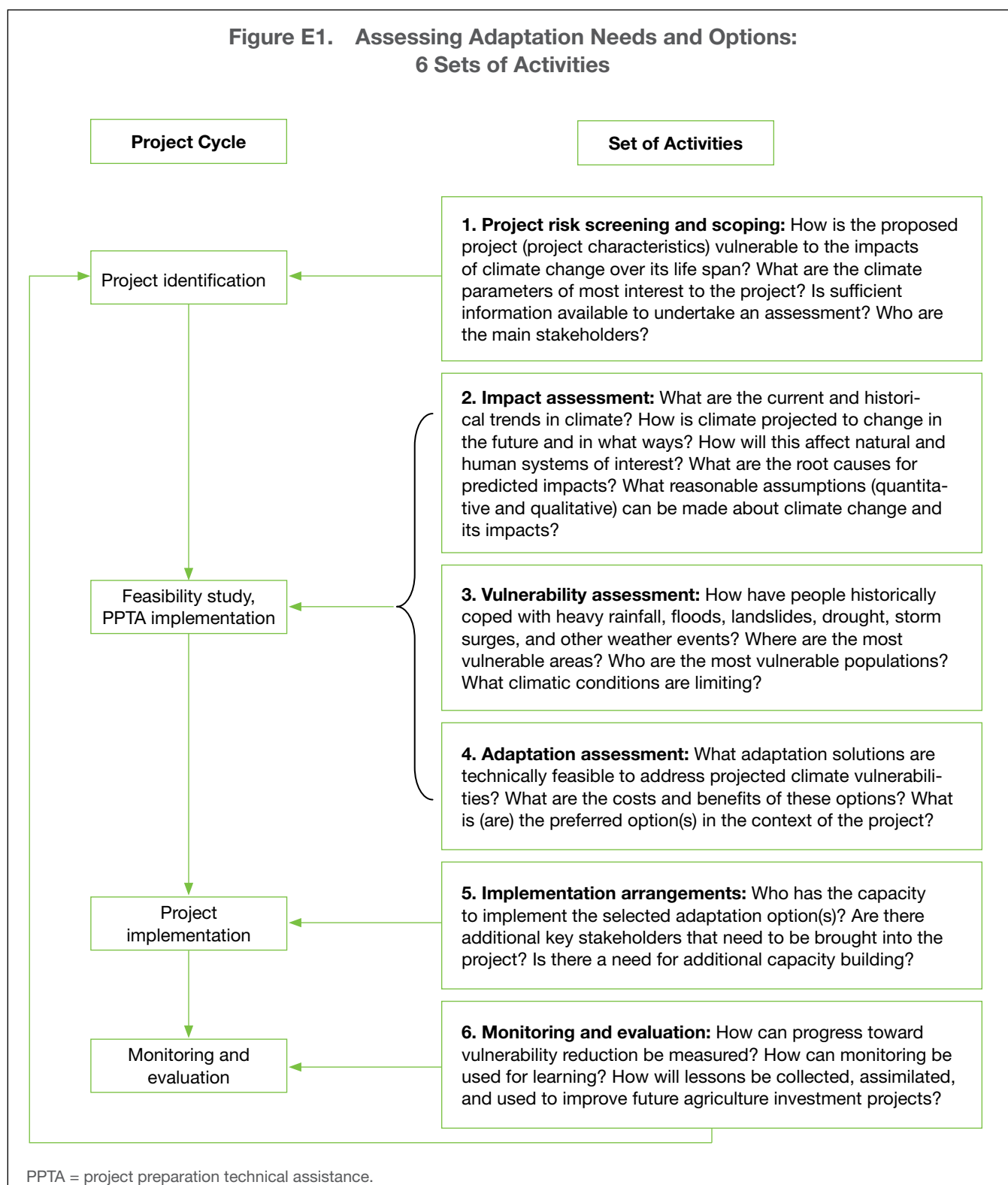
**Decision of Type 3:** Do no changes to project design, monitor changes in climate variables and their impacts on the infrastructure assets, and invest in climate proofing if and when needed at a later point in time.

A decision of Type 3 may result from circumstances where

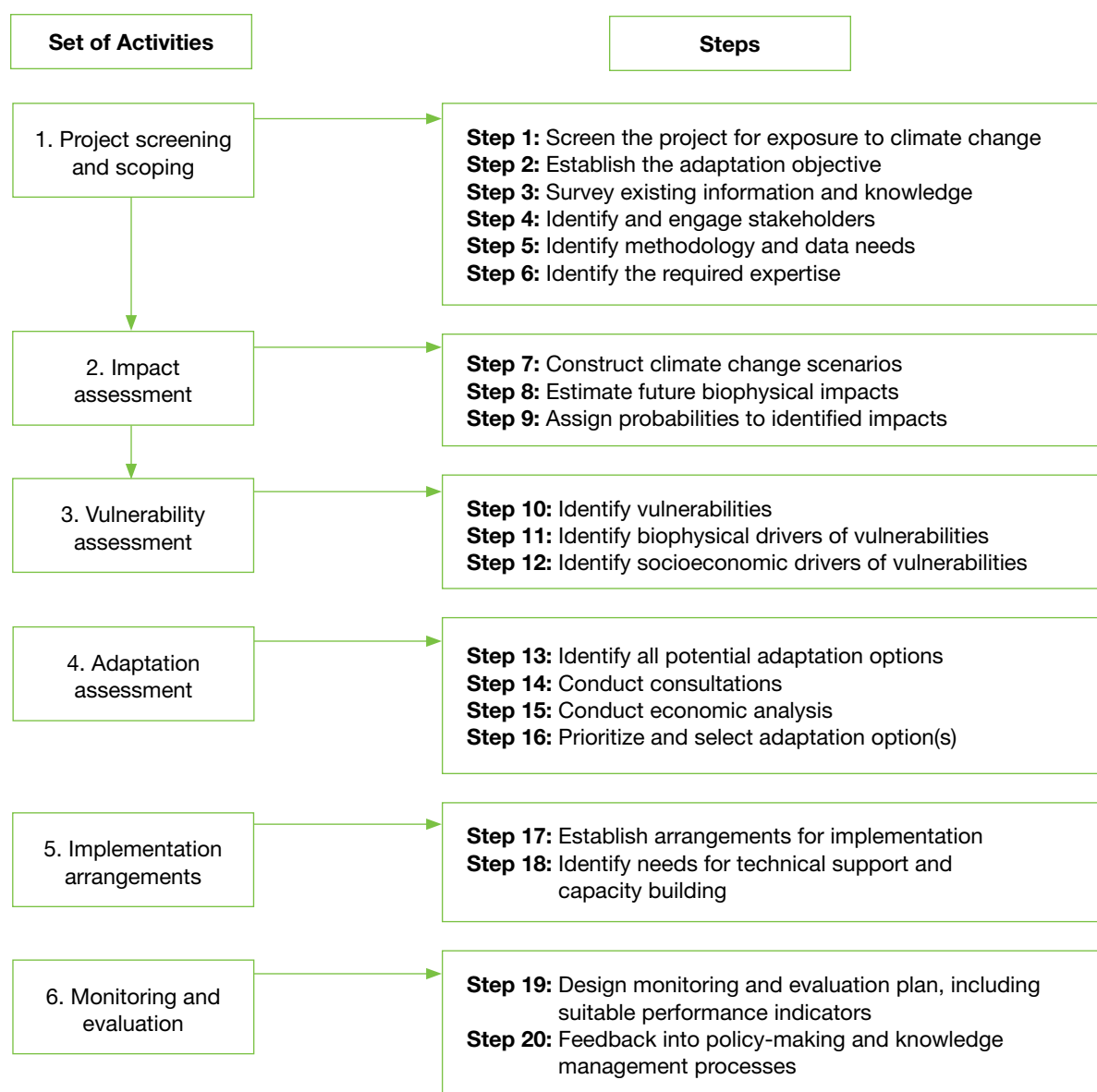
- (1) the costs of climate proofing now are estimated to be large relative to the expected benefits; and/or
- (2) the costs (in present value terms) of climate proofing (e.g., retrofitting) at a later point in time are expected to be no larger than climate proofing now; and/or
- (3) the expected benefits of climate proofing are estimated to be relatively small.

Both decisions of Type 2 and 3 may be referred to as **adaptive management**, which consists in putting in place incremental adaptation options over the project’s lifetime. A decision of Type 2 will differ from a decision of Type 3 in that project design will ensure “readiness” for climate proofing, while a decision of Type 3 will require no changes at all to project design.

**Figure E1. Assessing Adaptation Needs and Options:  
6 Sets of Activities**



**Figure E2. Assessing Adaptation Needs and Options:  
6 Sets of Activities and 20 Steps**



# Introduction

While the contribution of the agriculture sector to national economic growth is generally diminishing in the region (ESCAP 2009), the majority of the poor still live in rural areas where agriculture remains a key source of employment and income. As such, the ADB's Strategy 2020 recognizes sustainable food security in Asia and the Pacific as a crucial element in freeing Asia from poverty (ADB 2008). In so doing, the ADB operational plan to achieve food security in the region also recognizes climate change as one of the key binding constraints to achieving this objective (ADB 2010).

The agriculture, rural development, and food security (henceforth "agriculture") sector is particularly vulnerable to projected changes in temperature and rainfall, increased frequency and intensity of extreme weather events such as flood and drought, a rise in sea level, and the intensification of storm surges. All of these changes have consequences for the design of agriculture investment projects. Inadequate attention to these impacts can increase the long-term costs of agriculture investments and increase the likelihood that such investments will fail to deliver the benefits for which they were intended.

Adaptation options in the sector can generally be divided into engineering options (e.g., changes in

drainage, irrigation systems, rural roads, storage buildings), non-engineering options (e.g., changes in cropping patterns, soil, landscape, water), and biophysical options (e.g., development of new cultivars). In addition, it is important to recognize that in a number of circumstances, a "do nothing" response to climate change—for example, allowing an infrastructure to deteriorate and be decommissioned instead of investing in climate proofing the infrastructure—may be a preferred course of action. Adaptation options will also be influenced by the nature of the policy and regulatory environment, which may facilitate or constrain specific approaches to adaptation. Climate proofing investments in the agriculture sector will be achieved by assessing the potential impacts of climate change and the vulnerability of the sector to those impacts, evaluating the relative merits of technically feasible adaptation options, and effectively implementing selected option(s).

This publication, *Guidelines for Climate Proofing Investment in the Agriculture, Rural Development, and Food Security Sector* (henceforth *Guidelines*) is intended to guide project teams as they integrate climate change adaptation and risk management into each step of project processing, design, and implementation. Though rural development projects



include irrigation, rural infrastructure, agriculture production, and natural resource management, this *Guidelines* focuses mainly on irrigation infrastructure projects and agriculture production projects. These were selected because they represent 55% of planned and approved ADB investments in the agriculture sector in 2011.

The information presented in this *Guidelines* draws in part from the existing climate change and agriculture literature and knowledge. It also draws from the experience obtained from a number of ongoing agriculture and climate change projects in the region.

Part A presents a discussion of the possible impacts of climate change on the agriculture

sector and the nature of the adaptation options available. Part B describes a step-by-step approach to assessing climate vulnerabilities as well as adaptation needs and options relevant to the agriculture sector. As pointed out in FAO (2010), agriculture must undergo a significant transformation in order to meet the challenges of food security and climate change. This will require not only the implementation of effective “climate smart” agricultural practices, but also greater consistency between agriculture and climate change policies as well as intersectoral coordination and cooperation. Part C discusses in more detail issues pertaining to mainstreaming adaptation into agriculture sector development policy and planning.

# Part A: Climate Change and Agriculture

## The Case for Action

In early 2007, the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment report.<sup>2</sup> The IPCC then noted that over the period 1906–2005, global average surface temperature has increased by 0.74°C, and that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in atmospheric greenhouse gas (GHG) concentrations linked to anthropogenic (human) GHG emissions.<sup>3</sup> It is generally believed that this global warming has caused changes in precipitation patterns, increased the frequency and/or intensity of extreme weather events, and caused a rise in mean global sea levels.

Looking into the future, the IPCC (2007) concluded the following:<sup>4</sup>

- Even if greenhouse gas concentrations were to stabilize at existing levels, anthropogenic warming would continue for decades, and sea level rise for centuries, due to the time scales associated with climate processes and feedback effects.<sup>5</sup>
- World temperatures may rise by between 1.1°C and 6.4°C during the 21st century (relative to the period 1980–1999),<sup>6</sup> depending on the emissions scenario that is realized (the “best estimate” range is between 1.8°C and 4.0°C).
- Sea levels will rise by 18–59 centimeters by 2100 (Box 1), with thermal expansion of the oceans

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<sup>2</sup> The first, second, and third assessment reports were released in 1990, 1995, and 2001. They are available online at [www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data\\_reports.shtml](http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml)

<sup>3</sup> In the language of the IPCC, “very likely” stands for “with a probability greater than 90%.” Lean and Rind (2008) and Foster and Rahmstorf (2011) have shown that the global warming signal becomes even more evident once time series of global temperature are adjusted to remove the estimated impact of known factors on short-term temperature variations such as El Niño/southern oscillation, volcanic aerosols, and solar variability.

<sup>4</sup> More specifically, these conclusions were presented by IPCC’s Working Group I, which focused on the physical science of climate change.

<sup>5</sup> This phenomenon is generally referred to as *climate change commitment* (Solomon 2009).

<sup>6</sup> More precisely, 1.1°C is the lower bound estimate of the range of likely increase under the B1 emissions scenario, while 6.4°C is the upper bound estimate of the range of likely increase under the A1FI emissions scenario (IPCC 2007).

being the single most significant contributor to the rise in sea level.<sup>7</sup>

- There is a greater than 90% confidence level that there will be more frequent warm spells, heat waves, and heavy rainfall.
- There is a greater than 66% confidence level that future cyclones will be more intense.

Changes in the frequency and/or intensity of extreme weather events, as well as gradual changes in climate parameters (such as temperature and precipitation), are expected to impact agriculture infrastructure, crop productivity, and both the area and location of land suitable for agriculture.

### Vulnerability of the Agriculture Sector to Climate Change<sup>8</sup>

The agriculture sector is vulnerable to projected changes in *mean* climate conditions (such as mean temperature and rainfall), in climate *variability* (climate variability is expected to increase in a warmer climate), in the frequency and intensity of extreme weather events (Moriondo et al. 2011), and in sea level.

Climate change may have positive impacts on agricultural productivity by extending the geographical suitability of agriculture in some cold or high altitude areas of the world, or by increasing carbon fertilization

(IPCC 2007). For example, in a recent study of the possible impact of climate change in the Indo-Gangetic Plain, New et al. (2012) estimate that areas suitable for rainfed agriculture could increase in the future as a result of a projected general increase in precipitation.<sup>9</sup> However, most climate projections suggest that both agricultural productivity (crop production per unit area) and the area of arable land will fall in tropical and most temperate regions. Possible adverse impacts include the following:

- Changes in climate will have an impact on crop growing conditions, affecting agricultural productivity and the suitability of crops in different agroecological zones, potentially creating challenges and opportunities in both socioeconomic and food security terms.
- High temperatures can lead to negative impacts such as added heat stress, especially in areas at low and mid-latitudes already at risk today.
- Higher temperatures can increase evapotranspiration.
- Climate change may trigger the proliferation of weeds, pests, and diseases, which have the potential to severely limit crop production.
- Changes in precipitation can result in a reduction of water availability for rainfed crops, and alterations of discharge in river systems may lower reliability of irrigation water supply for irrigated crops and/or increase demand for irrigation.

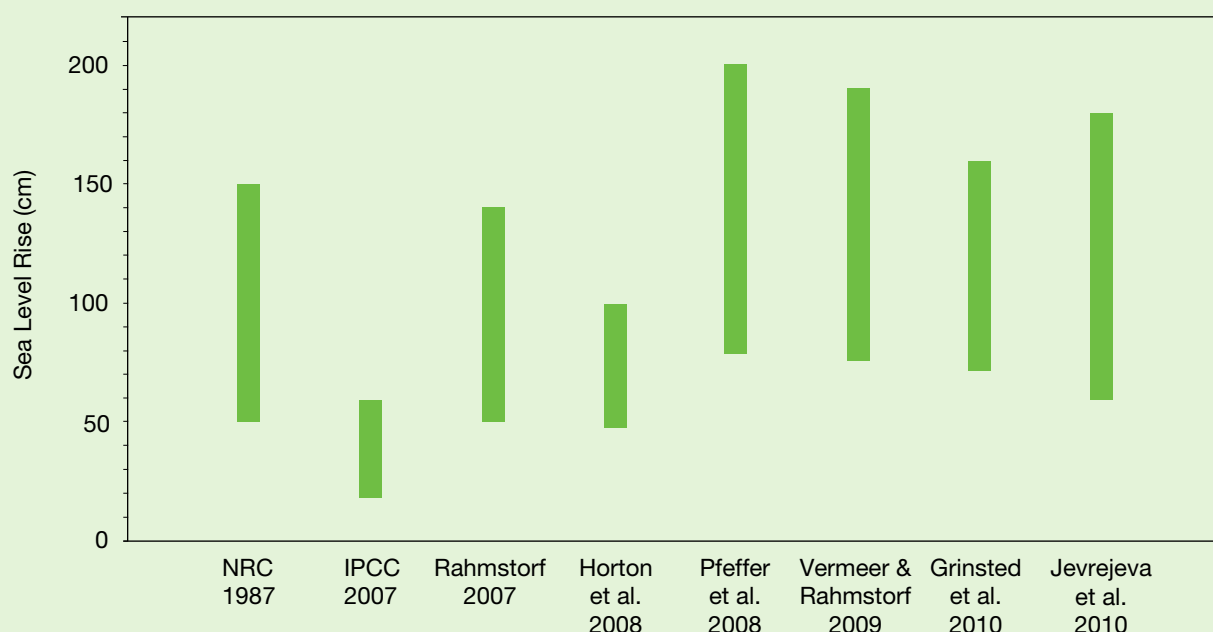
<sup>7</sup> Domingues et al. (2008) estimated that the thermal expansion of oceans contributed to approximately 40% of observed sea level rise over the period 1961–2003, glaciers and ice caps contributed 35%, and the large polar ice sheets of Antarctica and Greenland contributed 25%. Over the period 2003–2008, large polar ice sheets are estimated to have contributed to 40% of the observed sea level rise, glaciers and ice caps contributing another 40%, and thermal expansion 20% (Cazenave et al. 2008). However, as warming continues, melting and dynamic changes in the polar ice sheets on Antarctica and Greenland will become increasingly important.

<sup>8</sup> Comprehensive discussions of the vulnerability of the agriculture sector to climate change are available in ADB (2009a), Tubiello et al. (2008), Padgham (2009), and Turrall et al. (2011).

<sup>9</sup> See also Aggarwal (2009).

### Box 1. Sea Level Rise

IPCC (2007) projects a rise in sea level ranging between 18 and 59 centimeters (cm) by 2100. This range has been criticized by many experts as being too conservative (Krabill et al. 2004, Overpeck et al. 2006, and Rahmstorf 2007). Recent projections suggest that sea level may be 0.6–1.5 meters higher than present by 2100 (Hansen and Sato 2011, Jevrejeva et al. 2010, Horton et al. 2008, and Rahmstorf 2007), and up to 2 meters higher under extreme warming scenarios (Pfeffer et al. 2008, Vermeer and Rahmstorf 2009, and Grinsted et al. 2010). As shown in the figure below, IPCC's projections of sea level rise presented in its fourth assessment report rank among the lowest. However, the IPCC itself pointed out that its projections did not include changes within the polar ice sheets. The IPCC noted that the upper values of projected sea level rise presented in its report are not to be considered upper bounds and that higher rises in sea level cannot be ruled out.



Source: United States Geological Survey (USGS). Available at <http://wh.er.usgs.gov/slr/sealevelrise.html>

- Increasing frequency and intensity of droughts as well can disrupt agriculture production and may also increase salinity in soils and water, increasing the possibility of irreversible desertification.
- The demand for groundwater resources—already under stress in many countries of the Asia and Pacific region—could further increase as surface water availability becomes more uncertain.

- Sea level rise can increase salinity in water and land in coastal areas, severely disrupting agricultural production.

A summary of the potential impacts of climate change on the agriculture sector (some of which being possibly of a positive nature) is presented in Table 1.

Empirical evidence shows that changes in temperature and precipitation over the period 1980–2008 have resulted in global net loss of 3.8% of maize

and 5.5% of wheat relative to what would have been achieved without the climate trends observed over that period of time (Lobell et al. 2011). This study also shows that most of these estimated impacts are driven by changes in temperature rather than changes in precipitation. Globally, the impact of these changes on rice and soybean crops was insignificant, with gains in some countries offsetting losses in others.

Cline (2007) suggests a 9% decrease in agricultural production in developing countries by 2080.

**Table 1. Potential Impacts of Climate Change on Agriculture**

Climate Variable	Potential Impacts on the Agriculture Sector
<b>Temperature changes</b>	
Increases in very hot days and heat waves	Modification in crop suitability and productivity (heat stress). Increased in weeds, crop pests and disease outbreaks. Changes in crop water requirements. Increase risk of wildfire.  The quantity and quality of yield critically depend on the number of days that a crop is exposed to temperatures exceeding specific thresholds during critical growth stages (i.e., flowering, pollination, fruiting, or grain filling).
Fewer cold days and nights	Increased yields in colder environments. Reduction in the risk of frosts and subsequent crop failure.
<b>Precipitation changes</b>	
Increase in intense precipitation events	Damages to crops. Increased waterlogging, inability to cultivate lands. Damage to the drainage system due to flooding. Increased extent and intensity of erosion and waterlogging. Increased pest incidence.
Increases in drought conditions	Lower yields from crop damage, stress, and/or failure. Loss of arable land as a result of land degradation and wind erosion. Increased risk of wildfires.

*continued on next page*

Table 1. continued

Climate Variable	Potential Impacts on the Agriculture Sector
<b>Changes to extreme events</b>	
Increase in the frequency of floods and droughts	Crop failure and damage to crops due to flooding. Yield decreases. Land degradation and soil erosion, loss of arable land. Increased competition for water (drought).
More frequent strong tropical cyclones	Damage to crops and rural infrastructure.
<b>Sea level rise and storm surges</b>	Damage to crops and rural infrastructure due to flooding. Seawater intrusion, loss of arable land, salinization of water supply (groundwater in particular).
<b>Increase in CO<sub>2</sub> concentration</b>	Increased biomass production and increased physiological efficiency of water use in crops and weeds. Increased efficiency of water use by crops. Potential increased weed competition with crops.  The photosynthesis, growth, and yield of C3 plants such as wheat and rice tend to benefit more from high concentration of carbon dioxide than do C4 plants such as maize.

ASA = American Society of Agronomy; CO<sub>2</sub> = carbon dioxide.

Sources: Adapted from multiple sources, particularly IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; and American Society of Agronomy et al. 2011. *Position Statement on Climate Change*.

Both Nelson et al. (2009) and the World Bank (2010) indicate that for almost all crops, South Asia will be the region experiencing the largest yield and production decline. Rice production in Asia could decline by 3.8% by the end of the 21st century (Murdiyarso 2000). Under the most pessimistic scenario, rice yield potential may decline approximately 50% by 2100 (relative to 1990 level) in Indonesia, the Philippines, Thailand, and Viet Nam without adaptation (ADB 2009). Even with productivity improvements and adaptation, the declines in rice

yield potential would remain significant without stabilization of greenhouse concentrations. In the case of a one-meter sea level rise, a total of 7.7 million hectares (ha) of crop land could be submerged, with rice losing approximately 4.9 million hectares. Asia and the Pacific could thus lose 5%–11% of its rice cultivated area (ADB 2009a). In Viet Nam alone, total rice production could fall by up to 9 million metric tons in 2050 as a result of changes in climate and sea level rise (Box 2).



## Box 2. Estimated Impacts of Climate Change on Agriculture in Viet Nam

In a 2011 study, the World Bank estimated the impacts of climate change on Viet Nam's agriculture sector for a wet climate scenario, a dry climate scenario, and for the climate scenario adopted by Viet Nam's Ministry of Environment and Natural Resources (MonRE). Hydrodynamic simulations were also used to estimate the changes in sea inundation from 2000 to 2030 and 2050 on the assumption of a sea level rise of 17 centimeters (cm) by 2030 and 30 cm by 2050.

Results showed that rice production is projected to fall by between 5.8 and 9.1 million metric tons, approximately 2/3 of which is a result of reduced productivity (yield).

### Change in Crop Production in 2050 Due to Climate Change without Adaptation (million metric tons)

	Paddy rice			Maize	Cassava	Sugar	Coffee	Vegetables
Scenario	Yields	Sea level	Total	Yields	Yields	Yields	Yields	Yields
Dry	-6.7	-2.4	-9.1	-1.1	-1.9	-3.7	-0.4	-1.7
Wet	-5.8	-2.5	-8.4	-1.0	-2.6	-2.9	-0.4	-3.1
MoNRE	-3.4	-2.4	-5.8	-0.3	-0.6	-1.4	-0.1	-0.9

Using a computable general equilibrium model of Viet Nam's economy, it was estimated that as a result of these changes in the agricultural sector, Viet Nam's gross domestic product could be approximately 2.4% lower than what it would otherwise be in the absence of climate change. The impact is particularly severe in the northern agroecological zone. Perhaps more importantly, rural households in bottom quintile of the income distribution would experience the most severe reduction in income and consumption.

Source: World Bank. 2011. *Economics of Adaptation to Climate Change: Viet Nam*. Washington, D.C

In the People's Republic of China (PRC), recent estimates project an overall significant decline in rice output (16%–24% in 2030, and 26%–45% in 2050), but an increase for both corn and soybean (with corn output increasing 19%–24% in 2030 and 33%–50% in 2050, and soybean increasing 0.5%–6% in 2030 and 4%–6% in 2050). These estimates vary by region, with the impacts of climate change on grain output being positive in the northern and central regions of the PRC and negative in the southern part (Lin et al. 2011).

As a result, climate change will place an additional burden on efforts to meet long-term development goals in Asia and the Pacific. At the regional level, agriculture is not only an important source of income that contributes significantly to economic growth, it is also an important contributor to food security. Among ADB developing member countries, more than 60% of the economically active population and their dependents—or approximately 2.2 billion people—rely on agriculture for their livelihoods (FAO 2009).

Climate change impacts on agriculture will in turn affect food security (Box 3).

### Box 3. Food Security and Climate Change in the Pacific

Climate change—induced extreme weather events and sea level rise have direct effects on the biophysical and socioeconomic systems influencing food production, and indirect impacts and consequences on food security per se. The projected impacts of warmer atmospheric and open water temperatures, erratic rainfall intensity and distribution, more frequent and more intense tropical cyclones, and sea level rise on land, soil water resources, and agricultural production systems (including those of livestock and fisheries) will in turn influence the consequences of climate change on food security.

Projected changes and some of their key consequences in the Pacific are listed below.

Projected Climate Changes	Some Key Consequences
Increased surface atmospheric temperature (1.00°C–4.17°C in Northern Pacific and 0.99°C–3.99°C in Southern Pacific by 2070)	<ul style="list-style-type: none"> <li>• Plant and animal stress—heat and pest and disease incidence: slow growth and low yields</li> <li>• Water shortages for agriculture</li> <li>• Changes in soil quality</li> <li>• Effects on health, production, and reproductive capacity of animals</li> <li>• Decreased fish catches</li> <li>• Low productivity of farms</li> <li>• Increased risk of fires</li> </ul>
Sea level rise (8–51 cm)	<ul style="list-style-type: none"> <li>• Saltwater intrusion and flooding of low-lying farms and settlement areas</li> <li>• Erosion of soil and shorelines</li> <li>• Coral dieback affecting fishery production</li> <li>• Inundation of habitats for coconut crabs</li> </ul>
Acidification of ocean (pH level projected to drop by 0.3–0.4)	<ul style="list-style-type: none"> <li>• Slowdown of coral growth rates</li> <li>• Coastal waters become corrosive to the shells of some bottom dwellers</li> </ul>
Rainfall increase or decrease (–2.7% to +25.8% in Northern Pacific; –14% to +14.6% in Southern Pacific)	<ul style="list-style-type: none"> <li>• Erosion of soil and soil nutrients</li> <li>• Flooding of agricultural lands</li> <li>• Sedimentation of reefs and lagoons, affecting mangroves, marine species, and fisheries</li> <li>• Spread of pests and diseases</li> </ul>
El Niño Southern Oscillation/ cyclones/wave surges/salt spray	<ul style="list-style-type: none"> <li>• Production losses in rainfed areas with more frequent occurrences of El Niño</li> <li>• Damage to agricultural crops and forest trees from strong winds, salt spray, and wave surges</li> <li>• Loss of traditional food crops</li> <li>• Destruction of agriculture infrastructure</li> <li>• Spread of wind-borne diseases and pests</li> <li>• Invasion by alien plant and insect species</li> </ul>

Source: ADB. 2011. *Food Security and Climate Change in the Pacific: Rethinking the Options*. Manila.

Some of the possible adverse consequences of climate change on food security include the following:

- **Availability of food** may be reduced by a drop in food production caused by extreme events; changes in the suitability or availability of arable land and water; and the unavailability or lack of access to crops, crop varieties, and animal breeds that can be productive in changing conditions.
- **Access to food** may be worsened by climate change-intensified events that lead to damaged infrastructure and losses of livelihood assets as well as loss of income and employment opportunities.
- **Stability of food supply** could be influenced by food price fluctuations and a higher dependency on imports and food aid. High food prices will also affect access to nutrition by reducing household purchasing power.
- **Utilization of food** can be affected indirectly by food safety hazards associated with pests and animal diseases.

These may worsen a situation that has not necessarily improved over recent decades (Box 4).

### Adaptation Options in Agriculture Sector Investments<sup>10</sup>

Enhancing the climate resilience of the agriculture sector will be costly. Estimates of the global annual

cost of adaptation in the agriculture sector<sup>11</sup> range from approximately \$3 billion for each year of the period 2010–2050 (World Bank 2010) to \$7 billion per year by 2030 (UNFCCC 2007). ADB (2009a) estimated that investment expenditures in the agriculture sector across Asia and the Pacific would have to increase by approximately \$3 billion per year to counteract the effects of climate change on child malnutrition.

Adaptation options in agriculture sector projects may generally be grouped into engineering (or structural) options, non-engineering options, and biophysical options (Figure 1). Note that a decision not to act, or to maintain a business as usual approach (“do nothing option”) should also be retained as one possible option: In a number of circumstances, recommendations based on the findings of the technical and economic analysis of adaptation options may be to not climate proof a specific development project.

### Engineering Options

#### *Material specifications*

All materials have their own set of properties and will exhibit different behavior under different environmental conditions. The strength of these materials may have to be increased to withstand increased or decreased moisture content. The protection of these materials (for example, against increased moisture and salinity) may have to be enhanced to preserve the expected life time of the irrigation structure, or another material may need to be substituted.

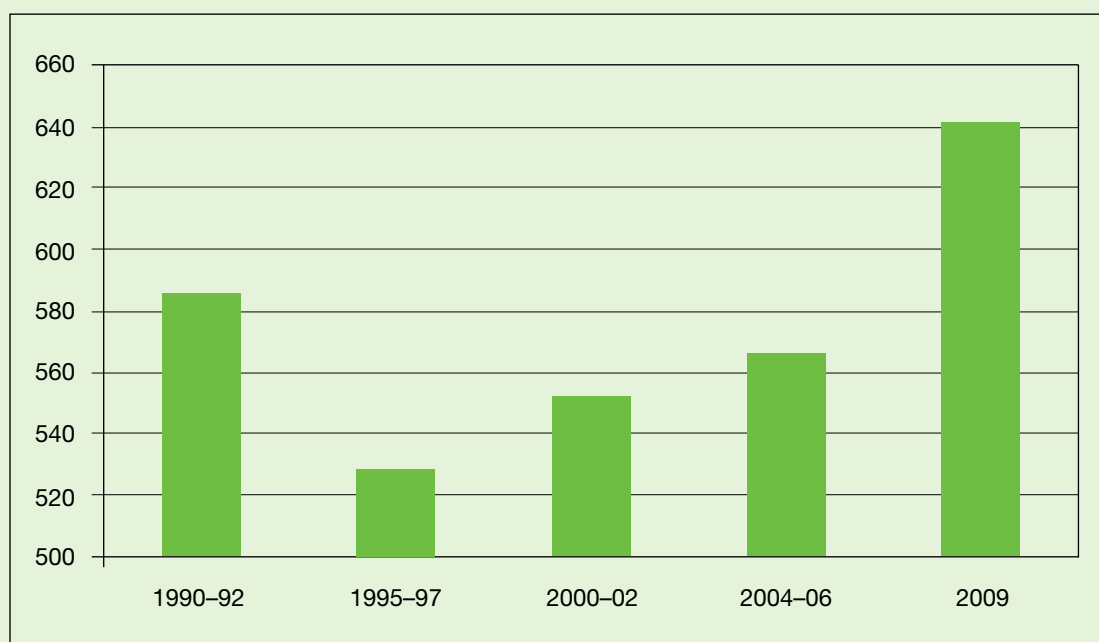
<sup>10</sup> This section does not aim to provide a comprehensive and exhaustive list of potential adaptation options in agriculture. Numerous documents provide such discussion including, more recently, Turral et al. (2011).

<sup>11</sup> In some studies, estimates of adaptation costs also include forestry and fisheries.

### Box 4. Food Insecurity in Asia and the Pacific

The proportion of undernourished in Asia and the Pacific fell from approximately 20% of the total population in 1990–1992 to approximately 16% in 2004–2006. However, despite this gain, the number of undernourished people has only slightly decreased, from approximately 585 to 566 million people over the same period of time. It is estimated that the number of undernourished reached approximately 642 million people in the region in 2009, mostly as a result of the global financial crisis.

**Number of People Undernourished in Asia and Pacific, 1990–2009 (millions)**



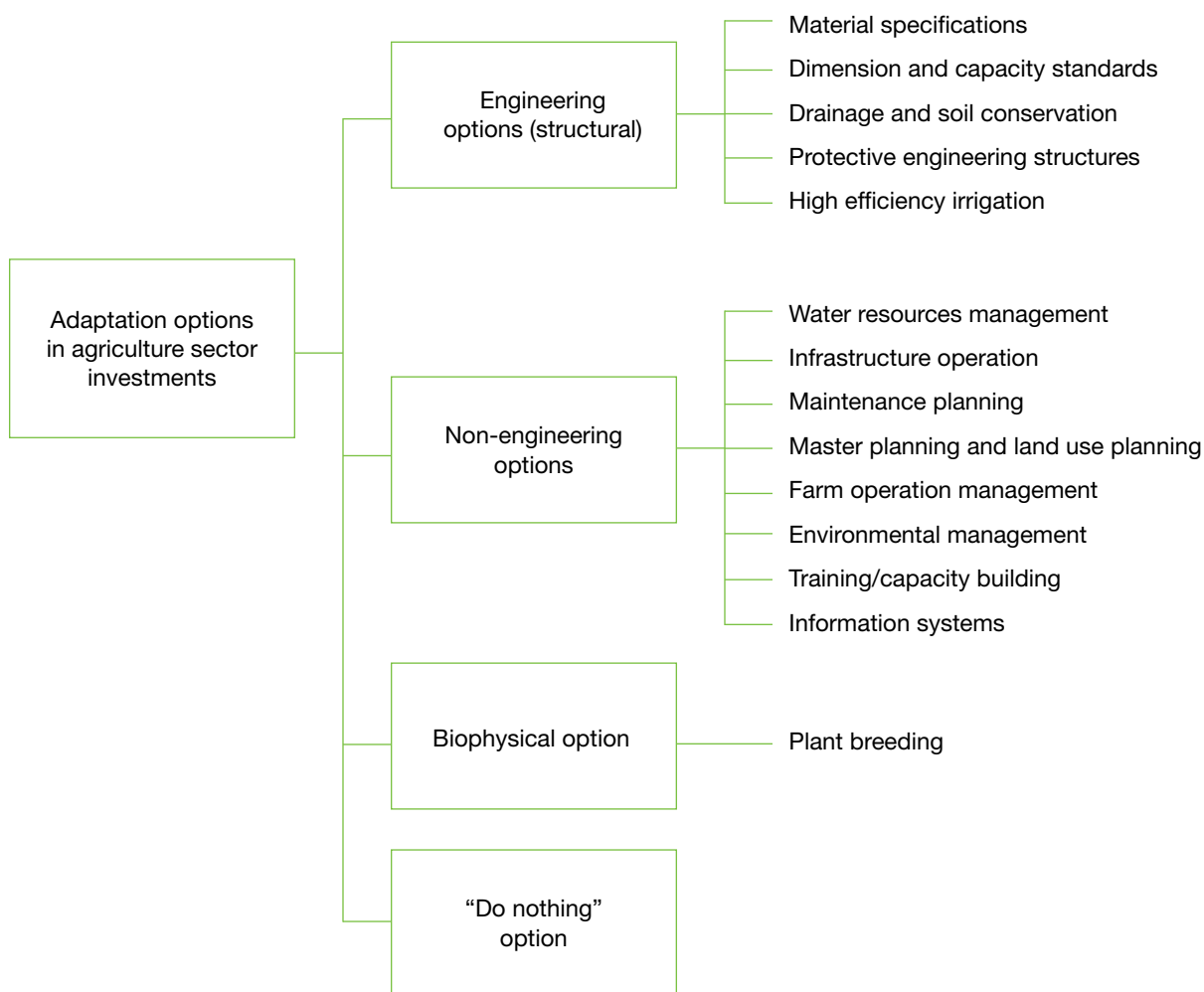
Source: FAO. 2009a. *The State of Food Insecurity in the World. Economic Crises—Impacts and Lessons Learned*. Rome.

### **Dimension and capacity standards**

The design of each component of irrigation infrastructure reflects design standards adopted by the agency that is sponsoring or regulating the infrastructure. Many of these standards are based

on field or laboratory studies. These standards tend not to change rapidly, and may not be responsive to changes in climate conditions.

Current practice is to use historical climate information as a basis for determining engineering specifications,

**Figure 1. Selected Adaptation Options in Agriculture Sector Investments**

under the (implicit or explicit) assumption that future climate variability will replicate historical variability. As a result of climate change, such an assumption (known as the stationarity assumption) is increasingly untenable (Milly et al. 2008). Using projection data

and trends can assist the engineer to design for future conditions rather than historical trends. A typical challenge in doing so, even in many industrialized countries, pertains to data, as it may not be collected or may be of inconsistent quality.

### ***Drainage and soil conservation***

If floods represent a key challenging factor for the design of irrigation infrastructure, then particular attention must be paid to design standards pertaining to drainage systems, open channels, or distribution systems to reflect changes in future expected runoff or discharge.

### ***Protective engineering structures***

In the case of coastal irrigation systems, protective engineering structures can be used to decrease salinity intrusion from rising sea levels or storm surges and include dikes, sluice gates, groundwater injections, and other structures. However, these systems on their own have often been found to be unstable, as waves hit the walls directly or scour the sandy sea floor and compromise structural integrity. Nevertheless, there may in some cases be feasible options, particularly when combined with softer measures such as mangrove rehabilitation and groundwater management.

### ***High efficiency irrigation***

High efficiency irrigation (including drip and trickle irrigation) aims to meet daily water needs by allowing water to drip slowly to the roots of plants without completely saturating the root zone. In so doing, this irrigation approach significantly increases water productivity, thus allowing reduced water abstraction for purpose of irrigation and/or increasing irrigated area coverage. Despite its high initial capital costs (for the laying of the piping system), this approach may be a good option if climate projections indicate increase in water scarcity and reduced water availability.

## **Non-Engineering Options**

### ***Water resource management***

Implementing integrated water resources management approaches can help manage some of the impacts of climate change, such as decreased runoff and water shortages. Reconfiguring production systems to accommodate the use of marginal water sources can also be an option to consider under such an approach. Furthermore, market-based water management policies can allow more efficient allocation of resources.

Water management options for adaptation should aim to improve both physical (more crop per drop) and economic (more income per drop) water productivity to better cope with potentially lower water supply and higher evaporative demand.

Rainwater harvesting, water conservation, and the conjunctive use of surface water and groundwater may also be effective management options effective at increasing climate resilience of an agriculture production system (Box 5).

### ***Infrastructure operations and maintenance planning***

Irrigation systems, if not properly managed, can face serious resource degradation issues related to salinity and waterlogging. For infrastructure that is already in place, increasing maintenance contingency budgets in areas where climate change impacts are acute can reduce the possibility of system failure or decrease in service. This can be done by providing more intensive supervision and monitoring of the most vulnerable areas. Furthermore, maintenance planning systems can include early warning systems to anticipate extreme events, and



### **Box 5. Climate Change Adaptation through Groundwater Management in the People's Republic of China**

The Water Financing Partnership Facility's activities of the Shanxi Integrated Agricultural Development Project aim to demonstrate the viability of more productive and efficient irrigation techniques. It also includes a component that aims to improve the capacity of water resource bureaus to better manage groundwater resources, as most farmers involved in the project use groundwater for irrigation. The project supports water resource bureaus in the development of groundwater management alternatives based on groundwater supply and demand. The project also includes the preparation of a strategy to address water-related climate change adaptation and a study on possible economic incentives to promote water savings.

Source: ADB. 2009b. *People's Republic of China: Shanxi Integrated Agricultural Development Project. Report and Recommendation of the President to the Board of Directors*. Project Number 38662. Manila.

systems to monitor demand via soil moisture remote sensing. This will ensure that irrigation system failures are kept to a minimum. This implies trading off increased capital costs for reduced future operating expenditures.

Management of irrigation systems by service oriented, autonomous irrigation management entities has been shown to improve the distribution and timeliness of water delivery and to improve water productivity.

#### ***Master planning and land use planning***

Large irrigation schemes influence development patterns. It is therefore important to consider whether irrigation infrastructure schemes are opening up areas for development that are hazard prone and/or will not be sustainable in the long run because recurring droughts will require frequent emergency responses or because the area is becoming increasingly inhospitable to the intended socioeconomic activity.

#### ***Farm operation and management***

Changing the timing and application of on-farm irrigation can be an attractive option to adapt

to changes in the crop growing season and the distribution of seasonal rainfall. Adopting new varieties or switching to different crops that are more tolerant of heat and moisture stress can also build resilience to climate change.

#### ***Environmental management***

Harnessing the services provided by environmental buffers can reduce the severity of floods and droughts. Examples include ensuring increased vegetative land cover and preserving and re-establishing mangroves, peat lands, and forests (which help to regulate the hydrologic cycle, improve soil moisture retention and groundwater recharge, and minimize the severity of floods).

#### ***Training and information systems***

Building capacity to better understand and cope with climate change impacts on institutions and rural communities is generally a useful option for building climate resilience. Increasing access to climate information, including longer-term weather forecasting and better seasonal forecasts to guide the selection and timing of seasonal

crops,<sup>12</sup> and early warning systems can improve the responses of the communities with respect to changes in the climate.

However, it has often been observed that there is commonly a wide gap between the output of weather and climate forecasts and the actual use of this information at local levels. Training could enhance the capacity of users (i.e., farmers) to effectively use information produced by weather forecasting (Padgham 2009).

### Biophysical Option—Plant Breeding

The adoption of drought-tolerant crop varieties may be an option in situations where water availability is projected to become a significant issue (Box 6). Plant breeding (including bioengineering) has potential to offset some of the risks associated with climate change, such as those associated with drought, salt tolerance, and heat stress. There is, however, widespread recognition that increased levels of investments in national and international agriculture

#### Box 6. Developing and Pilot Testing Climate-Resilient Crop Species in Bangladesh

Bangladesh is a densely populated country in which the agriculture sector provides approximately 20% of the country's gross domestic product and employment to approximately 50% of the labor force. Feeding a population of approximately 150 million people has become an increasing source of concern. Not only is areal expansion of agricultural activity almost nil, but agricultural land is progressively diminishing because of the expansion of urban settlement and infrastructure.

Climate change is projected to take various forms in Bangladesh (rising average temperatures, more flooding from higher rainfall in the monsoon season, and prolonged droughts and soil moisture deficiency due to less rainfall in the dry season). The nature of these changes is expected to have severe impacts on Bangladesh's agriculture sector, thus adding to existing sources of stress and pressure.

Recognizing that engineering (structural) options may not alone provide the sector with the means to offset the impacts of climate change, Bangladesh's National Adaptation Programme of Action (MoEF 2005) includes the promotion of research on drought, flood, and saline tolerance of crops. The Bangladesh Climate Change Strategy and Action Plan (MoEF 2008) identifies agricultural research to develop crop varieties that are tolerant of flooding, drought, and salinity as key to maintaining food security, social protection, and health.

ADB's Second Crop Diversification Project (ADB 2010a) will provide support to agricultural research through the pilot testing of climate-resilient varieties of high-value crops in areas of the country that are drought-prone (northwest) and vulnerable to cyclones, flood surges, and salinity intrusion (southwest).

<sup>12</sup> See Naylor et al. (2007) for the use of seasonal forecasts.

research are needed to achieve significant productivity improvements by means of plant breeding and gene manipulations (Turrall et al. 2011).

An alternative classification of adaptation options, consistent with the classification developed above, is presented in Box 7.

### Box 7. Selected Adaptation Options

#### Technological Developments

- **Crop development.** Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture, and other relevant climatic developments.
- **Weather and climate information systems.** Develop early warning systems that provide daily weather predictions and seasonal forecasts.
- **Resource management innovations.** Develop water management and farm-level resource management options to address the risk of moisture deficiencies, increasing frequency of droughts, changing temperature, and other relevant climatic conditions.

#### Government Programs and Insurance

- **Agricultural subsidy and support programs**
  - » Modify crop insurance programs to influence farm-level risk management strategies with respect to climate-related loss of crop yields.
  - » Change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate-related income loss.
  - » Modify subsidy, support, and incentive programs to influence farm-level production practices and financial management.
  - » Change ad hoc compensation and assistance programs to share publicly the risk of farm-level income loss associated with disasters and extreme events.
- **Private insurance.** Develop private insurance to reduce climate-related risks to farm-level production, infrastructure, and income.
- **Resource management programs.** Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions.

#### Farm Production Practices

- **Crop selection and crop calendar**
  - » Change to a crop with greater resilience to water shortages or greater economic value.
  - » Change planting dates to reflect alterations in seasonal rainfall discharge.
  - » Increase on-farm diversity of cropping mix.
  - » Increase cropping intensity where possible.

*continued on next page*

## Box 7. continued

- **Water management**

- » More efficient irrigation technologies to improve water productivity.
- » Conjunctive use of surface water and groundwater.
- » Deficit irrigation to reduce evapotranspiration.
- » Reduction in storage losses due to evaporation.
- » Alternate cultivation practices to reduce water requirements.
- » Intensification of use of other agricultural inputs.
- » Improved drainage.

- **Irrigation technologies**

- » Application of pressurized systems (e.g., sprinklers) to ensure appropriate application rates and timing of application.
- » Drip and trickle irrigation to supply water without having to saturate the root system.

The Food and Agriculture Organization (FAO) presents an alternative classification of adaptation options in the agriculture sector as follows:

Altering exposure	Reducing sensitivity	Increasing adaptive capacity
<ul style="list-style-type: none"> <li>» Assess impacts and map hazard zones</li> <li>» Conduct proper land and water use planning</li> <li>» Protect watersheds and establish flood retention zones</li> <li>» Resettle human and restructure agriculture</li> <li>» Change cropping patterns</li> </ul>	<ul style="list-style-type: none"> <li>» Develop or adopt suitable crop, plant, and animal varieties</li> <li>» Improve irrigation and drainage systems</li> <li>» Enhance soil nutrition and on-farm water management</li> <li>» Diversify cropping and agricultural activities</li> <li>» Adopt disaster-prevention construction standards</li> </ul>	<ul style="list-style-type: none"> <li>» Develop adaptive strategies and action plans</li> <li>» Diversify sources of household income</li> <li>» Improve water and other infrastructure systems</li> <li>» Establish disaster and crop insurance schemes</li> <li>» Promote technical transfer and capacity building</li> </ul>

Sources: Adapted from Smit, B. and M.W. Skinner. 2002. Adaptation response in agriculture to climate change: A typology. *Mitigation and Adaptation Strategies for Global Change*. Vol. 7, pp. 85-114; and Turrall, H. et al. 2011. *Climate Change, Water and Food Security*. Rome: FAO; FAO. 2012. *Incorporating Climate Change Considerations into Agricultural Investment Programmes: A Guidance Document*. Rome.

## Do Nothing Option

In some cases, it is plausible that sufficient risk allowance has been built into the project to account for climate change, or that the nature of the changes are too uncertain or minimal, or that the consequences of climate change are too severe to justify in situ adaptation. In the latter circumstance, a best course of action may be to allow the infrastructure to deteriorate and be decommissioned. In other cases, the up-front capital investment

associated with any technically feasible adaptation option may be so large as to outweigh any possible benefits associated with the climate proofing of the infrastructure. Not investing in adaptation in the context of a particular project may be the best course of action (from both a technical and economic assessment).

Part B presents and discusses a step-by-step approach to assessing the impacts, vulnerability, and adaptation to climate change.

# Part B: Climate Proofing Agriculture Investment Projects

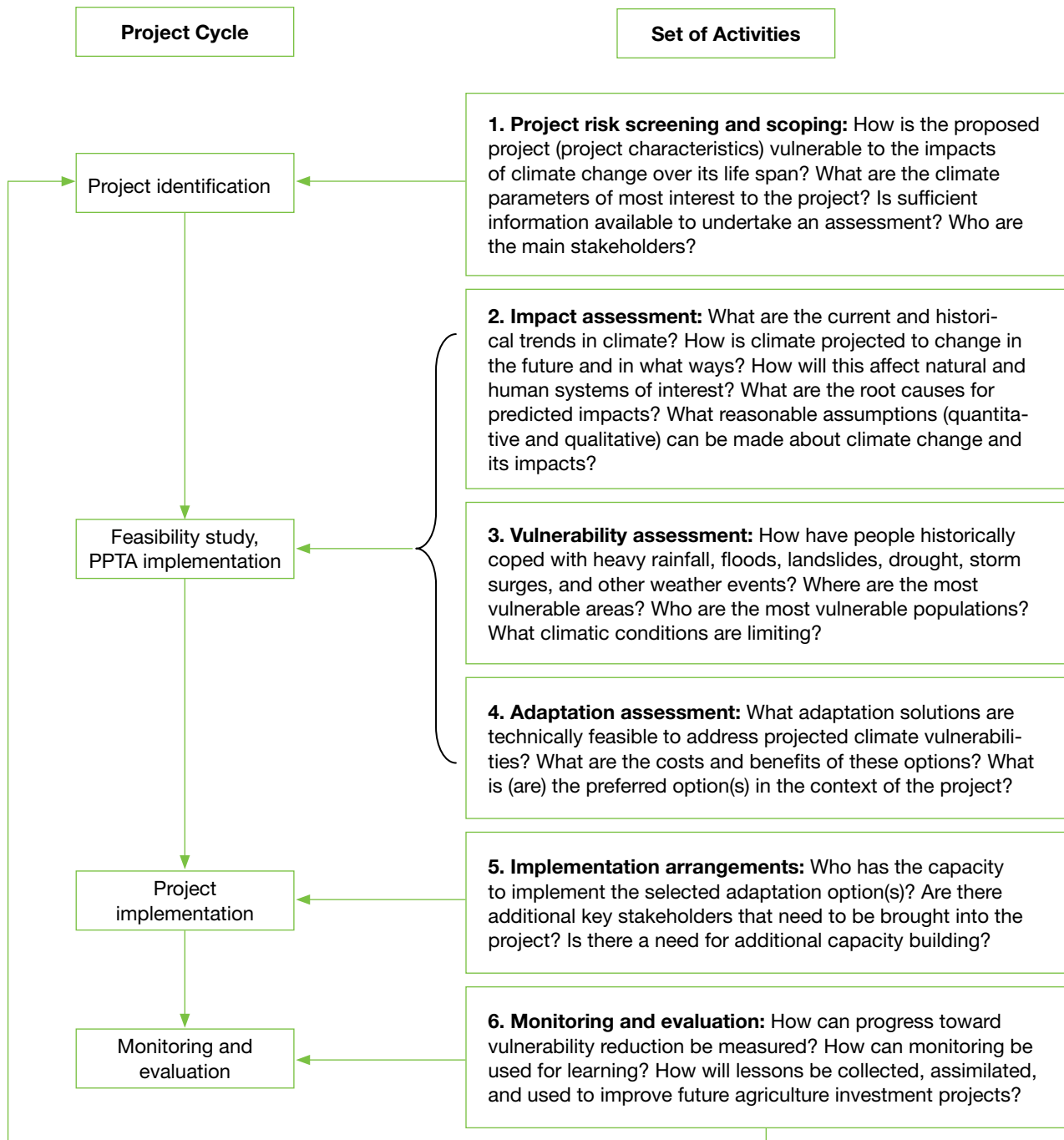
## Overview

In this *Guidelines*, the expression “climate proofing” is meant as a process that aims to identify risks that an investment project may face as a result of climate change, and to reduce those risks to levels considered to be acceptable. It does not imply a complete mitigation of the potential risks of climate change. The expression is used in a way similar to the meaning provided in ADB (2005):

Climate proofing is a shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning.

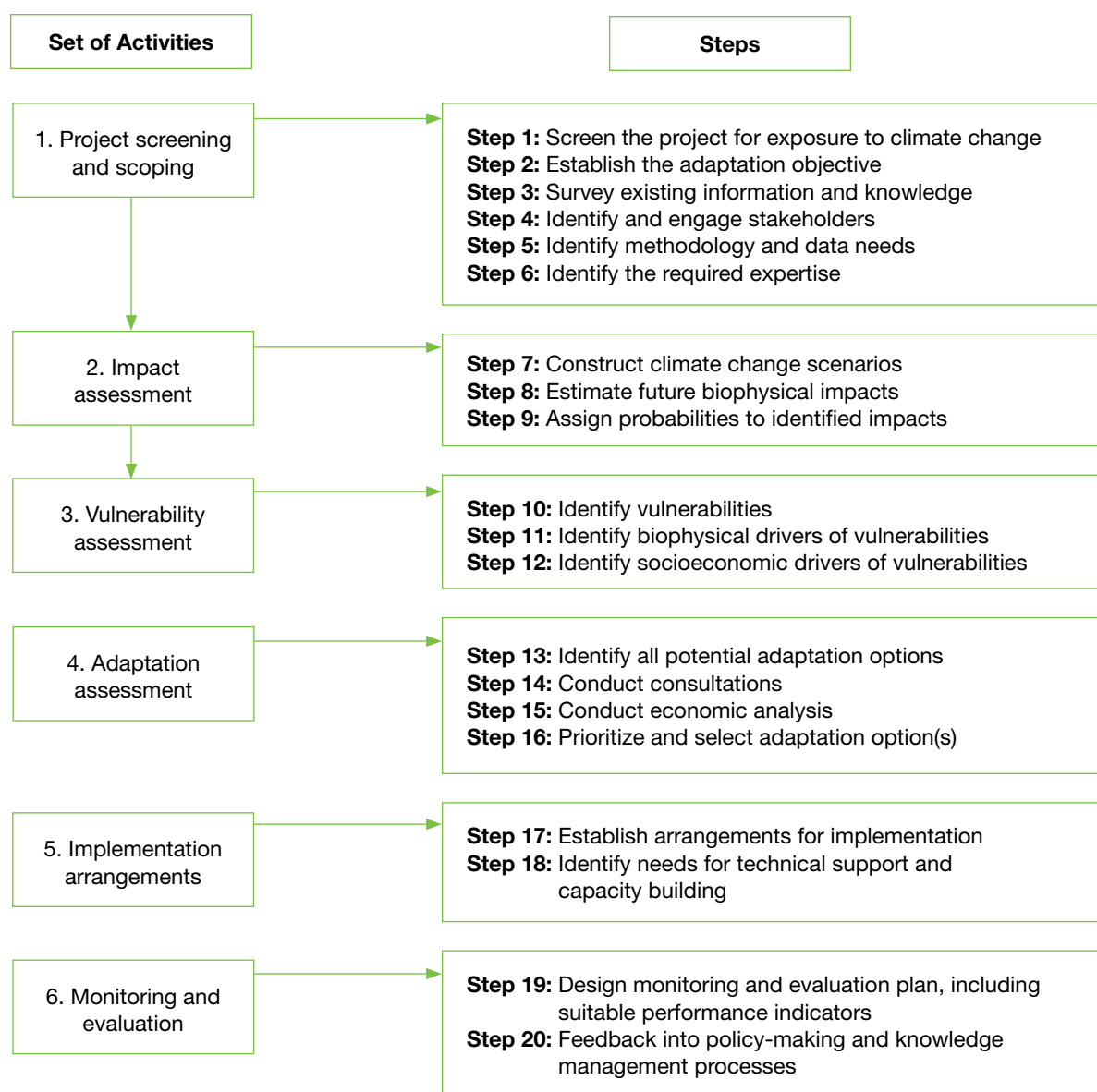
The methodological approach presented in this *Guidelines* for building adaptation into agriculture investment projects is divided into six different sets of activities (Figure 2). The process begins with scoping the project and defining the assessment and its objectives. The core activities related to project design fall under impact assessment, vulnerability assessment, and adaptation assessment. Finally, the process ends with defining implementation arrangements and monitoring frameworks. To facilitate the implementation of the methodological approach, these six sets of activities are broken into 20 steps (Figure 3). A process similar in nature as the one described above has also been referred as “adaptation science” (Box 8).

A climate change assessment is best integrated into the activities of the project preparation technical assistance, following the identification of climate change as a potential risk/opportunity factor to the project at the concept stage. For this purpose, a risk screening tool has been developed and is currently being tested by ADB (Appendix 1).

**Figure 2. Assessing Adaptation Needs and Options: 6 Sets of Activities**

PPTA = project preparation technical assistance

**Figure 3. Assessing Adaptation Needs and Options:  
6 Sets of Activities and 20 Steps**



### Box 8. Adaptation Science

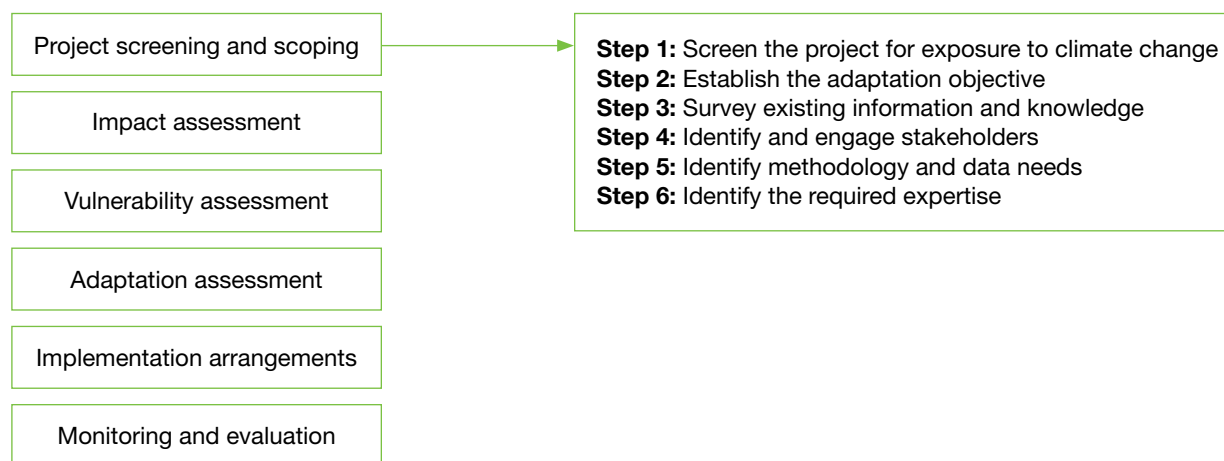
Meinke et al. (2009) defines “adaptation science” as “the process of identifying and assessing threats, risks, uncertainties and opportunities that generates the information, knowledge and insight required to effect changes in systems to increase their adaptive capacity and performance.”

The adaptation science process requires the following (in sequential order):

1. understanding the existing system and scope possible changes to norms and values;
2. identifying likely core issues and decision criteria and clarifying who, what, and when;
3. assessing climate impacts and trends, including their uncertainty;
4. evaluating if impacts matter;
5. assessing the adaptation options and their broader consequences; and
6. designing and evaluating implementation options.

Source: Meinke et al. 2009. Adaptation Science for agriculture and nature resources management—urgency and theoretical basis. *Current Opinion in Environmental Sustainability*. Vol. 1, pp. 69–76.

**Figure 4. Project Screening and Scoping**



### Project Screening and Scoping

The goal of project risk screening in this context refers to determining the potential nature and extent of risk the project may be exposed to as a result of climate change.

The goal of project scoping is to identify how climate change impacts can affect the overall project objective, and to set the boundaries within which the assessment of adaptation options will be undertaken.



### Step 1: Screen the Project Exposure to Climate Change

Risk screening tools have been developed by a number of organizations to rapidly assess the risks posed to a planned project, or caused by a planned project, as a result of climate change and natural hazards. These are meant to alert a project officer to the potential risk of climate change to the project and to determine whether further assessment is warranted. While different risk screening tools use slightly different approaches, expert opinion and judgment, based on awareness and knowledge of climate change and hazards, remain essential for all (Box 9).

ADB has developed a project risk screening tool that is being tested by a number of member countries (Appendix 1). This tool screens for risks from both climate change and natural hazards, and may be of interest at the stage of identifying and assessing project feasibility. A revised version of the risk screening tool is under development.

Alternatively, a series of screening questions specific to agriculture projects can be applied, such as those listed in Table 2.

Agriculture project components can be subject to high *direct risk* faced by the region where they are implemented—for example, agriculture production projects located in flood- or drought-prone areas, or irrigation or water management projects in areas where there is already water scarcity or an unsustainable trend in the demand for water. At the same time, agriculture project components can be subject to *indirect risks* when they have the potential to increase the vulnerability faced by the region. For example, an agricultural market reform project that removes government subsidies on certain crops can lead the farmers to switch to crops that could make them more vulnerable to climate variability and change.

One of the purposes of the risk assessment exercise at the project level is to identify the “high risk hazards” (i.e., the climate change events that are most likely to severely affect the performance of an agriculture project). The impacts from these high risk hazards can subsequently be the point of departure for identification and discussion of adaptation options. A risk score matrix is a graphic tool to classify the level of risk stemming from climate change hazards. Box 10 illustrates this with an example of climate change risk assessment in an agriculture project in Bangladesh.

### Box 9. Selected Climate Change Risk Screening Tools

Department for International Development, United Kingdom: Opportunities and Risks of Climate Change and Disasters (ORCHID) and Climate Risk Impacts on Sectors and Programmes. <http://tinyurl.com/ccorchid>

Dutch Ministry of Foreign Affairs: Climate quick scans. [www.nlcap.net](http://www.nlcap.net)

German International Cooperation: Climate check. [www.gtz.de/climate-check](http://www.gtz.de/climate-check)

World Bank: Climate change portal including ADAPT tool. <http://sdwebx.worldbank.org/climateportal>

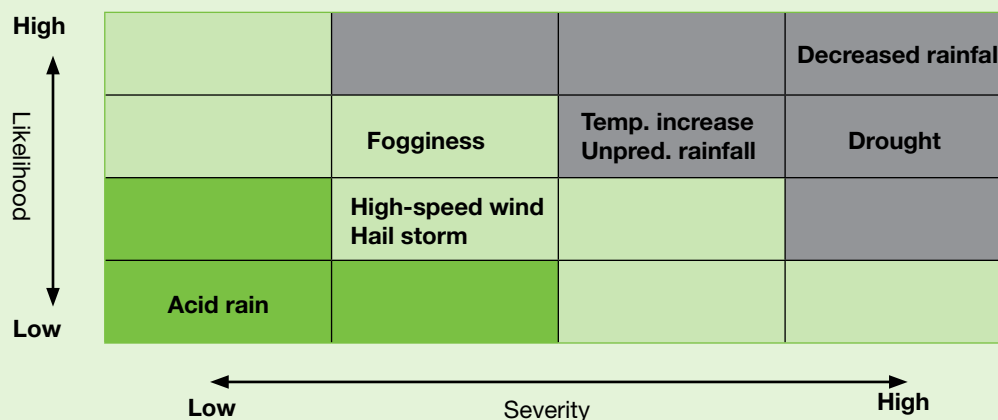
International Institute for Sustainable Development: Community-based Risk Screening Tool—Adaptation and Livelihoods (CRiSTAL). [www.iisd.org/pdf/2011/brochure\\_cristal\\_en.pdf](http://www.iisd.org/pdf/2011/brochure_cristal_en.pdf)

**Table 2. Climate Risk Screening: Example of Screening Questions**

Screening Questions	Yes	No	Remarks
Is the project area subject to climate hazards such as floods, droughts, landslides, tropical cyclones, storm surges, etc.?			
Could changes in precipitation patterns or evaporation rates over the life span of the project affect its cost and sustainability (i.e., decreased crop productivity and income, decreased water delivery, increased maintenance costs)?			
Are there any demographic or socioeconomic aspects of the project and project area that increase the vulnerability of the project to climate change?			
Could the project potentially increase the vulnerability of the surrounding area (i.e., by increasing runoff or by reducing available water supply)?			

**Box 10. Risk Score Matrix in Bangladesh**

By using a risk score matrix, different climate change hazards are divided into “high” risks (gray zone), “moderate” risks (light green zone), and “low” risks (green zone) based on how the hazards adversely impact the socioeconomic circumstances of farming households. In this case, as it can be seen from the figure, temperature increase and decrease and unpredictability in rainfall and drought are all located in the gray “high” risk area. Likewise, it can be seen that foggiess, high-speed winds, and stone rain/hail storm are considered to be of “moderate” risk, and that the risk for acid rain is “low to none.” It should be noted that risks due to the various hazards in this case are located throughout the whole diagram.



Source: Danish International Development Assistance (DANIDA). 2009. *Bangladesh Climate Screening Report* (draft).

The project scoping for adaptation will need to cover the following aspects of climate change impacts at the project level:

- direct threats to the project (e.g., effect of extreme weather events on rural infrastructure and standing crops);
- underperformance of the project (e.g., irrigation investments that fail to pay off when rainfall decreases);
- maladaptation, as when the project triggers settlement in vulnerable areas or decreases the resilience of agricultural production systems; and
- new opportunities to improve project performance that may arise from climate change and could be captured if factored into project design.

## Step 2: Establish the Adaptation Objective

A project's adaptation needs should be considered from two perspectives:

- (1) The risk climate change poses to the achievement of the project objective and outcomes, such as
  - reduced income opportunities for rural livelihoods;
  - reduced food security in the region;
  - reduced access and mobility of rural communities to markets due to road closures;
  - decreased crop yields due to heat stress or long periods of drought;
  - poor suitability of existing crops in the specific region as a result of climate change;
  - loss of agricultural land due to floods, desertification, or sea level rise (salinity);
  - decrease in water quality and performance of irrigation infrastructure;
  - irrigated water allocation and crop rotation schedules become unsustainable due to overall reduction of river discharge and total precipitation in the area;
  - increasing maintenance costs due to decreased water availability or increased occurrence of high-intensity rainfall events; and

- alternatively, some benefits may arise such as increased yield for some crops, suitability for new crops, or potential for multiple cropping.

- (2) The risks the project may pose by increasing the vulnerability of the surrounding area and population, such as
  - promoting settlements in areas where agricultural production systems can suffer significantly from future climatic stresses;
  - increased access into ecologically sensitive areas, which reduces environmental buffers against floods and droughts or other ecosystem services including water quality, biodiversity, and carbon sequestration; and
  - promotion of unsustainable agriculture water use.

Desirable features of agriculture production projects, such as enhancing agricultural competitiveness or value chain analysis, are exposed to climate change risks such as chronic supply breaks due to increased climate variability. For example, drought and flood risks can have a significant impact on the production chain.

Irrigation infrastructure projects will be subject to climate risks such as decreased water availability due to changes in precipitation patterns, increased evapotranspiration losses due to higher temperature, and general climate change impacts on basin-wide water resources.

The adaptation-related activities should seek to minimize these potential negative effects. Establishing how climate change may affect the project site and outcomes will assist in ensuring that the right data is collected throughout, that the right expertise is recruited from the outset, and that the most appropriate national or regional partners are brought into the project. The vulnerability, impact, and adaptation assessments that follow are intended to assist in further refining how climate change may impact on a project.

### Step 3: Survey Existing Information and Knowledge

A large amount of work related to climate change is ongoing in many countries, including governmental planning and policy processes as well as research and development programs such as those under the United Nations Framework Convention on Climate Change (UNFCCC). Identifying existing available information can help to avoid duplication of effort and ensure that coordination efforts within countries and between donors are being supported. Each country has a climate change focal point<sup>13</sup> under the UNFCCC and will, in most cases, have prepared a national communications to the UNFCCC, which is a good starting point for understanding the government's efforts related to climate change.<sup>14</sup> Least developed countries have also prepared national adaptation programs of action to identify their most urgent adaptation needs.<sup>15</sup> While some of these documents may benefit from being revised and updated, they provide a good basis for identifying country needs and a focal point around which to coordinate the multiple climate change initiatives underway.

In addition, the Global Environment Facility's Adaptation Learning Mechanism provides a list of country-level adaptation initiatives, together with relevant technical resources relating to climate change impacts and vulnerability assessments.<sup>16</sup>

### Step 4: Identify and Engage Stakeholders

Having an initial scope for the adaptation work as well as a survey of existing information will likely

expand the relevant stakeholders to include climate change focal points, disaster risk reduction focal points, and possibly flood management agencies. A number of institutions and research organizations may be conducting work relevant to the project. Further, specific engagement of local communities, nongovernment organizations, and small to large businesses operating in the area will be important for conducting a vulnerability assessment and for engagement in selecting the most effective adaptation strategies.

### Step 5: Identify Methodology and Data Needs

A preliminary identification of the climate parameters of greatest interest to the project should be initiated at the concept stage and can be further developed at later stages. Climate change parameters of interest (including variability and seasonal patterns) to agriculture projects include

- temperature (mean, minima and maxima),
- precipitation,
- relative humidity,
- sunshine hours, and
- wind velocity.

Specifying these requirements at the outset is important as it will guide the choice and extent of the information to be collected and used for assessing possible impacts and vulnerability.

Identifying the method(s) for the assessment and prioritization of options, such as cost-benefit analysis or multi-criteria analysis (among other possible

<sup>13</sup> Details of the national focal points are available at <http://maindb.unfccc.int/public/nfp.pl>

<sup>14</sup> National communications submitted by developing country parties to the UNFCCC are available online at <http://unfccc.int/2979.php>

<sup>15</sup> The following ADB developing member countries have prepared national adaptation programs of action: Afghanistan, Bangladesh, Bhutan, Cambodia, Kiribati, Lao People's Democratic Republic, Maldives, Nepal, Samoa, Solomon Islands, Tuvalu, and Vanuatu. They are available at <http://unfccc.int/4585.php>

<sup>16</sup> These country profiles can be accessed at [www.adaptationlearning.net/country-profiles](http://www.adaptationlearning.net/country-profiles)

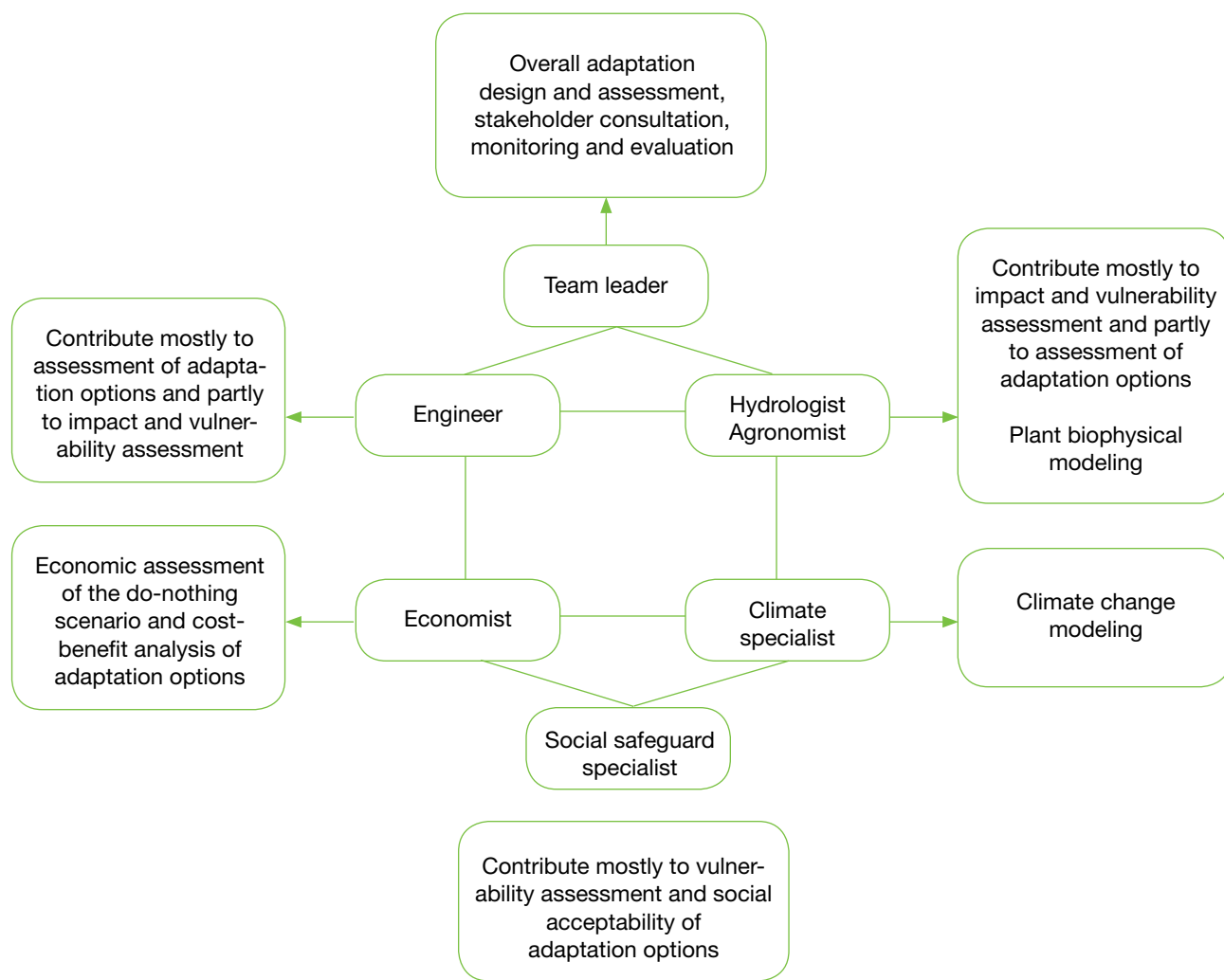
methodological approaches), will also determine and ensure that the needed data is collected during project preparation.

### Step 6: Identify the Required Expertise

The assessment of adaptation options requires interaction between different experts (Figure 5). Many of the activities required to develop a climate

change adaptation assessment for a project can be undertaken through an expansion of the tasks of a classic project preparation team, such as the project engineer and environmental specialist. Similarly, the economist conducting the economic analysis of the overall project may be in a position to assess the costs and benefits of the project with and without adaptation.

**Figure 5. Assessing Adaptation Needs and Options: A Web of Interaction**



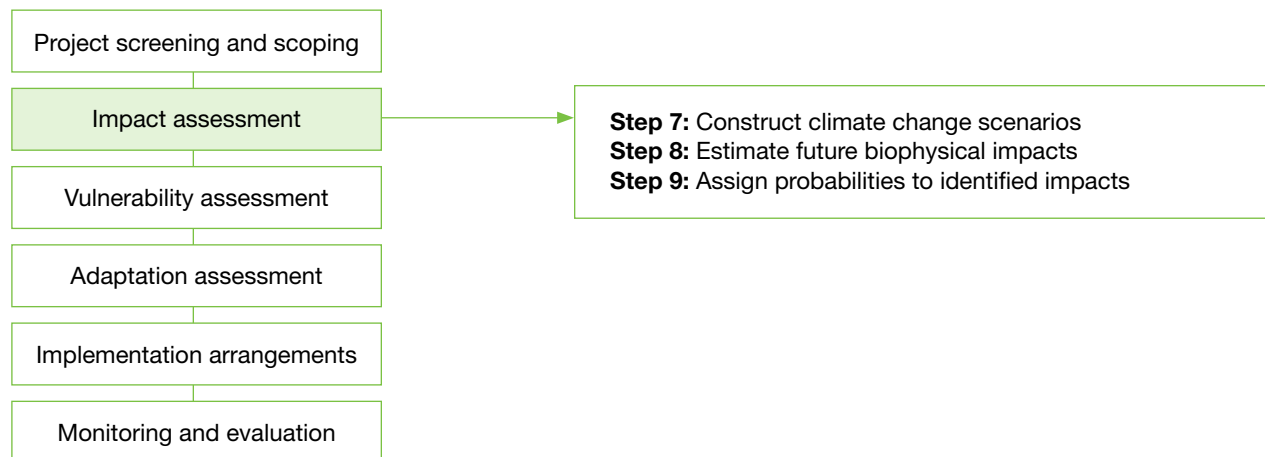
Appendix 2 provides examples of additional integrated activities for existing team members and a set of detailed terms of reference for impact, vulnerability, and adaptation assessments. These are meant to indicate the general nature of the tasks and deliverables that may be required, rather than providing a comprehensive list of such tasks and deliverables.

## Impact Assessment

The goal of the impact assessment is to identify and evaluate, in physical terms, the effects of climate change on natural and human systems. Typically, this entails (1) the analysis of current trends in relevant climate parameters, and observed impacts of these climatic trends on the natural and human systems; (2) development of climate, sea level, and socioeconomic scenarios for the relevant time frame, and at appropriate temporal and spatial scales; and (3) assessment of biophysical impacts of socioeconomic and associated climatic changes as well as sector- and/or system-specific analytical tools.

For any given project, the decision of which emissions scenarios and climate projections to use or develop is based on a number of factors, including the need to account for a wide range of uncertainty, time frames, budget, and data availability. In an increasing number of cases, climate change projections have already been developed through national and regional climate change initiatives, such as the national communications to the UNFCCC, and may be adapted for use by the project. In other cases (such as in Viet Nam), government has adopted an “official” set of climate change projections against which all line ministries must design their adaptation action plan (MoNRE 2009). It is thus important to begin by identifying whether climate projections are already available, as developing such projections can be costly and time consuming. It is also important to recognize that even with “localized” climate projections, these may not be to a desired spatial resolution at the project level. In all cases, understanding the history of climate (temperature, rainfall, storm surges, and extreme weather events) is always a necessary first step.

**Figure 6. Impact Assessment**



### Step 7: Construct Climate Change Scenarios

Climate projections represent the response of the climate system to emissions or concentration of greenhouse gases. They are typically based on simulations by climate models. Climate change projections can be useful in determining how climate variables such as temperature and precipitation may change in the future. However, projections based on climate model outputs are limited by the imperfect representation of the climate system within climate models, in addition to uncertainties associated with future greenhouse gas emissions. Therefore, climate projections are not forecasts or predictions, but provide plausible alternative characterizations of future climate conditions. They are helpful in exploring “what-if” questions; they do not aim to provide accurate predictions of how climate will behave in the future.

The IPCC’s Task Group on Data and Scenario Support for Impact and Climate Assessment provides general guidance on the use of data and scenarios in impacts and adaptation assessments.<sup>17</sup> The following points provide further information on guiding the development of climate change scenarios.

#### ***Identifying the relevant climate variables needed for the impact assessment***

The construction of climate change scenarios begins with an understanding of which climate variables are likely to affect the project. Individuals creating climate change scenarios need to discuss data needs with the team of experts assessing impacts for the agriculture project. The impact assessment experts must identify the variables they need as well as the required spatial and temporal resolution (e.g., 100 square kilometers at a daily time step). The climate change expert then

will be in position to determine how to meet the expressed needs for information

#### ***Learning from the past: Establishing the climate baseline***

Past climate data is generally needed to develop climate projections, given that biases are often found in climate model simulations. Observed meteorological data is also more reliable than climate models when it comes to representing climate variability on the project site. The analysis of historical data helps to identify trends in the main climatic variables and also allows for the ground-truthing of the simulation results from climate models. Historical climatic data can be used to assess the ability of a given climate model to reproduce local climate conditions (skill score)<sup>18</sup> by validating model simulations against the observational record. In addition, a climate baseline is needed to serve as a benchmark against which potential impacts of projected climate change can be assessed.

Impact assessments typically use observed meteorological data to define the “current climate baseline.” This baseline can be used to calibrate impact models and to quantify climate change impacts with respect to the climate baseline. This historical analysis can then shed light on the climate variables that crucially affect agriculture projects.

In general, detailed climatic data can be obtained from the national meteorological service of a given country. The main challenge in using local climate data is the availability of hydrometeorological stations with sufficient and consistent data representative of climate conditions of the project site. In many countries, it is common for weather data to be inconsistent (e.g., the weather station changed location) or incomplete (e.g.,

<sup>17</sup> Available at [www.ipcc-data.org/guidelines/TGICA\\_guidance\\_sdciaa\\_v2\\_final.pdf](http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf)

<sup>18</sup> See for example Tebaldi et al. 2006.



the weather station was not operational for periods of time). Furthermore, the weather station network may not cover the project area—the closest station may be far away from the project site. In such circumstances, spatial interpolation techniques may be used to solve coverage problems and data generation algorithms can improve completeness and consistency of data.

**Using climate projections from general circulation models: Model selection and downscaling techniques<sup>19</sup>**

Climate change scenarios are normally constructed using climate projections from general circulation models (GCMs). GCMs are computer models used to simulate the earth's climate systems. GCMs are the main tools used to project future climate changes due to the continued anthropogenic inputs of greenhouse gases. The major advantage of using GCMs as the basis for creating climate change scenarios is that they estimate changes in climate for a large number of climate variables, such as temperature, precipitation, pressure, wind, humidity, and solar radiation, in a physically consistent manner.

However, an analyst faces a number of issues when it comes to constructing climate scenarios using the projections from GCMs:

- *Model errors and biases:* GCMs may underestimate or overestimate current temperatures and precipitation and hence may not properly represent the climate in a region.
- *Uncertainty:* An additional disadvantage of GCM-based scenarios is that a single GCM, or even several GCMs, may not represent the full range of potential climate changes in a region.

- *Resolution:* GCMs do not produce information on geographic and temporal scales fine enough for many impact assessments at the project level. GCMs typically provide projections at a horizontal resolution of hundreds of kilometers, and are generally reported at monthly or seasonal time scales.

**Downscaling: From global to local climate projections**

The limitation that pertains to the coarse resolution of GCMs can be overcome by a process known as downscaling. Downscaling methods increase both spatial resolution (e.g., from hundreds to tens of kilometers) and temporal resolution (e.g., from monthly to daily).

There are two main approaches<sup>20</sup> for downscaling: dynamical downscaling (using regional climate models) and statistical downscaling (using empirical relationships). Each downscaling method has its strengths and limitations, and the appropriate method will depend on the specific needs of the impact assessment, data availability, and budget. However, it is important to note that since downscaling is a transformation of GCM outputs, it cannot add skill or accuracy that is not present in GCMs. If GCMs do not accurately project changes in large-scale atmospheric circulation patterns, downscaling techniques cannot correct the errors.

Appendix 3 provides further details on the different downscaling approaches that can be used to construct climate scenarios. The best approach to use for a given project is chosen based on the adaptation decision context, availability of data, time frame, and budget.

<sup>19</sup> See Trenberth et al. 2007 for an in-depth discussion on general circulation models.

<sup>20</sup> For a comprehensive discussion on the topics of downscaling, see Wilby and Wigley 1997, Wilby et al. 1998, Wood et al. 2004, and Wilby and Fowler 2011.



### Sea level rise

It is important to note that sea level rise is not a direct output of most GCMs. Methods to derive sea level rise include both global (global thermal expansion and meltwater from glaciers, ice caps, and ice sheets) and local (local land subsidence and local water surface elevation) components. Estimates of local apparent sea level rise take into account the vertical movement of land and coastal erosion. In spite of the importance of global sea level rise scenarios, when assessing impacts it is the local change in relative sea level that matters, not the global average. Relative—or observed—sea level is the level of the sea relative to the land. Subsidence of the land results in a relative sea level rise that is higher than the global rise, whereas uplift of the land leads to a relative rise that is less than the global average. This indicates that using global estimates of sea level rise (as provided by the IPCC, for example) may not be appropriate given local circumstances.

Accurately estimating sea level rise at a project site requires extensive data collection. The most relevant variables are (i) coastal geomorphology and topography, (ii) historical relative sea level changes, (iii) trends in sediment supply and erosion and accretion patterns, (iv) hydrological and meteorological characteristics, and (v) oceanographic characteristics. Using this data, hydrological digital elevation models can be used to estimate the area inundated given a specific assumption about the amount of sea level rise. When available, a detailed assessment on inundation areas with and without flood protection infrastructure can be done. For many countries where information on coastal elevations is lacking, surveying (sometimes airborne laser scanning) can be conducted to provide these most basic and essential data for sea level rise projections.

Due to the fact that coastal surveying and hydrodynamic simulations can be quite expensive, an acceptable alternative to identify geographical areas that may be exposed to any given level of sea rise is to use a geographic information system (GIS) approach. An overlay of coastal elevation data from satellite measurements and different sea level rise conditions can produce a reasonable approximation of coastal impacts.

### Step 8: Estimate Future Biophysical Impacts

Once climate change scenarios have been constructed, key relationships between changes in climate parameters—such as average temperature, average precipitation, temperature and precipitation extremes, sea level rise, and storm surges—and impacts on the agriculture must be quantified.

Modeling of future climate impacts on complex food security systems is still very much a research subject, particularly local impacts in agricultural systems at the project level. A summary of the methods used to analyze the impacts is presented in Table 3. Each of these methods yield information on different types of impacts. For example, *simple agroclimatic indices* can be used to analyze large-area shifts of cropping zones, whereas *process-based crop growth models* should be used to analyze changes in crop yields. Effects on income, livelihoods, and employment are assessed using *economic and social forms of analysis*.<sup>21</sup> In general, these models can provide information on how climate will affect crop production, employment, and income in rural areas.

If the project is dependent on supplemental irrigation from either surface water or groundwater sources, hydrological modeling will also be required to determine the likely impacts of climate change on

<sup>21</sup> Padgham (2009) reviews some of the crop models and their limitations. World Bank (2009) provides a review of economic models for agriculture impact analysis.

**Table 3. Methods to Estimate Biophysical Impacts in Agriculture**

Type of model	Description and use	Strengths	Weaknesses
Agroclimatic indices and geographic information systems	<ul style="list-style-type: none"> <li>Based on combinations of climate variables important for crops</li> <li>Used in many agricultural planning studies</li> <li>Useful for general audiences</li> </ul>	<ul style="list-style-type: none"> <li>Simple calculation</li> <li>Useful for comparing across regions or crops</li> </ul>	<ul style="list-style-type: none"> <li>Climate-based only</li> <li>Lack management responses or consideration of CO<sub>2</sub> fertilization</li> </ul>
Statistical models and yield functions	<ul style="list-style-type: none"> <li>Based on empirical relationship between observed climate and crop responses</li> <li>Used in yield prediction for famine early warning and commodity markets</li> </ul>	<ul style="list-style-type: none"> <li>Present-day crop and climatic variations are well described</li> </ul>	<ul style="list-style-type: none"> <li>Do not explain causal mechanisms</li> <li>May not capture future climate–crop relationship.</li> <li>May not be location specific</li> </ul>
Process-based crop models	<ul style="list-style-type: none"> <li>Calculate crop responses to factors that affect growth and yield (i.e., climate, soils, nutrients, and management)</li> <li>Used by agricultural scientists for research and development</li> </ul>	<ul style="list-style-type: none"> <li>Process-based, calibrated widely, and validated</li> <li>Useful for testing a broad range of adaptation options</li> <li>Available for most major crops</li> </ul>	<ul style="list-style-type: none"> <li>Require detailed weather, soil and management data as well as agronomic data and model expert(s).</li> </ul>

Source: Adapted from Iglesias et al. 2007. *Adaptation to Climate Change in the Agricultural Sector*. Report to European Commission Directorate-General for Agriculture and Rural Development.

water resources in the project area. GCMs do not provide usable estimates of runoff, river discharge, or groundwater recharge, which are required to assess the performance of irrigation systems under changing climatic conditions. Physically based, numerical watershed hydrology models are best suited for this purpose, since they are in principle capable of simulating hydrologic changes in response to both climatic and land surface/land cover conditions. A range of models are available for this purpose, and models should be selected on the basis of the desired space- and time resolution and evidence of skill in simulating historical patterns of hydrologic response within the region.

Numerical hydrologic models must first be calibrated to historical conditions using available climatic and hydrologic data records. A successful calibration is demonstrated by the model's ability to simulate a wide range of hydrologic conditions (both wet and dry) observed under the present climate. To generate future hydrologic scenarios, the calibrated model is run using climate model-generated meteorological variables as inputs. Comparison of model-generated patterns of river discharge and groundwater recharge under historical and future (climate change) conditions will enable the assessment of irrigation system design and performance (Watts 2011).

It is important to note that the results of these impact assessments will have significant implications for the cost of the project. Therefore, these assessments should provide, in addition to the estimates of biophysical impacts, an explicit account of the caveats and uncertainties associated with the methods (including the underlying climate and sea level scenarios) and resulting impacts.

### Step 9: Assign Probabilities to Identified Impacts

Conducting a quantitative assessment of the need for adaptation measures requires an estimate of how likely a given climate change (and its impacts) may be. This is yet another task that requires expertise.

There are methods to estimate what future probabilities may look like. In this section we briefly describe two methods that have been used in previous agriculture impact assessments:

- One method to infer probabilities for different conditions related to climate change involves *counting the number of climate and impact models* in which the event occurs (Tebaldi and Knutti 2007) and constructing a probability distribution based on the frequency of occurrence.

- Another method to estimate probabilities at the project level is the *Monte Carlo-type simulation*<sup>22</sup> based on climate scenarios, climate sensitivity, and local change projections. This method can be used to produce probability distributions for changes in temperature and precipitation based on climate change projection scenarios. The climate data generated through Monte Carlo simulations can then be used as an input into impact assessment models such as rainfall-runoff models or agronomic models to generate a probability distribution of climate change impacts.

Additional sources of information for scenario development and impact assessments are presented in Box 11.

### Vulnerability Assessment

The goal of the vulnerability assessment is to identify current and future vulnerabilities and to understand the key determinants of this assessed vulnerability. A vulnerability assessment attempts to identify the root causes for a system's vulnerability to climate change. This work helps to compensate for uncertainties in the modeling and to ensure that adaptation measures are locally beneficial and sustainable because of their explicit relevance in the socioeconomic context in which adaptation may be taking place.

**Table 4. Likelihood Scale Used by the Intergovernmental Panel on Climate Change**

Terminology	Likelihood of the Occurrence
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability of occurrence
Likely	> 66% probability of occurrence
About as likely as not	33 to 66% probability of occurrence
Unlikely	< 33% probability of occurrence
Very unlikely	< 10% probability of occurrence
Exceptionally unlikely	< 1% probability of occurrence

<sup>22</sup> New and Hulme (2000) and New et al. (2007).

### Box 11. Additional Resources for Scenario Development and Impact Assessments

*General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment*, Version 2, June 2007. Intergovernmental Panel on Climate Change (IPCC) Task Group on Data and Scenario Support for Impact and Climate Assessment. [www.ipcc-data.org/guidelines/TGICA\\_guidance\\_sdciaa\\_v2\\_final.pdf](http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf)

Opportunities and Risks of Climate Change and Disasters (ORCHID). Institute of Development Studies. [www.ids.ac.uk/climatechange](http://www.ids.ac.uk/climatechange)

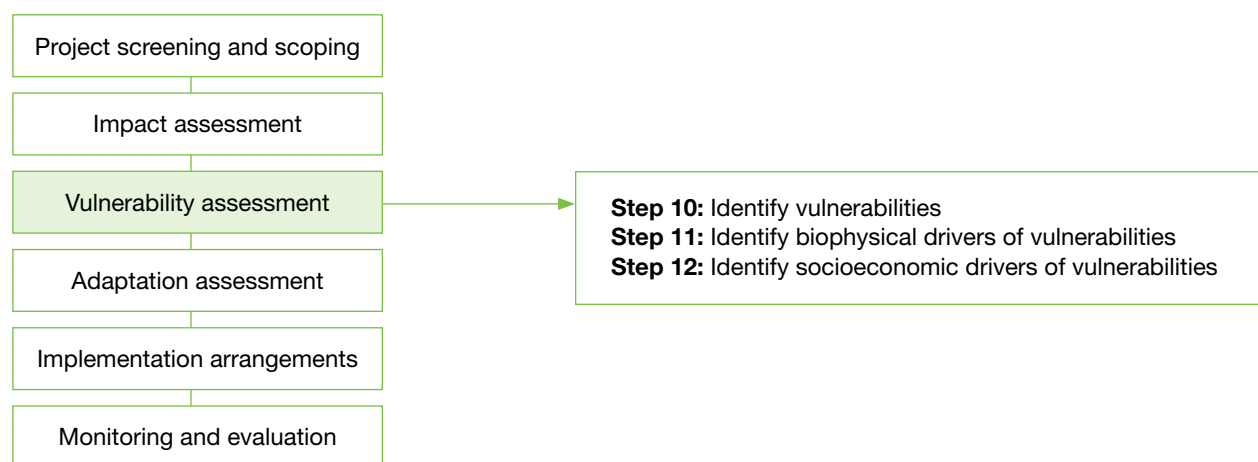
Climate Change Explorer Tool (weADAPT). [http://wikiadapt.org/index.php?title=The\\_Climate\\_Change\\_Explorer\\_Tool](http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool)

SERVIR. United States Agency for International Development. [www.servir.net](http://www.servir.net)

World Bank Climate Change Data Portal. <http://sdwebx.worldbank.org/climateportal/home.cfm?page=globemap>

The Data Distribution Centre of the IPCC. [www.ipcc-data.org](http://www.ipcc-data.org)

**Figure 7. Vulnerability Assessment**



### Step 10: Identify Vulnerabilities of the Planned Project and Area

Vulnerability refers to the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed; its sensitivity; and its adaptive capacity. Vulnerability and in particular adaptive capacity also manifest themselves locally. Indeed, the specific nature and degree of the vulnerability is very much site specific and must be assessed at the project level.

As such, identification and assessment of vulnerability at the local level will increase the likelihood that the proposed adaptation measures are relevant. Both vulnerability and adaptive capacity are also a result of the interaction between socioecological factors

and processes such as income level and income diversification, education, settlement patterns, infrastructure, ecosystem and human health, gender, political participation, and individual behavior (OECD 2009).

Hence, the information gathered during a vulnerability assessment may include local experiences related to shifting precipitation patterns and water availability, effects of warming on vegetative health, incidence of extreme climate events such as floods, and melting of permafrost. These are relevant to designing both engineering and non-engineering solutions. They are based on observable information and can be both qualitative and quantitative. Extrapolating from the present to predict how vulnerability may change in the future, given both climate and non-climate trends, is an essential step to capture the climate change impacts.

**Table 5. Indicators of Vulnerability and Measurement**

Categories of indicators	Metric	Description (units)
Biophysical indicators	Crop suitability	Soil and climate factors
	Crop yield	Grain production (e.g., tons/hectare)
	Water stress index	Ration of actual versus potential
	Drought index (such as the Palmer Drought Severity Index)	Cumulative water stress over time
Agricultural system characteristics	Land resources	Ratio of used vs. available land
	Regional cereal production	Major cereal crops (tons/year)
	Water resources	Irrigation requirements over water availability
Socioeconomic data	Economic value at risk	Net production value; agricultural GDP
	Land value at risk	Land value of areas most affected
	Nutrition index	Food demand relative to food supply
	Risk of hunger	Cumulative number of people whose calorie intake falls below a specific value (e.g., FAO calorie intake requirements)

Source: Tubiello, F.N. and C. Rosenzweig. 2008: Developing climate change impact metrics for agriculture. *Integrated Assessment Journal*. 8. pp. 165–184.

### Step 11: Identify Biophysical Drivers of Vulnerability

Some biophysical drivers of vulnerability include poor land management, deforestation, slash and burn agriculture, monoculture cropping, slope instability, and geophysical instabilities. Some ecosystems are also inherently more sensitive to changes, such as mountain ecosystems, while others are more exposed to climate changes and risks, such as low-lying coastal areas.

As a first step, it is useful to construct maps reflecting exposure to projected climate change. For example,

- future flood hazards maps can be developed using existing flood risk maps, historical rainfall maps, and projected rainfall change maps for the years 2020 and 2050;
- future drought hazard maps can be developed using existing drought hazard maps, historical rainfall and temperature maps, and projected rainfall and temperature change maps for the years 2020 and 2050; and
- maps can be developed to show the potential impacts of sea level rise.

Using GIS, it is then possible to overlay agricultural land use mapping with variables that indicate exposure to projected climate change, such as those mentioned above. The mapping can point out areas that are vulnerable because of their geographic as well as socioeconomic characteristics, such as

- areas that are sensitive due to topography (e.g., steep slopes), soil composition, geophysical instabilities, or elevation (e.g., meters above sea level);
- areas in a watershed that are exposed to climate-related hazards, including floods, landslides, and droughts; and
- areas with large number or concentration of poor households.

From this type of assessment, it is then possible to develop a significant understanding of the areas and populations most exposed and most vulnerable to climate change.

### Step 12: Identify Socioeconomic Drivers of Vulnerability

In addition to biophysical drivers of vulnerability, socioeconomic drivers should be included in the overall vulnerability assessment to provide a clear understanding of possible areas of intervention. For this purpose, biophysical vulnerability maps can be extended to examine overlaps with population areas as well as projected populations based on future growth scenarios. It is useful at this stage to identify those socioeconomic factors that influence adaptive capacities. Common indicators of adaptive capacity include human development indexes, population density, level of economic diversification, and extent of dependence on agriculture for livelihoods. Education levels and literacy rates have also been associated with a population's ability to adapt to changes.

Rural communities face multiple hazards that undermine livelihood security and exacerbate vulnerability to extreme events. Key determinants of adaptive capacity (and, inversely, of vulnerability) include

- ownership of land, livestock and other assets;
- land size and productivity;
- access to credit and markets;
- availability and affordability of agricultural inputs;
- access to cash income from off-farm livelihood activities;
- state of village infrastructure, including health services;
- gender of household head;
- connection to family and social networks; and
- effective local governance.

While it is important to recognize that climate risks may change over the lifetime of an investment project,

it is equally important to recognize that adaptive capacity can also change. This particularly may be the case in developing countries where socioeconomic conditions are often rapidly changing and population is rapidly growing. For example, an area with low population may become highly populated over the lifetime of the project. Hence, the assessment of the adaptation options may be considerably different if based on an assumption of *existing* population, ignoring that *future* population may be considerably different over the lifetime of the project. These changes in vulnerability need to be explicitly accounted for in the assessment, including the costs and benefits of the adaptation options identified during the vulnerability assessment.

Although such assessments can be time consuming, many countries have prepared development assessments that can be drawn from, such as the country profiles and International Human Development Indicators produced by the United Nations Development Programme (<http://hdr.undp.org/en/countries>).

ADB also collects key development statistics and publishes them on [www.adb.org/Economics/default.asp](http://www.adb.org/Economics/default.asp).

Finally, community participation in identifying vulnerabilities and adaptation strategies promotes good governance and ensures that measures are relevant and sustainable (Box 12). As indicated earlier, the involvement and awareness of local communities in identifying vulnerability and adaptation options contribute to the community acceptance of project activities.<sup>23</sup>

Where there can be co-benefits between climate change adaptation and other economic or social objectives, there will be increased motivation for early action. Affected stakeholders can often identify risks, benefits, and lessons from past experiences that can be factored into the design of the adaptation strategy. These factors, which are not always easily quantifiable, can contribute to decision-making processes leading to the selection of adaptation strategies.

### Box 12. Additional Resources on Community Participation

ADB Consultation and Participation Toolkit. [www.adb.org/participation/toolkit.asp](http://www.adb.org/participation/toolkit.asp)

Community Based Adaptation Exchange (CBA-X), a shared resource supporting the exchange of up-to-date and relevant information about community-based adaptation to climate change. This page contains initiatives, case studies, and lessons learned from several adaptation projects around the world. Project descriptions can be retrieved for evaluation and comparison among similar communities and ecosystems. <http://community.eldis.org/cbax>

Web-based tools such as the Community-based Risk Screening Tool—Adaptation and Livelihood (CRISTAL). These are specifically developed to assist community-based programs and provide adaptation options for farming practices and sustainable livelihoods. [www.cristaltool.org](http://www.cristaltool.org)

International Institute for Environment and Development website. [www.iied.org](http://www.iied.org)

<sup>23</sup> The ADB manual on consultation and participation tools, techniques, and templates offers further specialized information on this subject and can be found at [www.adb.org/participation/toolkit.asp](http://www.adb.org/participation/toolkit.asp). While many of these tools do not specifically focus on climate change, they can be adjusted to include such inquiries. Many countries have prepared national adaptation programs of action with an emphasis on community-level vulnerability analysis.



## Adaptation Assessment

The goal of the adaptation assessment is to identify and prioritize the most appropriate adaptation measures to incorporate into the project. This includes the identification of strategies to minimize damages caused by the changing climate and to take advantage of the opportunities that a changing climate may present.

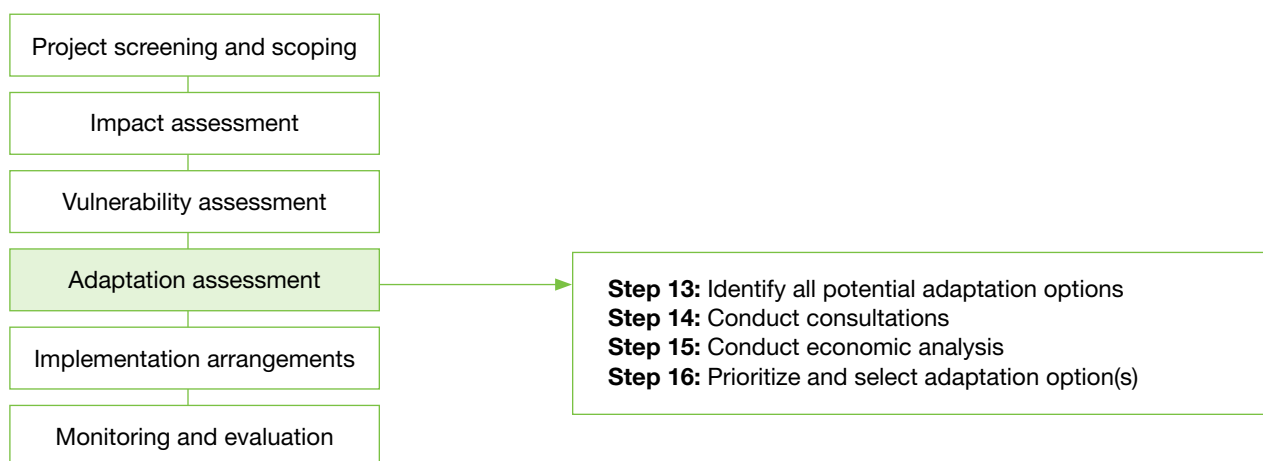
The adaptation assessment results in a prioritized list of adaptation options for implementation, which are selected from among several options such as changes in engineering designs, biophysical- and ecosystem-based measures, alignment changes, and business-as-usual or “do nothing.” Their prioritization can be based on an assessment of their respective benefits and costs in the context of the project goals but can also be prioritized on the basis of opportunities for synergies, national priorities, or co-benefits, which cannot be easily quantified. In reality, project developers often have access to imperfect data and

therefore more qualitative methods of selection, such as multi-criteria analysis, can be used. Often, the method used will be dependent on the needs of decision makers and financiers.

In some cases, the best adaptation solutions may be beyond the scope of an existing project but should be taken up as part of upstream planning and can be “flagged” for such higher-level discussions, as discussed in Part C of this *Guidelines*. For example, improved upstream land management may be the most effective way of reducing damages from flooding downstream but can be difficult to address in the context of a specific agriculture project.

Nevertheless, this observation can be used to revise policies and plans to prioritize more integrated or “climate resilient” agriculture planning and management. For this reason, casting the identification of adaptation options widely is encouraged in order to influence both the project and policy levels. In some cases, project implementation

**Figure 8. Adaptation Assessment**





arrangements are flexible enough to incorporate non-agriculture specific adaptation measures, as can be the case with executing agencies with cross-cutting mandates, such as ministries of rural development. Parallel or piggyback projects or programming can also allow for greater flexibility to implement comprehensive adaptation strategies that climate proof agriculture projects and/or irrigation infrastructure.

The expertise required is multidisciplinary and as such is one of the more challenging aspects of adaptation planning. Options must be scientifically sound, socially beneficial, and economically viable. Roundtable discussions involving different stakeholders can work well and can include, for example, the project engineers, environmental specialists, social safeguards experts, nongovernment organizations, implementing entities, and national climate change representatives.

### Step 13: Identify All Potential Adaptation Options

Based on an understanding of expected and current climate change impacts and vulnerabilities, the project team can identify a wide range of adaptation options.

A range of adaptation options has been discussed in Part A. Comprehensive lists of adaptations options have been presented in numerous papers, including ADB (2009a), Iglesias et al. (2007), World Bank (2009), and Turrall et al. (2011).

### Step 14: Conduct Consultations

As may be understood from the partial list of adaptation options, the identification of adaptation options will necessarily involve inputs from a number of stakeholders. Conducting roundtable consultations provides useful input for the process

of identifying and appraising the whole range of adaptation options.

### Step 15: Conduct Economic Analysis

The goal of the economic analysis of adaptation options is to provide decision makers with information pertaining to the expected costs and benefits of each technically feasible option and to rank these options according to the net total benefit (measured in present value terms) that each delivers. In circumstances where all adaptation options are expected to deliver exactly the same benefits, it is sufficient to undertake a cost-effectiveness analysis where adaptation options are compared simply in terms of the cost of achieving the stated benefits. In this sense, the cost-benefit analysis of adaptation options is no different than for any other investment project and will be implemented along a similar stepwise process.<sup>24</sup>

This being said, a specific feature of climate change pertains to the uncertainty associated with its various impacts. For example, will extreme weather events become more frequent or more severe, and if so, by how much? Or will the recurrence of flood or drought events increase? Given the significant uncertainty associated with the predicted impacts of climate change, conducting a cost-benefit analysis of adaptation options requires paying particular attention to the treatment of risk and uncertainty (arguably more so than any other exogenous factors impacting a project's costs and benefits).

This process is described in more detail below.

#### ***The methodological approach to cost-benefit analysis of adaptation options***

The cost-benefit analysis of climate change adaptation options is to a large extent similar to the

<sup>24</sup> See Boardman et al. (2010) for a description of the stepwise process.

type of cost-benefit analysis developed in the context of natural disaster risk management.<sup>25</sup> As such, it is important to recognize that the economist's task is to monetize the impacts of climate change and of the adaptation options that have been identified and quantified by other experts (engineers, hydrologists, etc.). As illustrated in Figure 4, the economic assessment of the adaptation options is not undertaken in isolation and requires inputs from all team experts.

A key feature of the approach is to recognize that the costs and benefits of adaptation options must be assessed by identifying and quantifying the climate change impacts along two scenarios:

**Scenario 1:** What are the *expected* impacts of future climate change on the project if no adaptation measures were in place?

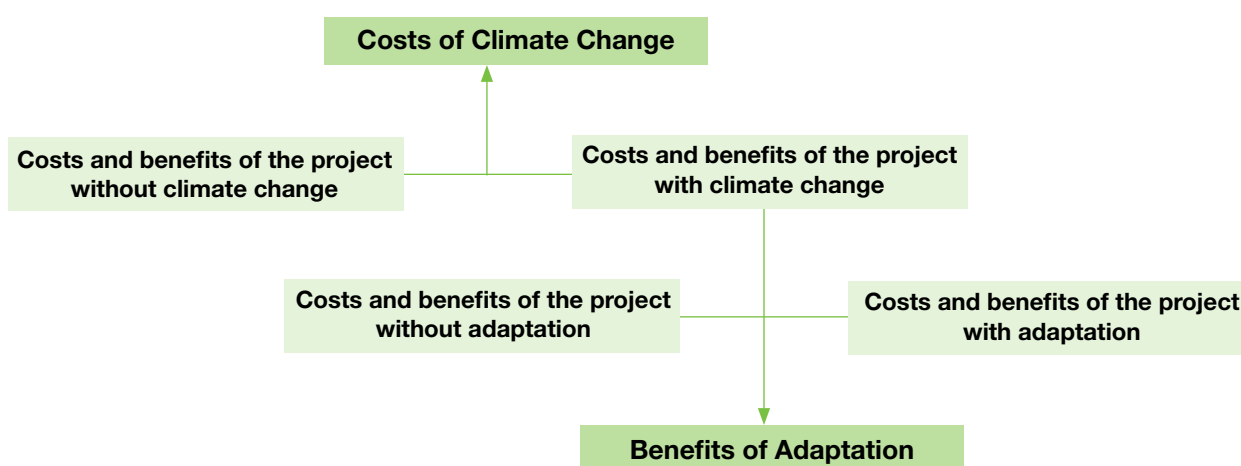
**Scenario 2:** What are the *expected* impacts of future climate change on the project if there were adaptation measures in place?

Once these two scenarios are described, the benefit of the adaptation options is assessed as the difference in the quantified and monetized impacts “with vs. without” the adaptation options in place (Figure 9).

The cost-benefit analysis of alternative adaptation options should account for at least the following three important factors:

- While all adaptation options aim to climate proof the project, some adaptation options may also deliver benefits additional to the climate-proofing benefits (co-benefits). For example, the reforestation of a hillside in order to protect

**Figure 9. Assessment of the Economic Benefits of Adaptation**



<sup>25</sup> See for example Mechler (2005).

the agricultural land from landslides may also deliver fruit crops, or the planting of mangroves to protect a road from storm surges may also serve as habitat for shrimp fisheries. These positive additional benefits need to be considered in the cost-benefit analysis and may affect the ranking of the adaptation options based on a net present value criterion.

- While all adaptation options aim to climate proof the project, some adaptation options may do so at the expense of other sectors of the economy. For example, a floodwater diversion option may keep an irrigation infrastructure functional but increase flooding in another area. These impacts, whether intentional or not, need to be accounted for in the cost-benefit analysis.
- Finally, as pointed out earlier, it is important to recognize that climate change hazards may change over the lifetime of an investment project, but it is equally important to recognize that vulnerability also may change. Hence, the assessment of the benefits of adaptation may be considerably different if based on an assumption of *existing* population, ignoring that *future* population may change considerably over the lifetime of the project. These changes in vulnerability need to be explicitly accounted for in the cost-benefit analysis.

While the overall framework presented above remains simple, a key issue is related to the treatment of risk and uncertainty in the cost-benefit analysis. While all cost-benefit analyses of any investment project are conducted in the presence of risk and occasionally uncertainty, this issue is felt to be particularly acute in the context of climate change. It is briefly addressed below.

### ***Cost-benefit analysis of adaptation: Accounting for risk and uncertainty***

Conducting any cost-benefit analysis implies looking into the future and asking what the “universe of interest” might look like *without* the project and *with* the project (the impacts of the project being the difference between these two scenarios). The exercise is fraught with incomplete information, risk, and uncertainty; this is true of all cost-benefit analyses, whether related to climate change or not. Hence, the same analytical tools currently available to account for risk and uncertainty in the conduct of a project cost-benefit analysis are of relevance in the context of assessing the costs and benefits of climate change adaptation options.

The following two approaches may be applied to explicitly account for risk and uncertainty within the framework of the cost-benefit analysis.<sup>26</sup>

#### ***Approach 1: Sensitivity analysis***

The technique most widely applied to account for risk and uncertainty is known as sensitivity analysis (or sensitivity testing).

For conducting a cost-benefit analysis of an adaptation option, this simple type of analysis involves changing the value of one or more uncertain variables at a time and re-computing the option's net present value for each change. This exercise may be repeated as much as necessary.

In sensitivity testing, *switching* values are often computed, where a switching value is the value of a specific variable that makes the net present value *switch* from positive to negative, or conversely.

<sup>26</sup> ADB (2002) and Rayner et al. (2002).

The purpose of such sensitivity testing is to raise the level of confidence one has when recommending the adoption or rejection of an adaptation option.

A key advantage of sensitivity testing is that it is relatively easy to conduct.<sup>27</sup> However, it has a number of severe limitations, including the following:

- Sensitivity testing is highly subjective in that there is often no specific reason justifying the direction (smaller or larger) or the extent by which the value of a specific variable may be assumed to change.
- More importantly, sensitivity testing does not take into account the *probability* that the value of any specific variable may differ from the value originally estimated. As a result of this serious limitation, while sensitivity analysis allows computing a range of net present values within which the actual net present value of the adaptation option may fall, it does not allow computing the *expected* net present value of the adaptation option.

This last shortcoming explains the second approach used to account for risk and uncertainty in the cost-benefit analysis.

### **Approach 2: Probabilistic (or risk) analysis**

Conducting a “probabilistic cost-benefit analysis” involves attaching a probability distribution for the possible value of any given specific cost or benefit component of the project instead of attaching a single deterministic value. Such probability distributions may be constructed using historical data.

Probabilistic (or risk) analysis allows selecting multiple variables that can all be varied simultaneously

according to the specific probability distribution attached to each variable. This process, known as a Monte Carlo simulation analysis, involves randomly generating a specific value for each individual variable (cost component or benefit component) according to the specific probability distribution attached to each variable. For any given draw of specific values, the net present value of the adaptation option is calculated. This process, by means of computer, is then repeated many thousands of times.

The outcome of the analysis is a probability distribution of net present values. This probability distribution allows the computation of an “expected” net present value of the option, instead of solely a given net present value or a range of net present values. The same probability distribution also allows computing the probability that the net present value of the adaptation option will be negative.

Conducting probabilistic (or risk) analysis can be demanding if performed manually. However, packaged software allows Monte Carlo simulation analyses to be completed relatively simply.<sup>28</sup> It is important to note that the conduct of probabilistic cost-benefit analysis is an important recommendation already found in ADB (2002) to supplement the simplistic use of sensitivity analysis.

In a number of circumstances, there may exist “low-regret” or “no-regret” options that provide positive net economic benefits regardless of the actual realization of climate in the future. In effect, the possibility of exploiting low-regret or no-regret options reduces the sensitivity of the outcome of the economic analysis to specific parameterization of the probabilistic analysis.

<sup>27</sup> ADB (2002) and Rayner et al. (2002).

<sup>28</sup> Without endorsing these packages, two widely used software programs are @RISK (built as an Excel template) and Crystal Ball.

**Decision rule**

It should not be presumed that adaptation (climate proofing) should be pursued wherever technically feasible. From an economic point of view, *not* climate proofing a project may indeed be the best course of action in a number of specific circumstances. The outcome of the economic analysis of adaptation options, summarized as the net present value (NPV) of these options, will guide the nature of the recommendations.<sup>29</sup>

The decision rule guiding the selection of adaptations is similar to the decision rule for any investment project. If only one *technically* feasible adaptation option exists, then the decision rule is as follows:

- |                     |   |
|---------------------|---|
| If expected NPV > 0 | Recommend implementing the adaptation option based on the outcome of the economic analysis.           |
| If expected NPV < 0 | Recommend rejecting the adaptation option (do nothing) based on the outcome of the economic analysis. |

If more than one technically feasible adaptation option exists, then the decision rule is to select the option with the largest expected NPV. If all adaptation options yield a negative expected NPV, then the best option is to do nothing.

**Step 16: Prioritize and Select Adaptation Options**

The adaptation assessment results in a prioritized list of adaptation options for implementation, which

are selected from among several possibilities. Their prioritization can be based on an assessment of their technical feasibility, their benefits and costs, their social acceptability, and the opportunities they may offer for synergies with national priorities. While the use and outcome of a cost-benefit analysis are often given more weight in the prioritization process, it is important to recognize that other factors and criteria may also influence decision making.

The expertise required to prioritize and select adaptation options is multidisciplinary and as such is one of the more challenging aspects of adaptation planning. Options must be scientifically sound, socially beneficial, and economically viable. Roundtable discussions involving different stakeholders can work well and can include, for example the project engineers, environmental specialists, social safeguards experts, nongovernment organizations, implementing entities, and national climate change representatives.

The ingredients of multi-criteria analysis are objectives, alternative measures and interventions, criteria (or attributes), scores that measure or value the performance of an option against the criteria, and weights (applied to criteria). Table 6 presents an example of the application of multi-criteria analysis to evaluate adaptation options in agriculture projects. As indicated in the IPCC (2007) report:

Responding to climate change involves an iterative risk management process (...) taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. Risk management techniques

<sup>29</sup> While other criteria may be used to select an adaptation option (such as the economic internal rate of return), the NPV criterion is generally preferred, especially when one adaptation option has to be selected from a set of mutually exclusive adaptation options. In such circumstances, the use of the economic internal rate of return may lead to recommending an option that does not maximize society's welfare. A similar issue may arise with the use of the benefit-cost ratio criterion to rank adaptation options.

Table 6. Example of Criteria for Evaluating Adaptation Options

Assessment Indicators		Descriptions	Rating*					
Policy and Institution			N/A	5	4	3	2	1
Consistency and relevance with adaptation in national and sector policy goals		This will cover the degree of relevance of the options to the national policy, sector policy, plans, and programs						
Acceptability by implementing agency (e.g., agriculture extension)		Acceptability of the options to different organs of the implementing agencies						
Technical capacity of institution to implement adaptation options		All refer to an assessment of the capacity of the implementing agency to implement adaptation options						
Physical capacity of institution to implement adaptation options								
Financial capacity of institution to implement adaptation options								
Socioeconomic								
Acceptability by the community		Assess the familiarity and acceptability of the options to the community						
Sustainability of adaptation		Community will continue adaptation after withdrawal of support						
Probability of success in increasing adaptive capacity		Assess the degree to which an option will better prepare communities for climate change						
Economic and Financial								
Financial and technical affordability		As determined in the course of project design and feasibility analysis						
Economic returns		Assess the degree to which the option contributes to welfare						
Environmental								
Applicability and compatibility with local area farming system		Eco-specific applicability to field conditions						
Soil characteristics		Soil quality and its characteristics to support the option						
Land use		Degree of harmony with existing land use						
Water availability		Assess the degree to which the option contributes to water availability						
New pests and diseases		Possibility of intrusion of new pests and diseases as a result of the option						
Total Scores								

\*5=very high, 4=high, 3=medium, 2=low, 1=very low

Source: Yu, W. 2010. *Climate Change Risks and Food Security in Bangladesh*. London: Earthscan.

### Box 13. Additional Resources on Adaptation Learning

Adaptation Learning Mechanism. [www.adaptationlearning.net](http://www.adaptationlearning.net)

weAdapt knowledge network on adaptation. [www.weadapt.org/knowledge-base/guidance/knowledge-base](http://www.weadapt.org/knowledge-base/guidance/knowledge-base)

United Nations Framework Convention on Climate Change (UNFCCC) compendium of methods and tools to assess impacts, vulnerability and adaptation to climate change. [http://unfccc.int/adaptation/nairobi\\_workprogramme/knowledge\\_resources\\_and\\_publications/items/5457.php](http://unfccc.int/adaptation/nairobi_workprogramme/knowledge_resources_and_publications/items/5457.php)

UNFCCC database of local coping (adaptation) strategies. <http://maindb.unfccc.int/public/adaptation>

can explicitly accommodate sectoral, regional and temporal diversity, but their application requires information about not only impacts resulting from the most likely climate scenarios, but also impacts arising from lower-probability but higher-consequence events and the consequences of proposed policies and measures.

The outcome of the adaptation assessment activity may result in three different types of decisions:

**Decision of Type 1:** Invest in climate proofing the project at the time the project is being designed or implemented.

A decision of Type 1 may result from circumstances where:

- (1) the costs of climate proofing now are estimated to be relatively small while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large. This is occasionally referred to as a **low-regret** approach; and/or
- (2) the costs of climate proofing at a later point in time are expected to be prohibitive or climate

proofing at a later point in time is technically not possible; and/or

- (3) among the set of climate proofing options, there exist (an) option(s) that deliver net positive economic benefits regardless of the nature and extent of climate change, including the current climate conditions. Such options are often referred to as **no-regret** climate-proofing options; and/or
- (4) the set of climate-proofing options includes (an) option(s) that not only reduce climate risks to the project, but also have other social, environmental or economic benefits. Such options are occasionally referred to as **win-win** climate proofing options.

**Decision of Type 2:** Do not invest now in climate proofing but ensure that the project is designed in such a way as to be amenable to be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing.

For example, while current sea level rise and storm surge scenarios may not warrant the construction today of sea dykes suitable to projected higher sea level and stronger storm surges in a distant future, the base of the sea dyke may nonetheless be built large enough today to accommodate a heightening of the sea dyke at a later point in time.



A decision of Type 2 aims to ensure that the project is “ready” to be climate proofed if required. As such, the concept of **climate readiness** is occasionally being referred to. This concept is akin to the **real options** approach to risk management.<sup>30</sup>

**Decision of Type 3:** Do no changes to project design, monitor changes in climate variables and their impacts on the infrastructure assets, and invest in climate-proofing if and when needed at a later point in time.

A decision of Type 3 may result from circumstances where

- (1) the costs of climate proofing now are estimated to be large relative to the expected benefits; and/or
- (2) the costs (in present value terms) of climate proofing (e.g., retrofitting) at a later point in time are expected to be no larger than climate proofing now; and/or
- (3) the expected benefits of climate proofing are estimated to be relatively small.

Decisions of Type 2 and 3 may be referred to as **adaptive management**, which consists in putting in place incremental adaptation options over the project’s lifetime. A decision of Type 2 will differ from a decision of Type 3 in that project design will ensure “readiness” for climate proofing while Decision of Type 3 will require no changes at all to project design.

## Doing Away with Climate Projections?

A number of authors have pointed out the inherent difficulty associated with undertaking the impact and vulnerability assessments described above given

the degree of uncertainty associated with climate change. A key issue pertains to the efficacy of GCMs for climate-proofing analysis. Kundzewicz and Stakhiv (2010) have noted that GCMs still cannot reconstruct the important details of smaller scales.

On the other hand, quantified climate projections do provide information which may be of interest to project designers and sector planners in some locations and for some climate variables (for example, it is well known that there are far few differences across models pertaining to temperature projections than there are for precipitation projections). As pointed out by Kundzewicz and Stakhiv (2010), “reliance on stochastics alone (...) would be tantamount to incomplete use of available information” (p. 1088).

As a result, a number of authors refer to the concept of *robust adaptation* to climate change. The decision outcome of undertaking a process leading to robust adaptation is to a large extent similar to the types of decision described above except for the specific use of a range of climate projections obtained from the downscaling of numerous GCMs (Box 14).

Wilby (2010) points out that “characterizing uncertainty through concerted scientific action may be a tractable proposition, but there appears to be no immediate prospect of *reducing* uncertainty in the risk information supplied to decision makers” (p. 1092). The literature certainly contains warnings pertaining to the use of climate projections obtained from the downscaling of GCMs (Anagnostopoulos et al. 2010 and Water Utility Climate Alliance 2009).

<sup>30</sup> In the world of finance, the real options approach is analogous to the price paid to acquire a financial option, as the price paid allows the possibility of investing in the full asset if and when required, but not the obligation.



### Box 14. Robust Adaptation to Climate Change

Wilby and Fowler (2011) note that “the sheer scale of the uncertainty to be sampled (but never entirely quantified) by hypermatrix experiments shows the fallacy of scenario-led adaptation, and sets the scene for an adaptation paradigm based on robustness, flexibility, monitoring, and review.”

Robust adaptation measures are defined as measures which satisfy a number of “robustness principles” such as (i) low regret, (ii) reversible and flexible (to keep the cost of being wrong about future climate change as low as possible), (iii) incorporate safety or security margins to design criteria, and (iv) employ “soft” (e.g., institutional and planning solutions (Hallegatte 2009).

The search for robust adaptation measures has been characterized as follows (Wilby and Dessai, 2010):

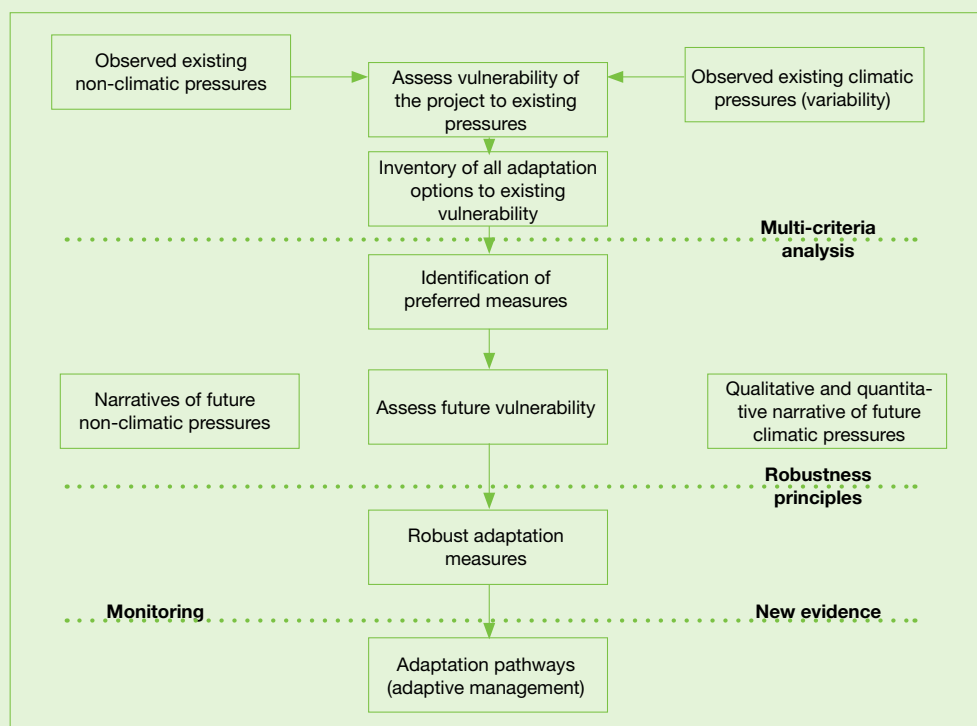
Step 1: Construct an inventory of all adaptation options for the most significant risks caused by climate change.

Step 2: Through a process of screening and appraisal, identify preferred adaptation options that would reduce vulnerability under the present climate regime.

Step 3: Describe quantitatively and qualitatively plausible changes in climate and non-climate variables to identify future vulnerability.

Step 4: Among the set of preferred adaptation options (Step 2), identify those measures which are robust to future vulnerability.

Step 5: Establish an adaptation pathway which will be shaped by a careful monitoring of the changing climate and environmental conditions, the scientific evidence, and society’s attitudes to climate risk (adaptive management).



Source: Adapted from Wilby, R.L. and S. Dessai. 2010. Robust adaptation to climate change. *Weather*. 65 (7). pp. 180–185.

## Implementation Arrangements

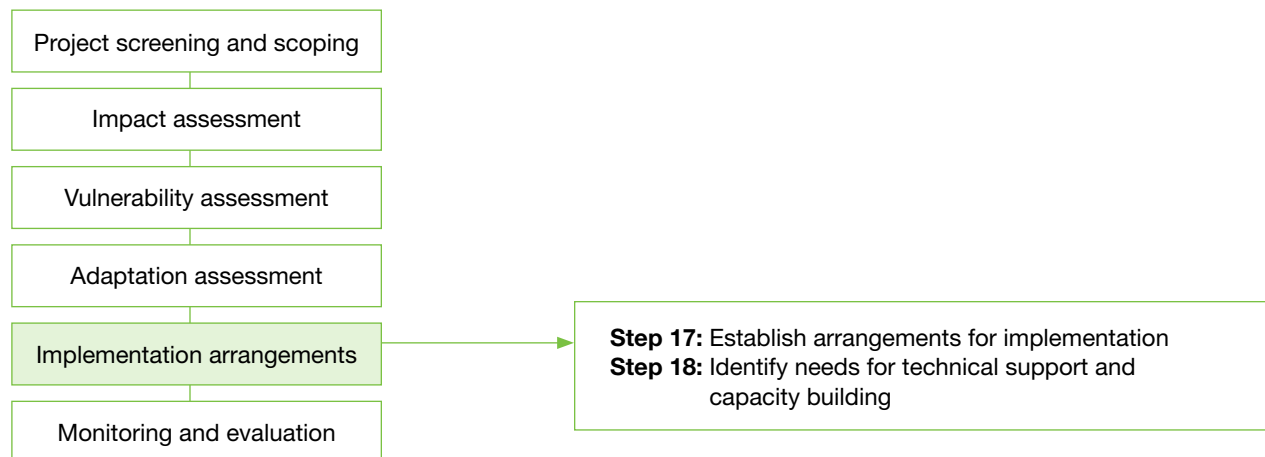
The goal of establishing implementation arrangements is to ensure the effective implementation of the identified adaptation option(s).

An ideal adaptation strategy will be fairly comprehensive and will include a mix of solutions. This is because the causes of vulnerability are diverse and will relate to social, environmental, engineering, policy, and institutional challenges. The effective implementation of adaptation strategies requires the establishment of roles and responsibilities, the identification of training needs, and the development of a monitoring and evaluation framework. Also, recognizing that the policy processes include uptake of information and recommendations from the project level, opportunities to feed back into policy processes should be seized.

### Step 17: Establish Arrangements for Implementation

A lead organization should be selected to implement the adaptation measures. While this organization may be the main executing agency responsible for the agriculture sector project (such as the Ministry of Agriculture, Ministry of Rural Development, or Ministry of Planning), involving other ministries, organizations, and institutes in the country may be needed given the nature of the adaptation activities, which may cut across sectors. For instance, climate change and disaster preparedness focal points and departments managing climate change and disaster data will need to be engaged where there are planned activities to improve the information base or early warning systems along selected roads. Many of the “low-risk” adaptation strategies, such as improved watershed management or mangrove rehabilitation to protect

**Figure 10. Implementation Arrangements**



coastal agricultural land, may require engagement of land management and forestry experts and organizations.

In all cases, examining a project and its relationship to climate and projected climate change requires identifying executing partners with capacities and mandates to coordinate and manage adaptation-related projects. While it may not be appropriate for climate change experts to be responsible for implementing projects rooted in sector plans, scientific and technical backstopping from the climate change expertise in different countries may assist in building overall capacity in the country. Finally, community participation may not be limited to the identification of vulnerabilities and adaptation options and strategies, but may also play an important role at the implementation phase.

When the project partners are already selected, the scope of the project is likely to be limited by each partner’s lines of responsibility. For instance, while the ideal adaptation approach may include engineering and environmental measures, the latter is likely to

fall outside the roles and functions of a ministry of agriculture. This adds further reasons for addressing adaptation at the earliest stages of policy and strategy development, as will be discussed in Section C.

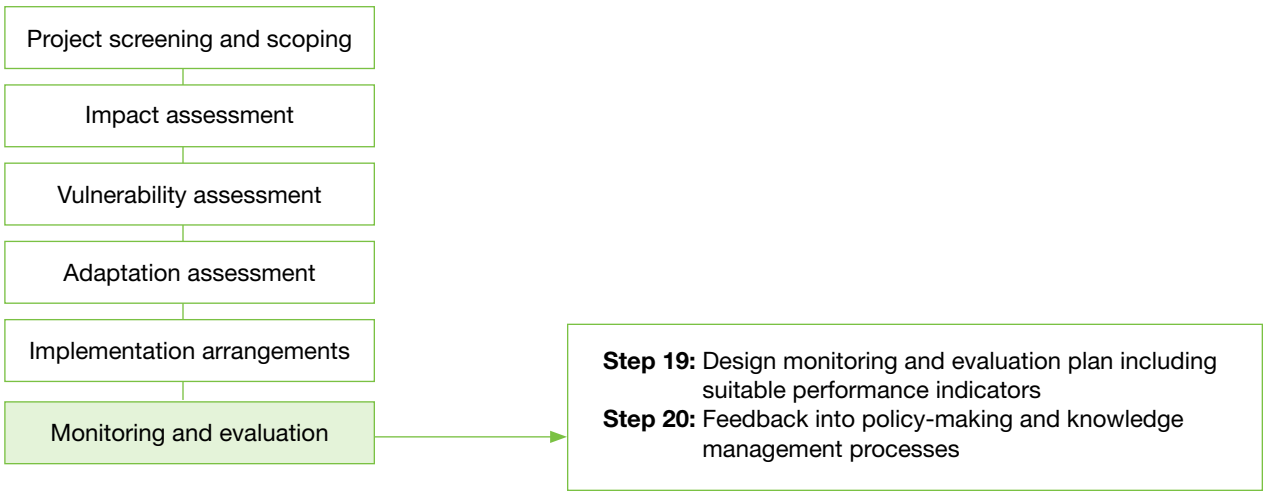
**Step 18: Identify Needs for Technical Support and Capacity Building**

Experience indicates that the capacity and awareness required to manage climate change and adaptation is currently limited. Provisions for training and capacity building will likely be needed for executing agencies, partner institutes, local communities, project management units, and contractors. An institutional assessment of existing capacity and gaps should inform this plan.

**Monitoring and Evaluation**

The goal of establishing monitoring and evaluation frameworks is to ensure accountability and that lessons are learned to inform future adaptation efforts.

**Figure 11. Monitoring and Evaluation**



Finally, establishing monitoring and evaluation frameworks will ensure accountability and implementation and is important for collecting lessons learned of effective adaptation with a view to continuous improvement and replication of good practices.

### Step 19: Design Monitoring and Evaluation Plan Including Suitable Performance Indicators

There is little experience worldwide in understanding how effective different adaptation options will be in reducing vulnerability to climate change in the agriculture sector. In such context, monitoring and evaluation are all the more important to develop this knowledge.

As indicated in Spearman and McGray (2011), monitoring and evaluation systems can provide critical support in learning what works in adaptation by helping understand

- how an adaptation intervention influences and is influenced by policies, institutions, and other factors;
- what factors contribute to autonomous adaptation;
- historical coping mechanisms and evidence of resilience to previous climate-related events;
- socially and economically acceptable levels of risk in decision making; and
- how to develop new adaptation strategies for addressing the effects of climate change.

Monitoring and evaluation systems can also provide information to

- adjust adaptation activities based on how successful they are in achieving intended adaptation objectives;
- adjust adaptation activities to address unexpected events and challenges;
- compare results across various interventions and/or different locations; and
- share learning about the outcomes of adaptation initiatives.

There are a number of challenges in developing monitoring and evaluation indicators, including the long-term nature of actual climate change, the need to acquire appropriate baseline data and metrics for measuring vulnerability, and isolating vulnerability to climate change from other sources of pressure.<sup>31</sup>

Development is ongoing for outcome-level and output-level indicators to assess the impacts of adaptation investments. ADB identifies three levels of results monitoring: impacts, outcomes, and outputs.<sup>32</sup> Table 7 provides some examples of indicators at each level. An additional example of project-level outcome and indicators is presented in Box 15. Given the challenges related to measuring for impact, which may occur beyond the project life, output-level indicators may be the most reliable.

<sup>31</sup> See the UNFCCC synthesis report on monitoring and evaluating adaptation for further details: <http://unfccc.int/resource/docs/2010/sbsta/eng/05.pdf>

<sup>32</sup> ADB. 2007. *Guidelines for Preparing a Design and Monitoring Framework*. [www.adb.org/Documents/guidelines/guidelines-preparing-dmf/guidelines-preparing-dmf.pdf](http://www.adb.org/Documents/guidelines/guidelines-preparing-dmf/guidelines-preparing-dmf.pdf)

**Table 7. Example of Indicators for Measuring Adaptation Results in Agriculture Projects**

Impacts indicators (long-term effect)	<ul style="list-style-type: none"> <li>• Increased robustness of agriculture land use and irrigation planning design and long-term investment development</li> <li>• Improved decision making and sector planning based on climate change considerations</li> </ul>
Outcome-level indicators (process indicators)	<ul style="list-style-type: none"> <li>• Supply chains for different climate-resilient crops analyzed and economic impacts and market barriers assessed</li> <li>• Agricultural land use planning in flood- and drought-prone areas analyzed and alternative land use plans developed based on climate risk scenarios</li> </ul>
Output-level indicators	<ul style="list-style-type: none"> <li>• Agriculture sector planning documents include adaptation strategies</li> <li>• Number of hectares where climate-resilient cropping practices are introduced</li> <li>• Number of hectares/communities where rainfall capture and adaptive irrigation management are introduced</li> <li>• Area of mangrove planted to protect coastal agricultural land</li> <li>• Number of agricultural officers, extension workers, and farmer cooperatives in target districts trained in climate change impacts on agricultural production and potential community-based adaptation options</li> </ul>

### Step 20: Feedback into Policy-Making and Knowledge Management Processes

An adequate adaptation strategy is likely to be composed of a number of activities including engineering measures, such as incorporating design changes, and non-engineering measures, such as ecosystem resilience measures and early warning systems for disasters. Lessons from adaptation measures undertaken at a project level should inform policy makers about appropriate approaches at the sector and/or national levels. This issue is discussed in greater detail below.

The adaptation assessment promoted here is fairly broad, where all options should be listed. A few scenarios may arise:

- The ideal mix of adaptation solutions is feasible in the context of the current project partners.
- The ideal mix of adaptation solutions requires a broadening of the partnership base to include a wider range of executing partners. Some resources for increased coordination should be foreseen.
- The adaptation assessment highlights the need for critical decision making regarding major issues such as agriculture land use planning and revised country strategies and sector policies.
- The adaptation assessment highlights needs that may not be appropriate in the context of a given project but needs warrant the development of a new project.

**Box 15. Example of Project-Level Outcomes and Indicators in Agriculture**

<b>Project objective: To reduce the vulnerability of farmers and pastoralists to increased drought and rainfall variability</b>	
<b>Outcomes</b>	<b>Indicators</b>
1. Rainfall capture and storage systems introduced or improved where rainfall is declining or becoming more variable	1.1 Number of farms and pastoralist households participating in rainfall capture and storage schemes 1.2 Farmers/pastoralists utilizing rainfall capture and storage systems for food production (% change from baseline) 1.3 Perceived impact of project expansion of rainfall capture and storage systems on food security in the event of drought
2. Irrigation introduced or expanded where feasible in areas where rainfall is declining or becoming more variable	2.1 Number of farms including smallholdings participating in irrigation schemes 2.1 Proportion of farmers utilizing efficient irrigation in cultivated areas (% change from baseline)
3. Food production methods that are less sensitive to emerging climate hazards piloted	3.1 Number of farms and smallholdings participating in “low climate sensitivity” food production methods 3.2 Farmers utilizing low climate sensitivity food production methods (% change from baseline) 3.3 Households with capacity to utilize new land resources for food production (% change from baseline)
4. Vulnerability-reduction benefits in the context of emerging climate risks integrated into food security policies	4.1 Number of policies revised to integrate climate change risks 4.2 Farmers/pastoralists utilizing seasonal forecast information provided under agricultural extension program (% change from baseline) 4.3 Number of policy makers trained in climate change risk assessment and scenario-based planning
5. Capacity to respond and adapt to changes in rainfall enhanced through use of short-term planning based on climate change scenarios	5.1 Proportion of farmers and pastoralists receiving new/improved/expanded forecast information 5.2 Farmers/pastoralists utilizing forecasts in decision making (% change from baseline) 5.3 Use of scenario planning to develop longer-term adaptation strategies at policy and local/community levels
6. All outcomes	6.1 Perceived change in food security due to measures implemented under each outcome 6.2 Perceived capacity of farmers/pastoralists to adapt to future changes in rainfall variability 6.3 Perceived ability of farmers/pastoralists to sustain interventions implemented by the project beyond the end of the project’s lifetime 6.4 Number of “lessons learned” about managing rainfall variability for food security as a result of the project 6.5 Food production deficits during years characterized by climate extremes, compared with deficits in previous years characterized by similar extremes 6.6 Attributable changes in food security among project participants

Source: Frankell-Reed, J. and N. Brooks. 2008. *Proposed Framework for Monitoring Adaptation to Climate Change*. United Nations Development Program.

# Part C: Building Adaptation into Policy and Sector Planning

## Implications for Policies and Planning

Decisions pertaining to priority areas, alignment, land zoning, spatial planning, technology, and implementation plans are made at policy and sector planning levels. Many of the examples of comprehensive adaptation strategies rely on the participation of multiple partners, such as ministries of infrastructure and ministries of environment, which is more readily established if set at the policy level.

Countries undertake policy processes in order to establish overarching frameworks for making decisions and setting priorities. Enhancing decision making by factoring in climate change risks will require a different process than for project-level interventions where many key parameters are established, such as geographic location, scale, and technology. Therein lies the difficulty with policy mainstreaming: merely mentioning climate change in policy documents does not ensure its implementation. In part, this is often because of lack of information about climate change, poor interministerial coordination, weak implementation capacity and resources, and a lack of experience in designing and

implementing climate change adaptation in both developed and developing countries.

For these reasons, many of the first climate change adaptation funds have advocated learning by doing or through pilot project initiatives.<sup>33</sup> Establishing some implementation experience can inform the development of appropriate policy-level guidance. Another approach for developing policy experience that has been tested is policy-driven information gathering, or the explicit link between pilot project and policy mainstreaming. Adaptation strategies are tested and evaluated in the context of a given policy sphere and successful measures are fed back up into the given policy. This integration can help improve the policy's general direction and achievement of its objectives.

## National Policy Processes

The Organisation for Economic Co-operation and Development (OECD 2009) identifies the national and sector levels as policy entry points that may be useful for adaptation mainstreaming. National policies and

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<sup>33</sup> For example, see Least Developed Countries Fund, Special Climate Change Fund, Adaptation Fund. UNFCCC Decision 5/CP.7 and Decision 5/CMP.2.

plans (note that in some countries the word policies is used while in others these are referred to as plans) include national visions, poverty reduction strategies, multiyear development plans, and national budgets. Sector development plans, such as agriculture master plans and their budgets, often flow from national plans and policies. Projects support sector plans and in some cases also national plans, particularly those that are cross-sector, regional, and of extremely high priority. Therefore, influencing these overarching frameworks can affect which projects are prioritized and the criteria they must meet in order to be financed.

The OECD guidance recommends two main courses of action for integrating adaptation at this level:

- (1) *A clear recognition of climate risks and the need for adaptation within relevant national policies.* Incorporating climate change at this level can ensure that it filters down into sector plans and other levels of decision making. In the case of agriculture, and for infrastructure

development generally, guidance intended to strengthen cross-sector cooperation between ministries can be very helpful. For instance, flood management around critical agriculture infrastructure can be better managed between ministries of water and hydrology, meteorology, and agriculture. Integrated planning around geographically vulnerable areas can produce high-quality development plans for disaster-prone areas. Moreover, climate change impacts are not set by national boundaries; its effects require regional coordination, for example in the Mekong subregion. Harmonization between national and regional road network development activities requires coordination at this level.

- (2) *Applying a climate change lens in the formulation of national policies and strategies.* A climate lens is an analytical process/step/tool to examine a policy, plan, or program. It can be useful, for example, to identify areas of the country that are most vulnerable to climate change impacts and where priority action can be directed (Box 16).

### Box 16. Applying a Climate Lens

The application of a climate lens at the national or sector level involves examining

- (i) the extent to which the policy, strategy, regulation, or plan under consideration could be vulnerable to risks arising from climate variability and change;
- (ii) the extent to which climate change risks have been taken into consideration in the course of program formulation;
- (iii) the extent to which the policy, strategy, regulation, or plan could lead to increased vulnerability, leading to maladaptation or, conversely, to missing important opportunities arising from climate change; and
- (iv) for preexisting policies, strategies, regulations, or plans that are being revised, what amendments might be warranted in order to address climate risks and opportunities.

A first quick application of the climate lens should enable a policy maker to decide whether a policy, plan, or program of investments is at risk from climate change. If deemed to be at risk, further work is required to identify the extent of the risk, assess climate change impacts and adaptation responses in more detail, and identify possible recommendations and downstream actions.

Source: Organisation for Economic Co-operation and Development (OECD). 2009. *Integrating Climate Change Adaptation into Development Co-operation*. Paris.



The approach taken when analyzing adaptation in the sector should acknowledge the following:

- Climate impacts may not be the most important constraint on development objectives of the sector; climate considerations therefore need to be embedded in a planning process that considers all risks.
- The basis for adapting to the future climate lies in improving the ability to cope with existing climate variations. Climate change projections inform this process to ensure that current coping strategies are consistent with future climate change.
- In tackling current hazards, adaptation processes can draw and learn from approaches to disaster risk reduction.
- Because of uncertainty over future climate variability and change, management responses should build in flexibility to cope with a range of different potential future climate regimes.
- Managing climate impacts enables an examination of how wider development processes can contribute to reducing vulnerability to climate change.

## Sector Policies and Plans

Sector-level policies are important for climate change because it is often at this stage that criteria such as engineering designs, alignment, technology, and priority areas will be established. Adaptation responses vary significantly by place and sector, and therefore this publication seeks to develop some highly specific approaches for the agriculture sector. There is, however, little detailed experience at the policy level to draw from, with few agriculture ministries going beyond awareness raising and research.

Incorporating adaptation considerations into, for example, agriculture master plans will further secure the likelihood of meeting the given agriculture-related

objectives and may also identify new priorities. The simplest way for an agriculture plan to incorporate climate change adaptation is to acknowledge the relationship between climate change impacts and the plan's goals, such as improving crop productivity. The structure of this incorporation will vary from case to case. It may include stand-alone components within the agriculture strategy, such as conducting a climate change risk assessment for each project identified, or involve incorporating climate change adaptation within other sub-goals of the agriculture plan.

Box 16 presents an example of how adaptation mainstreaming is being done in an irrigated agriculture project in the People's Republic of China (PRC) funded by the Global Environment Facility.

Challenges faced by the agriculture sector with respect to climate change cannot be separated from the interaction between the built environment and the natural environment. Infrastructural changes that do not address some of the root causes—such as deforestation, land degradation, and water use efficiency—will provide only a temporary and superficial fix. Agriculture sector ministries will need to coordinate more effectively with other line ministries in dealing with climate change issues. There are a number of options for doing this:

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including for agriculture.
- Strengthen departments of disaster risk management and meteorology to improve information on which to make decisions.
- Introduce early warning and response systems for agriculture ministries to improve maintenance schedules and to respond quickly to post-disaster recovery needs.
- Promote low-regret or no-regret adaptation strategies that will have development benefits regardless of the nature of climate changes that may take place. This is a useful approach where

### **Box 17. Global Environment Facility-Funded Project: Adaptation Planning for Irrigated Agriculture in the People's Republic of China**

Agriculture in the northern People's Republic of China (PRC) Huang-Huai-Hai (3H) River Basin is an important concern as the PRC begins to deal with potential negative impacts from climate change on its food production systems. The 3H Basin produces half of the PRC's grain, and yet it faces significant challenges caused by a recent increase in the frequency and intensity of droughts and flooding, stagnant grain production, and water resources that are fully allocated and often overexploited. Temperatures in the region are projected to increase by 2°C by mid-century, placing a significant additional burden on water availability and crop productivity.

The Global Environment Facility (GEF)-funded project Mainstreaming Climate Change Adaptation in Irrigated Agriculture aims to introduce climate change adaptation concepts and measures into the Irrigated Agriculture Intensification Project III (IAL3), a comprehensive initiative to modernize irrigated agriculture throughout many areas in the PRC, including the 3H Basin. The aims of the GEF adaptation project are as follows:

- Identification and prioritization of adaptation options through a climate change impact assessment using integrated hydrologic, agronomic, economic, and climate models; gap analysis of potential climate change sensitivities in the IAL3 design; and a selection of adaptation options at the local scale.
- Implementation of pilot-scale adaptation measures, including water-conserving irrigation and drainage practices, deep plowing, improved fertilizer management, introduction of crop varieties suited to warmer and drier conditions, and capacity building of water user and farmer associations. The pilot actions target areas with different vulnerabilities, including severe groundwater depletion, high interannual climate variability, and high dependence on surface water and groundwater irrigation.
- Mainstreaming of adaptation into national agriculture planning through the development of an adaptation action plan to be integrated into the Comprehensive Agriculture Development Program, which is the PRC's largest national investment program in irrigated agriculture.

Source: Adaptation Learning Mechanism. Available at [www.adaptationlearning.net/project/mainstreaming-climate-change-adaptation-irrigated-agriculture-project](http://www.adaptationlearning.net/project/mainstreaming-climate-change-adaptation-irrigated-agriculture-project)

uncertainty is high regarding climate change and capital investments cannot be justified for large-scale infrastructural changes.

- Incorporate climate change adaptation into environmental impact assessments and strategic environmental assessment guidelines. This can take place specifically in the agriculture sector or, preferably, as part of the national standards. Agriculture ministries can test tools and adaptation approaches by applying strategic environmental assessments with climate change to their sector policies and plans.

Such intersectoral coordination and collaboration is more likely to lead in the assessment of a broader set of adaptation options, which not only may provide multiple benefits across multiple sectors but also recognizes that effective adaptation in one sector (e.g., agriculture) may lie in better operation or more investment in another sector (e.g., energy supply). This is illustrated by the set of adaptation options recently identified in the context of an ADB-supported project to the Government of India, Support for the National Action Plan on Climate Change (Table 8).

## Guidelines For Climate Proofing Investment In Agriculture, Rural Development, and Food Security Sector

**Table 8. Support for the National Action Plan on Climate Change (India): Summary of Sub-Basin Adaptation Action Plans**

Lower Sutlej Sub-Basin, Punjab	Kshipra Sub-Basin, Madhya Pradesh	Cauvery Delta Sub-Basin, Tamil Nadu
Improved agriculture productivity & marketing systems	Sustainable agriculture and conservation	Integrated flood and salinity management
<ul style="list-style-type: none"> <li>Improved infrastructure for marketing</li> <li>Market information systems</li> <li>Support for mechanization, diversification</li> </ul>	<ul style="list-style-type: none"> <li>Infrastructure for crop marketing and processing, marketing, access roads</li> <li>Market information systems training</li> <li>Public-private partnership initiatives to support production, marketing, conservation</li> <li>Micro irrigation and farm tanks</li> <li>Improved water supplies</li> </ul>	<ul style="list-style-type: none"> <li>Investments in drainage and flood dykes</li> <li>Construction/reconstruction of tail end regulators</li> <li>Development and rehabilitation of flood alleviation</li> <li>Rehabilitation of floodwater for groundwater recharge and micro irrigation</li> <li>Maintenance of drains, removal of weeds</li> <li>Integrated catchment management over whole basin to reduce floods</li> </ul>
Upscaling resource conservation technologies (RCTs)	Water resources and catchment management	Sustainable agricultural systems
<ul style="list-style-type: none"> <li>Support to upscale and mainstream RCTs</li> <li>Support for private sector partnership for RCTs</li> <li>Upscaling micro irrigation</li> <li>Improved water supplies for agriculture</li> </ul>	<ul style="list-style-type: none"> <li>Investment for small and medium reservoirs and projects for water supply and irrigation</li> <li>Catchment management and artificial recharge</li> <li>Wastewater management</li> <li>Water re-use, rainwater harvesting, sustainable drainage</li> </ul>	<ul style="list-style-type: none"> <li>Farm ponds, farm drainage, micro irrigation</li> <li>Increased mechanization</li> <li>Infrastructure for marketing, processing storage, market areas, crop and fish processing, farm roads</li> <li>Support for aquaculture and flood alleviation/retention.</li> </ul>
Water resources and catchment management	Water quality management and pollution control	Shoreline protection and management
<ul style="list-style-type: none"> <li>Saline water management</li> <li>Pollution control and water treatment</li> <li>Catchment management and artificial recharge</li> <li>Rehabilitation of water bodies, ponds, wetlands</li> <li>Investment in surface water systems</li> <li>Urban water management, leakage control, rainwater harvesting, drainage and water re-use</li> </ul>	<ul style="list-style-type: none"> <li>Pollution control and water treatment</li> <li>New initiatives for wastewater management</li> <li>Urban water management</li> </ul>	<ul style="list-style-type: none"> <li>Beach and dune management</li> <li>Dredging of river mouths and beach nourishment</li> <li>Mangrove rehabilitation and management</li> <li>Support for other coastal infrastructure</li> </ul>

Source: ADB. 2011a. *Support for the National Action Plan on Climate Change: Support to the National Water Mission (TA 7417-IND)*. Final Report. Manila.

Further, agriculture ministries can incorporate the following measures into their implementation plans:

- Introduce climate change vulnerability and adaptation considerations to criteria used for selecting projects for implementation and financing.
- Develop sector-specific and country-specific screening tools to identify projects at risk.
- Incorporate contingency budgets for specific adaptation interventions as the need arises.
- Adjust zoning regulations for agriculture infrastructure (for example, to avoid flood or permafrost zones).
- Design flexible agriculture infrastructure that can accommodate incremental changes over time.
- Incorporate climate change indicators into agriculture planning budgeting frameworks to ensure accountability.

### Mainstreaming Adaptation into Agriculture Sector Policies

A number of management and policy options are relevant to sector actions at the national level as indicated in Table 9.

**Table 9. Management and Policy Options for Sector National-Level Actions**

Issues	Management and Policy Options
Climate change, water and food security	<ul style="list-style-type: none"> <li>• Integration of adaptation measures for agricultural water, management in national development plans</li> <li>• Technical and management measures to improve water use efficiency in rainfed and irrigated agriculture</li> <li>• Increased knowledge of climate change and water and sharing of good practices among countries and regions</li> <li>• Risk management in national policies through better monitoring networks</li> </ul>
Climate change and disaster risk management	<ul style="list-style-type: none"> <li>• Better understanding of climate change impacts at local level</li> <li>• Diversifying livelihoods and adapting agriculture, fishing, and forestry practices</li> <li>• Improving and expanding weather and climate forecasting and early warning systems</li> <li>• Preparing contingency plans</li> <li>• Adjustment of land use plans</li> <li>• Cost/benefit analysis on structural mitigation measures</li> </ul>
Climate-related transboundary pests and diseases	<ul style="list-style-type: none"> <li>• Strengthening national animal and plant health services</li> <li>• Investing in early control and detection systems</li> </ul>
Climate change, fisheries and aquaculture	<ul style="list-style-type: none"> <li>• Adaptation strategies based on ecosystem approach</li> <li>• Understanding and anticipating ecological changes and developing appropriate management responses</li> </ul>
Climate change and land	<ul style="list-style-type: none"> <li>• Sound land tenure policies and planning</li> <li>• Enabling and encouraging investments in sustainable land use practices</li> </ul>
Climate change and biodiversity	<ul style="list-style-type: none"> <li>• Assessment of distribution of biodiversity for food and agriculture both in the wild and in the fields</li> <li>• Assessment of vulnerability of biodiversity to climate change</li> </ul>

Source: Adapted from Glantz, M.H., R. Gommers, and S. Ramasamy. 2009. *Coping with a Changing Climate: Considerations for Adaptation and Mitigation in Agriculture*. Rome: Food and Agriculture Organization.

Practical steps may be followed to incorporate climate change in agricultural planning and policy. This analysis intends to complement the work of a project team that is already undertaking a general assessment of agriculture policies, so this part offers some recommendations on how to expand the project team's analysis and incorporate climate change. The following are the suggested steps or phases to mainstreaming adaptation:

***Phase 1: Conduct climate change impact, vulnerability, and adaptation assessments in agriculture at the national level.***

This assessment should cover the following aspects of climate change and agriculture investments:

- direct threats to investments (e.g., effect of extreme weather events on rural infrastructure or agricultural land);
- underperformance of investments (e.g., irrigation investments that fail to pay off when rainfall decreases);
- maladaptation, as when rural development triggers settlement in vulnerable areas or decreases the resilience of agricultural production systems; and
- in addition, there is the risk of forgoing opportunities that may arise from climate change and could be captured if factored into plans and projects.

Examples of the outputs from this activity include

- assessment of scenarios for agricultural production in a country based on global and regional climate models,
- analysis of agricultural land use planning in flood- and drought-prone areas and development of alternative land use plans based on climate risk scenarios, and
- analysis of supply chains for different climate-resilient crops and assessment of economic impacts market barriers.

In the irrigation sector itself, a number of specific adaptation measures may be identified (Box 18).

***Phase 2: Identify priority areas for intervention and implement pilot initiatives.***

Although this step is not fundamental in the policy mainstreaming work, it can generate grounded information about adaptation policy options and investments, their feasibility, and the potential for replication. Reviewing past pilot adaptation initiatives in the country can also be helpful at this stage.

Examples of the outputs from this activity can be

- climate-resilient cropping practices introduced in at least one flood-prone and at least one drought-prone watershed;
- diversified agricultural production demonstrated in at least 40% of target districts where farming communities are dependent on rainfed crops; or
- rainfall capture, storage, and adaptive irrigation management introduced in at least 40% of target drought-prone districts where rainfall is declining or becoming more variable.

The above set of actions can be implemented in the short-term and guide the planning of climate-proofing investments (Box 19).

***Phase 3: Identify relevant institutions and their role and mandate with respect to agriculture and climate change to build capacity by disseminating results of previous steps.***

Institutions relevant for agriculture and climate change considerations include ministries (such as the ministries of agriculture, rural development, and environment) and departments or institutes involved in irrigation, flood control, or extension services.

### Box 18. Adaptation Recommendations in Irrigation

Adaptation recommendations in the irrigation sector may include the following:

- Prioritize drought-sensitive farming and ecosystems for irrigation investment and facilitate sustainable groundwater development where abstraction and capital costs are low.
- Reduce rice production on highly permeable soils to conserve water and minimize salinity, preferably through reasonable incentives and removal of perverse incentives.
- Build capacity to integrate climate change scenarios in water resources policy planning.
- Develop policies to externalize poor water and fertilizer use and achieve synergy in mitigation and production efficiency.

Source: Padgham, J. 2009. *Agricultural Development under a Changing Climate: Opportunities and Challenges for Adaptation*. Washington, DC: World Bank.

### Box 19. Near-Term Climate Proofing Actions

Ebinger and Vergara (2011) identify a set of near-term climate proofing actions for the energy sector. Adapted to the agriculture, rural development, and food security sector, these actions would read as follows:

**Support awareness and knowledge exchange.** Disseminate experience and learn from the increasing data and knowledge of climate impacts on the sector.

**Undertake climate impacts needs assessments.** Quantify the impacts and risks through the life cycle of projects to guide adaptation practice.

**Develop project screening tools.** Develop templates to screen individual projects for climate vulnerability and risks.

**Develop adaptation standards for the sector.** Such standards should cover engineering matters and information requirements.

**Revisit planning time frames and the use of historical data for future investments.** Traditional planning approaches that use historical data may need to be revisited and adjusted to reflect anticipated climate trends.

**Assess potential climate impacts when retrofitting existing infrastructure.** Already available technologies can help identify any needed changes in operational and maintenance protocols, structural changes, and/or the relocation of existing infrastructure assets.

**Implement specific adaptation measures.** Adaptation measures can include a range of off-the-shelf and innovative solutions, which may require investment in a pilot or demonstration project to illustrate their costs and benefits.

**Identify policy instruments.** Policy instruments are needed to support climate impact management.

**Support capacity building.** Increase the capacity of key stakeholders including agriculture, rural development, and food security sector policy makers, regulators, and operators for climate risk management.

Source: Ebinger, J., and W. Vergara. 2011. *Climate Impacts on Energy Systems: Key Issues for Energy Sector Adaptation*. The World Bank. Washington, D.C.

At the same time, provincial departments of agriculture, water user associations, and farmer cooperatives in prioritized areas should also be identified.

The following are two examples of outputs from this activity:

- Sectoral planners in the ministries of agriculture, planning and investment, and environment are trained to understand climate change risks for

agricultural production and review policy options for enhanced climate resilience.

- At least 75% of agricultural officers, extension workers, and farmer cooperatives in target districts are trained in climate change impacts on agricultural production and potential community-based adaptation options.

A recently funded project in the Lao PDR by the Least Developed Countries Fund (LDCF) illustrates some of the above actions (Box 20).

### Box 20. Improving the Resilience of the Agriculture Sector to Climate Change Impacts in the Lao PDR

The major climate hazards which that the Lao PDR regularly faces include flooding caused by heavy rainfall during the rainy season, drought caused by extended dry seasons, sudden flash floods in the mountainous parts of the country, landslides and large-scale land erosion on slopes, occasional windstorms and—recently—typhoons in the south. Climate change is expected to change the frequency, intensity, and location of existing climate hazards and challenge the existing coping mechanisms of the population, especially those living in rural and remote places.

The Least Developed Countries Fund is currently funding a project in the Lao PDR with the overall objective to minimize food insecurity resulting from climate change, and to reduce vulnerability of farmers to extreme flooding and drought events. It includes the following outcomes and outputs:

Outcome	Output
Knowledge base on Climate Change impacts in the Lao PDR on agricultural production, food security and vulnerability, and local coping mechanisms strengthened	Existing climate hazard and vulnerability information for the Lao PDR compiled and integrated into an agriculture and climate risk information system leading to the establishment of a long-term warning system linked through to province and district level agriculture and forestry departments and the rural farmers via the extension services they provide.
	Scenarios for agricultural production in the Lao PDR assessed on the basis of local expertise and regional and global climate change models.
	Agricultural land use planning in flood- and drought-prone areas in three target sites in three provinces analyzed and alternative land use plans developed based on climate risk scenarios and long-term warning indicators.
	Comprehensive national long-term information system established for flood and drought-related hazards and vulnerabilities and their on agriculture.

*continued on next page*



Box 20. continued

Outcome	Output
Capacities of sectoral planners and agricultural producers strengthened to understand and address climate change – related risks and opportunities for local food production and socioeconomic conditions	<p>Planners and technical staff within relevant agencies trained to understand climate change risks for agricultural production and review policy and planning options for enhanced food security.</p> <p>Climate-resilient land use planning principles developed and integrated into the Lao PDR's poverty reduction and agricultural policies and action plans.</p> <p>Agricultural officers, extension workers, farmer cooperatives, and Technical Service Center members in target districts trained in climate change impacts on agricultural production and socioeconomic conditions, and potential community-based adaptation options.</p> <p>District disaster management committees in target districts trained in climate risk assessment and potential community-based risk reduction strategies, including periodical ground practice with communities.</p>
Community-based adaptive agricultural practices and off-farm opportunities demonstrated and promoted within suitable agroecological systems	<p>Resilient elements in existing farming systems identified and strengthened as a basis both for wider replication of successful practices and for the introduction of additional adaptation measures using these existing coping mechanisms as entry points.</p> <p>Supply chains for different climate-resilient crops, livestock, etc., and farming inputs analyzed and economic impacts/market barriers assessed.</p> <p>Climate-resilient cropping, livestock, fisheries, and forestry practices introduced across at least one flood-prone and one drought-prone area.</p> <p>Diversified agriculture, livestock, fish, vegetables, non-timber forest production, and alternative feasible off-farm activities demonstrated in target districts where farming communities are dependent on rainfed crops.</p> <p>Rainfall capture, storage and adaptive irrigation and/or drainage management, and small-scale flood protection measures introduced in target drought-prone districts where rainfall is becoming more variable.</p>
Adaptation monitoring and learning as a long-term process	<p>Project lessons captured in systematic monitoring, and periodically disseminated through the Adaptation Learning Mechanism and other suitable regionally based networks.</p> <p>Project knowledge shared with other countries in the Greater Mekong Subregion.</p> <p>Project knowledge incorporated into national flood and drought prevention and agricultural training programs in the Lao PDR.</p>

Adapted from Global Environment Facility. 2010. *Lao PDR: Improving the Resilience of the Agriculture Sector in Lao PDR to Climate Change Impacts*. Washington, D.C.



### **Box 21. Nine Hallmarks of Institutions that are Adapting to Climate Change**

1. Climate change champions are clearly visible, setting goals, advocating and resourcing initiatives on climate change adaptation.
2. Climate change adaptation objectives are clearly stated in corporate strategies and regularly reviewed as part of a broader strategic framework.
3. Flexible structures and processes are in place to assist institutional learning, upskilling of teams, and mainstreaming of adaptation within codes of practice.
4. Progress in adapting is monitored and reported against clearly defined targets.
5. Comprehensive risk and vulnerability assessments are being undertaken for priority activities at early stages of the planning cycle.
6. Scientifically based, workable guidance and training on adaptation is being put in place for operational staff.
7. Adaptation pathways are being guided by the precautionary principle in order to deliver low-regret solutions that are robust to uncertainty about future risks including, but not exclusively, climate change.
8. Multi-partner networks are in place that are sharing information, pooling resources, and taking concerted action to realize complementary adaptation goals.
9. Effective communication with internal and external audiences is raising awareness of climate risks and opportunities, realizing behavioral changes, and demonstrating adaptation in action.

Source: Wilby, R.L. and K. Vaughan. 2011. Hallmarks of organizations that are adapting to climate change. *Water and Environment Journal*. 25 (2). pp. 271–281.

Hence, despite the uncertainty associated with climate risk, institutions can take a number of practical steps to reduce the climate vulnerability of the sector they manage and increase resilience to climate threats (Box 21).

# Conclusions

The agriculture, rural development, and food security sector is particularly vulnerable to projected changes in temperature and rainfall, increased frequency and intensity of extreme weather events such as flood and drought, a rise in sea level, and the intensification of storm surges. All of these changes have consequences for the design of agriculture investment projects. Inadequate attention to these impacts can increase the long-term costs of agriculture investments and increase the likelihood that such investments will fail to deliver the benefits for which they were intended.

This publication aimed to present a step-by-step methodological approach to assist project teams to assess and incorporate climate-proofing measures into agriculture, rural development, and food security investment projects. The key is to recognize that climate proofing, or more generally adaptation to climate change, is essentially characterized by decision making under uncertainty and with incomplete information. Uncertainties associated with global,

regional, and local climate projections as well as national and local socioeconomic trends require a pragmatic, participatory, and flexible approach to constructing climate and development scenarios, and to assessing impacts, vulnerability, and adaptation.

Additional and predictable financing is needed to support the assessment of climate-proofing options at the project level and to fully integrate adaptation into development planning and processes. Most adaptation financing is now allocated by donors on a project-by-project basis, which forcibly separates adaptation activities from mainstream development work. While separating out funding for adaptation is important for accountability and transparency purposes, it can also add to the challenge of mainstreaming efforts, particularly when adaptation funds and sector budgets are administered independently.

Existing adaptation funds such as the Least Developed Countries Fund<sup>34</sup> and the Special Climate Change

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<sup>34</sup> Specifically, the LDCF was tasked with financing the preparation and implementation of national adaptation programs of action (NAPAs). Consistent with the findings of the NAPAs, the LDCF focuses on reducing the vulnerability of those sectors and resources that are central to development and livelihoods, such as water; agriculture and food security; health; disaster risk management and prevention; infrastructure; and fragile ecosystems. For more details, see [www.thegef.org/gef/LDCF](http://www.thegef.org/gef/LDCF).

Fund<sup>35</sup> administered by the Global Environment Facility, as well as the Adaptation Fund<sup>36</sup> established under the Kyoto Protocol, all aim to finance concrete adaptation projects and programs. While of significance, these funds are not necessarily amenable to supporting the design and assessment of climate-proofing options of specific sector investment projects and are not easily accessible for timely integration in the ADB project cycle. Alternative funding mechanisms may be required to facilitate this process.

While the focus of the *Guidelines* is on the project level, an improved understanding of climate change

impacts should also be used to incorporate climate change considerations into agriculture planning and policy at the country level. Sector-based approaches have their limits, and regional ecosystem-based assessments and analysis are needed to influence integrated planning in the agriculture sector. Given that agriculture infrastructure has a long life cycle, its planning should be developed further and integrate new approaches such as green infrastructure planning. Most adaptation responses will require participation across ministries; coordination efforts are intense and should be supported.

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<sup>35</sup> The SCCF was established to support adaptation and technology transfer in all developing country parties to the UNFCCC. The SCCF supports both long-term and short-term adaptation activities in water resources management, land management, agriculture, health, infrastructure development, fragile ecosystems including mountainous ecosystems, and integrated coastal zone management. For more details, see [www.thegef.org/gef/SCCF](http://www.thegef.org/gef/SCCF).

<sup>36</sup> The Adaptation Fund was established to finance concrete adaptation projects and programs in developing countries that are parties to the Kyoto Protocol and are particularly vulnerable to the adverse effects of climate change. For more details, see [www.adaptation-fund.org](http://www.adaptation-fund.org).

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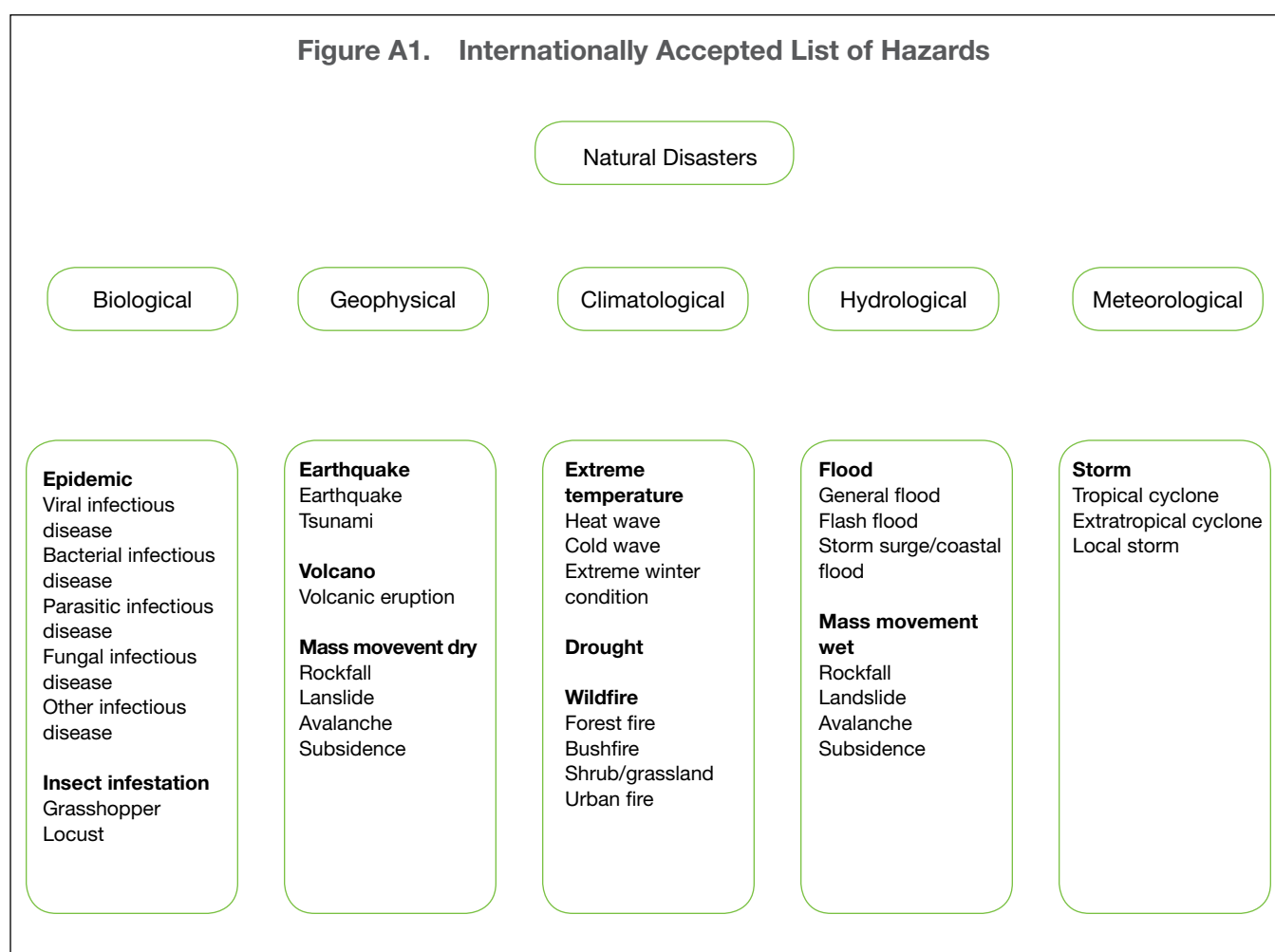
# Appendix 1: ADB Draft Risk Screening Tool (September 2009)

1. The screening tool has been designed to take into account climate-induced risks and natural hazards of geophysical origin (as listed in Figure A1). This screening tool will expand the bank's risk assessment capacity within the ADB policy framework and project life cycle operations. This proposed risk screening exercise will be conducted before project preparation technical assistance (PPTA) F/F mission as part of ADB environmental safeguards considerations/requirements in the project life cycle. It aims to make investments more resilient to risk, in alignment with ADB's Strategy 2020 and developing member countries' partnership strategies.
2. With the impacts of natural hazards and climate change expected to increase, ADB has developed this risk screening tool to rapidly assess impacts and associated risk at the project preparation stage. This snapshot of project risks helps project officers, mission leaders, environmental specialists, and project stakeholders consider the potential incorporation of risk management measures in project design, technical assistance concept papers, and project operations.
3. **Risk** is often regarded as a function of hazard, vulnerability, and exposure and commonly expressed as  $R = H \times V \times E$ . The overall **risk** of damage or losses is determined by the nature, intensity, and frequency of the **hazard** (e.g., the frequency of flood at a certain level); the exposure to the hazard (e.g., the number of people living on a flood plain); and the **vulnerability** to the hazard—that is, the conditions determined by physical, social, economic, and environmental factors or processes that increase the susceptibility of an ADB-funded project or a community to the impact of the hazard.
4. Some risks, such as damaging earthquakes and volcanic eruptions, may have return periods averaging hundreds of years. While such events may not appear in the historic record for the project area, this should not imply that such risks cannot occur.
5. As some risks may increase during the project design life (e.g., strengthening of cyclonic winds, sea level rise, more frequent landslides as the result of an increase in intense rainfalls), project design must take these potential changes into account. For example, where infrastructure with a design life of 20 years is constructed with a 1-in-50 year flood in mind, the project design must consider the 1-in-50 year flood applicable in 20 years time.
6. Answers to questions in the risk screening tool, when totaled, generate a risk value of High,

Medium, or Low. Where projects are deemed to be at medium or high risk, other risk management measures (such as climate risk mapping, vulnerability assessments to extreme events,

and risk reduction policies and practices) will need to be introduced during project design and implementation.

**Figure A1. Internationally Accepted List of Hazards**



Risk Screening Tool			
General Project Identification			
1. Date:			
2. Country & Project Title:			
3. Lending or Financing Modality:			
4. Department & Division:			
Risk Assessment Category	Risk Values	Total	Remarks
<b>Pre-determined impacts and risk factors</b>			
1. Which physical environment best describes the project area?	Using Appendix I, add the score for the physical environment that best describes the project location.		
2. Categorize sectoral risk of project	Add risk value from 0–3.		
3. List individual hazards that may impact project (Figure A1 above)	Add risk value of 1 for each natural hazard (up to a maximum of 4). If hazards unknown, use 3 as a risk value		
4. Estimate the number of people in the project area “exposed” to risk after the project is completed	For <100 score = 0, 100–1000 score = 1, 1000–10,000 score = 2, >10,000 score = 3		
<b>If the TOTAL value for the first 4 questions sums to 4 or less there is no need to complete the remaining questions.</b>			
<b>Stakeholder engagement and risk knowledge</b>			
1. Do the project proponents have the institutional capacity to successfully incorporate, manage, and deliver risk management measures to the project?	Good capacity, risk value = 0; poor capacity, risk value = 1; very poor capacity, risk value = 2		
2. Will potential hazard impacts on communities, gender, indigenous peoples, or the social dimensions of risk be considered in the concept paper?	Yes/No (If No or unsure, add 1 risk value)		
3. Are there any demographic or socioeconomic variables (i.e., population increase, settlement patterns, biophysical and environmental conditions) that may increase exposure to hazard impacts?	Yes/No (If Yes or unsure, add 1 risk value)		
4. Is it likely that executing agency stakeholders have some practical knowledge of risk reduction measures for the project?	Yes/No (If No or unsure, add 1 risk value)		
5. Will the project reduce, leave unaltered, or increase the risk to project beneficiaries?	Reduce risk, score = 0; leave risk unaltered, score = 1; increase risk, score = 2		
6. Will the project reduce, leave unaltered, or increase the risk to the localized environment/project dependent ecosystem?	Reduce risk, score = 0; leave risk unaltered, score = 1; increase risk, score = 2		
7. Do country/institutional policies or environmental laws significantly promote risk management measures?	Yes/No (If No or unsure, add 1 risk value)		
8. Does the project require a risk expert to introduce risk reduction measures in project design, implementation, or operations and maintenance?	No = 0 Yes = 1 or 2 based on your assessment of the level of risk		
<b>Total Risk Value (Range 0 to 25)</b>		<b>High Risk: 17–25</b> <b>Moderate Risk: 8–16</b> <b>Low Risk: 0–7</b>	

**Low Risk (0–7):** This range indicates the project proposal has considered risk management measures to minimize hazard impacts and associated risks, and that the project may therefore have a potentially higher threshold against current and anticipated risks

**Moderate Risk (8–16):** Project exposure to risk is likely. It is recommended that risk reduction measures be incorporated into project design and activities.

**High Risk (17–25):** Project exposure and vulnerability to potential risks are very likely. It is highly recommended that risk reduction measures be incorporated into project design and activities, and that a further review of the project proposal be undertaken.

## Proposed Actions

1. Review and analyze expected natural hazard or climate impacts, and where appropriate, incorporate risk reduction measures in PPTA.
2. During fact-finding mission and PPTA development, environment specialist and project officer or mission leader should consult with risk management specialist or seek other assistance to better identify potential risk reduction opportunities.
3. Insight gained from this risk screening tool will help the project officer or mission leader consider incorporating risk management measures in project budgets and in consultant terms of reference.
4. Consider (i) conducting impact and vulnerability assessments, (ii) cost-benefit analysis regarding climate adaptation and disaster risk reduction in the project, and (iii) financing strategy to cover incremental hazard management costs.

## Appendix 2: Draft Terms Of Reference

### 2.1 Examples of Additional Activities for Project Preparation Team Members

The project team will undertake the following activities in order to identify and recommend an adaptation strategy for the project, both in terms of protecting the investment and ensuring that the project does not increase the vulnerability of the relevant area and people. This work will include a detailed climate change impact, vulnerability, and adaptation assessment, including an economic assessment, in the project context.

The results of the assessment should be fully incorporated into the project design, including the detailed engineering design, environmental management plan, social safeguard measures, monitoring and evaluation framework, and budget. Inputs will consist of approximately 4 person-months by international consultants and 5 person-months of national consultants assisting the international consultants.

#### **Team Leader** (International, 1.0 person-month)

- (i) Oversee and coordinate the implementation of the draft strategy for vulnerability, impact, and adaptation assessment.
- (ii) Identify and discuss the adaptation objective with all relevant stakeholders.

- (iii) Synthesize vulnerability and impact information collected by other members of the team into the decision matrix provided by ADB.
- (iv) Organize and lead multi-stakeholder consultations to identify and prioritize adaptation options, based on economic assessment in addition to any other prioritized conditions identified (i.e., through multi-criteria analysis).
- (v) Recommend adaptation options in a presentation to the government, ADB, and other relevant stakeholders.
- (vi) Ensure integration of adaptation components into the project design.
- (vii) Identify additional training needs, indicators for monitoring, and budget for adaptation components as needed.

#### **Agriculture Development Expert** (International, 1.0 person-month)

- (i) Identify adaptation options and their costs for the project.
- (ii) Assist other team members in identifying all benefits of the adaptation options from an agriculture development perspective.
- (iii) Prepare revisions to project design taking climate change into account.
- (iv) Recommend to ADB adjustments and improvements toward development of a replicable model to be used in the project and in the future.

- (v) Contribute to specialists' advice including preliminary designs and cost estimates.
- (vi) Prepare technical documentation, including project design and specifications with adaptation considerations.

**Economist** (International, 1.0 person-month)

- (i) Identify and estimate all costs and benefits of the various adaptation options taking into account agronomic, engineering, environmental, and socioeconomic perspectives including the economic assessments.
- (ii) Apply a cost-benefit/cost-effectiveness analysis for the adaptation options identified above.
- (iii) Make recommendations on improvements based on the cost-benefit/cost-effectiveness analysis with a view to developing a replicable model for future projects.

**Environmental and Rural Livelihood Specialist**

(International, 1.0 person-month)

- (i) Identify the climate parameters of concern for the project, including but not limited to changes of precipitation, temperature regimes, and extreme events.
- (ii) Conduct a vulnerability assessment in the project area to identify vulnerability of the agriculture project as well as potential effects of the project on the vulnerability of the area and people.
- (iii) Coordinate the climate impact assessment with assistance from a climate modeler and in coordination with the team hydrologist and agronomic expert.
- (iv) Facilitate participation of government counterparts in ongoing capacity building activities to ensure skills transfer for improved sustainability of designs.
- (v) Conduct community and expert consultations to verify and refine selected adaptation options.
- (vi) Revise the environmental management planning in line with findings.

- (vii) Assist the economist in estimating the life cycle project costs and benefits of climate change adaptation options, including socioeconomic and environmental benefits.
- (viii) Assist the project manager in adjusting the design of the project by incorporating climate change adaptation.
- (ix) Provide recommendations and suggestions for environmental or nonstructural adaptation interventions.

**Environmental and Rural Livelihood Specialist**

(National, 4.0 person-months)

- (i) Facilitate participation of government counterparts in ongoing capacity building activities to ensure skills transfer for improved sustainability of designs and to identify additional training needs.
- (ii) Undertake initial poverty and social assessment, including field assessment of vulnerability to climate change.
- (iii) Collect and summarize existing impact assessments and reports, and prepare a summary of existing information and potential gaps.
- (iv) Collect all relevant climate change data from government ministries and international and community organizations.
- (v) Identify potential adaptation options.

**Hydrologist** (National, 1.0 person-month)

- (i) Undertake hydrological assessment under various climate change scenarios.
- (ii) Produce flood and drought maps and hot spots for current and future scenarios.
- (iii) Provide recommendations for adaptation interventions.

**Agronomist** (National, 1.0 person-month)

- (i) Undertake agronomic assessments under various climate change scenarios.
- (ii) Provide recommendations for adaptation interventions.

## 2.2 Terms of Reference for Impact Assessment Specialist

### Objective of the Assignment

Based on available and relevant information, conduct a desktop assessment of anticipated climate change impacts on a selected agriculture project, using downscaling techniques of global circulation models and integrated impact assessments.

### Skills Required

It is preferable that this contract is implemented by a team of consultants with the following expertise: climate change modeling (including downscaling techniques), hydrological/irrigation modeling, and agricultural and economics knowledge for impact assessment in the relevant sector.

### Scope of the Work

The purpose of this contract is to conduct a detailed climate change impact analysis as input for project design. The assessment will in part be led by the identified climate parameters of relevance to the project design, such as

- changes in maximum and minimum temperatures,
- changes in the distribution of precipitation,
- changes in the length of growing period,
- increase in intensity of and frequency of droughts and floods,
- sea level rise where applicable, and
- any other climate variable relevant for agriculture

The consultant will also provide an expert opinion as to the probability and reliability of climate change modeling scenarios.

### Detailed Tasks

1. Review the PPTA and the climate change adaptation methodology prepared for the project.

2. Identify with the project team the climate change parameters to be assessed and the modeling scale (temporal and spatial) to be used in the impact assessment. Identify the goal of the climate change impact assessment in the context of the overall project objectives.
3. Survey the existing information, such as relevant climate change projections and local historical climate data, that is available. Prepare an assessment of the reliability of existing climate change projections based on the model's ability to represent past climate conditions. Evaluate the range of climate projections and select projections that would be representative of this entire range (i.e., dry, average, and wet scenarios). Identify any need for further modeling. Where existing modeling is sufficient for the project, prepare a short synthesis report.
4. Identify the probabilities of occurrence of specific climate changes and the level of certainty. Identify assumptions and limitations in terms of the use of the projections for influencing project design.
5. Formulate downscaled climate change scenarios for the relevant time horizon of the project, specifying the technique used for downscaling.
6. Identify possible technical gaps in the relevant country for the purpose of improving capabilities for climate change projections.
7. Submit for review and approval a draft outline of the analysis to be undertaken, including recommended methodology for impact assessment (i.e., hydrological modeling, agronomic assessment, clear statement of the climate scenarios to be used in the analysis, and the impact models and a justification for their choice).
8. Provide an expert opinion on the probability of further climate change research potentially altering project design protocols or operations requirements, including master planning.
9. Submit a draft report for review.
10. Finalize the report based on comments received by ADB.

**Output and Report Requirements**

Final report containing estimated projections for key climate parameters, probability analysis, impact assessment, risks, and assumptions.

**Size of Contract**

1–5 person-months

## 2.3 Draft Terms of Reference for Vulnerability Assessment Specialist

**Objective of the Assignment**

To identify the root causes for a system's vulnerability to climate changes and existing trends in climate.

**Skills Required**

The consultant is expected to have a multidisciplinary agriculture or natural resource management background and to have a good understanding of the social and economic aspects of vulnerability in rural areas. (Note: This work can often be led by a rural livelihood specialist with inputs from other technical assistance team members.)

**Scope of the Work**

The goal of the vulnerability assessment is to identify existing vulnerabilities and coping strategies and to confirm and calibrate the climate modeling undertaken by the climate change modeler. A vulnerability assessment attempts to identify the root causes for a system's vulnerability to climate changes and may include collecting raw and observational data of current practices to compensate for vulnerability. This includes collecting and analyzing raw and observational data of current practices to compensate for vulnerability. (Note: a local nongovernment organization may be an appropriate partner for conducting local consultations.)

**Detailed Tasks**

1. Collect data and identify observed trends in climate.

2. Work with impact modeler to verify and ground-truth climate change predictions.
3. Conduct field consultation with local community groups on existing vulnerabilities and coping strategies.
4. Prepare climate vulnerability maps based on existing environmental and climate data, including land and vegetation cover, slopes, geological hazards, and precipitation distribution.
5. Identify priority areas with high vulnerability, to be verified during ground-truthing along the proposed rural investments to assess current observed changes and coping practices.

**Final Outputs**

1. The final GIS-based vulnerability and risk map.
2. Report containing summary of key observable vulnerabilities, sensitivities, coping strategies, and needs.

**Size of Contract**

1 person-month

## 2.4 Draft Terms of Reference for Adaptation Specialist

**Objective of the Assignment**

The consultant's objective is to lead the identification and prioritization of adaptation options in the context of the project, and to highlight findings to ADB for future work (optional).

**Skills Required**

The consultant expected to have a multidisciplinary agriculture or natural resource management background and have a good understanding of the social and economic aspect of adaptation. (Note: This work can often be led by a rural development specialist with inputs from other technical assistance team members.)



**Scope of the Work**

Adaptation is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that which moderates harm or exploits beneficial opportunities. The objective of the adaptation assessment is to identify all potential adaptation options, identify their costs and benefits, and prioritize their implementation in the context of the project goals.

**Detailed Tasks:**

1. Identify all potential adaptation solutions, including soft and hard measures.
2. Identify the expected co-benefits.
3. Conduct multi-stakeholder consultations to identify and confirm all options, including their costs, benefits, and risks.
4. Based on tasks 1–3, evaluate adaptation measures and options for the proposed agriculture project jointly with the executing agency, TA team economist, agronomist, irrigation engineer, and poverty reduction expert to provide an economic assessment of adaptation options and to define co-benefits for other aspects of development.
5. Organize a second consultation meeting with the project executing agency and other stakeholders' to seek agreement on prioritized adaptation measures to undertake during project implementation.
6. Incorporate selected adaptation priorities into the project design, including institutional arrangements and budget.
7. Identify any additional capacity building needs required for the project implementation unit.
8. Identify indicators to monitor vulnerability reductions and sustainability of adaptation measures in the context of the project implementation.

**Final Output**

1. Synthesis of the results from the impact assessment, vulnerability assessment, and economic analysis. Recommendations should be included as part of this report.

2. Adaptation strategy including prioritized adaptation options, implementation arrangements, implementation risks, training and capacity building plan, budget, and input into the project design and monitoring framework

**Size of Contract**

1–2 person-months

## 2.5 Draft Terms of Reference for Economic Analysis

**Objective of the Assignment**

The overall objective of this study is to conduct a cost-benefit analysis or a cost-effectiveness analysis of the various technically feasible adaptation measures which may be implemented to climate proof the different components under consideration in the agriculture project. This study aims to inform project officers and policy makers with respect to the desirability (from an economic point of view) of investing in adaptation, and to assess and rank adaptation options with respect to their economic outcomes.

**Detailed Tasks and Outputs**

Specific tasks and deliverables may be divided into two phases.

### Phase 1: Assessment of historical records and data, and design of methodology

**Tasks**

- (1) Conduct a detailed review of the historical records and data of relevance, especially those pertaining to direct damages to agriculture production and infrastructure and indirect impacts resulting from the damage to agriculture production.
- (2) Provide a list of alternative adaptation measures that may already have been undertaken and implemented for similar situations in the country,

or that are in the process of being designed and implemented, along with their expected impacts and costs. For this purpose, all available information from primary and from secondary data should be used.

- (3) Identify datasets that may be used to implement the objectives of the study.
- (4) Prepare a detailed framework (tasks, activities, responsibilities, time lines) for the successful implementation of the study.
- (5) Prepare a report early on the study to identify possible means by which the expected impacts of adaptation measures may be modeled, and their possible costs and benefits estimated, and validate the proposed methodological approach and framework.

#### **Final Output**

A report covering in detail all of the above tasks.

#### **Phase 2: Cost-benefit analysis of adaptation measures**

##### **Tasks**

1. Evaluate the effectiveness of the past and present adaptation initiatives with quantitative estimates (to the extent data allows) with notes on circumstances/conditions/reasons behind successes or failures of the initiatives.

2. Based on historical data and the study information, provide an estimate of the benefits and costs of adaptation for each possible adaptation measure.
3. Based on the outcome of the analysis, make recommendations pertaining to the adoption of adaptation measures in the context of the project.

#### **Final Output**

Report on analysis of the costs and benefits of potential adaptation measures to climate proof the components of interest in the agriculture project, along with recommendations pertaining to the nature of the adaptation measures to receive priority based on the outcome of the economic analysis.

#### **Size of Contract**

0.5 person month

## Appendix 3: Climate Downscaling and Projections Methods and Requirements

*Dynamical downscaling or regional climate models* (RCMs) simulate climate using similar processes as general circulation models (GCMs) but at much finer scales (10–50 kilometers). GCM outputs are inputted as boundary conditions for the RCM. The primary contribution of RCMs is the inclusion of more realistic topographic and land cover features, which is not comprehensively included in GCMs. These models are computationally intensive and costly. They are not recommended for downscaling to the project level due to their cost unless there is already an existing model for the region.

*Empirical or statistical downscaling* is one technique for projecting climate change on a much smaller scale and relies on determining statistical relationships between large-scale atmospheric variables with local response variables, such as daily precipitation as measured at weather stations. Changes in those large-scale variables projected under climate change (as simulated by GCMs) can be translated into changes in the local variables. Statistical downscaling has the advantage of being less expensive and less computationally onerous compared with RCMs. However, statistical downscaling does not simulate

climate; it is just a technique to project results from GCMs. There are two types of statistical downscaling: *spatial* and *temporal*.

*Spatial downscaling* is possible through a variety of empirical/statistical methods (linear interpolation, kriging, spline fitting, and intelligent interpolation). Straight linear interpolation may be the simplest statistical technique for downscaling large-scale GCM projections to finer grids or points. Uncertainty estimates can be obtained by applying Monte Carlo or other stochastic tools. Additional statistical or empirical methods utilized for climate change downscaling include *weather generators* among others (Wilby et al. 1998).

*Temporal downscaling* is often needed to generate realistic series of daily rainfall given that GCMs do not produce reliable climate data in a resolution that is less than months or seasons. A simple method for downscaling temporally (i.e., monthly to daily) is to use the changes in monthly means of variables from GCM projections to adjust a daily baseline period obtained from meteorological stations.

Method	Assumptions	Type of Result	Limitations	Required Data	Cost	Time Demand	Computing Demand	Required Analyst Skill
General Circulation Models (GCMs) <sup>a</sup>	The model simulates the important climate process well	200-400 kilometers (km) resolution; monthly and daily data; means and time series	Grid boxes have low resolution	Some data for validation purposes; combine with 30 years of observed data	Low/medium	Medium	PC or workstation	Modest
Regional Climate Models (RCMs) <sup>b</sup> ----- existing	The models have higher spatial resolution and they simulate important climate processes well	25-100 km resolution; monthly and daily data; means and time series	RCMs use boundary conditions from GCMs so they may not correct for errors	Maybe some data for validation purposes; may need to combine with 30 years of observed data	Low/medium	Medium	PC or workstation (maybe some large data storage requirement)	Modest
Regional Climate Models (RCMs) <sup>b</sup> ----- new	The models have higher spatial resolution and they simulate important climate processes well	25-100 km resolution; monthly and daily data; means and time series	RCMs use boundary conditions from GCMs so they may not correct for errors	Extensive data for initialization and validation purposes; may need to combine with 30 years of observed data	Very high	Very high	Workstation or mainframe computer	Extensive knowledge of climate modeling
Empirical Downscaling <sup>b</sup>	Use existing relations to calculate small-scale climate	Site-specific time series; monthly or daily data	Scale relations are constant over time	Extensive daily or monthly series of climate variables	High if data to be purchased	High	PC or workstation	Some understanding of climate dynamics
Weather Generators (WGs) <sup>b</sup>	Weather can be described as a stochastic process	Site-specific time series; daily data		Extensive daily weather series for sites or grids	High if data to be purchased	Medium/ High	PC	Some understanding of statistical properties of weather series

<sup>a</sup> It is assumed that people will use existing GCM results, and not run their own. <sup>b</sup> These methods must all be used in conjunction with GCM results.



## **Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security**

This publication aims to present a step-by-step methodological approach to assist project teams assess and incorporate climate change adaptation measures into investment projects in agriculture, rural development, and food security. While the focus of the publication is at the project level, an improved understanding of climate change impacts should also be used to incorporate climate change considerations into agriculture planning and policy at the country level. Though rural development projects include irrigation, rural infrastructure, agriculture production, and natural resource management, this report focuses mainly on irrigation infrastructure projects and agriculture production projects.

### **About the Asian Development Bank**

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.7 billion people who live on less than \$2 a day, with 828 million struggling on less than \$1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.



### **Adaptation Solutions**

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