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APPLYING CLIMATE INFORMATION FOR ADAPTATION DECISION-MAKING

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GUIDANCE & RESOURCE

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APPLYING CLIMATE INFORMATION FOR ADAPTATION DECISION-MAKING

A GUIDANCE AND RESOURCE DOCUMENT

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FOREWORD

The science of climate change has witnessed tremendous progress in recent decades. At the same time, public awareness of the need to address climate change has also increased significantly across the globe. In the face of recent climate events and climate-related disasters, governments, local communities, and civil society in general gained an increased understanding of the potential impacts of climate change and the need to take actions. Climate change cuts across many different sectors and affects people in many different ways. As a result, livelihoods and ecosystems are at risks in all regions of the world, but the most vulnerable communities are usually found in developing countries and among the world's poorest. Governments of these countries are confronted with the additional challenge of increasing the climate resilience of their vulnerable populations while having to address pressing development needs. In this regard, it is critical to ensure the effective integration of adaptation efforts into sectoral policies and national development plans.

Among other prerequisites, climate information is needed to characterize climate risks and to inform decision-making for effective risk management. However, decision makers, particularly those in developing countries, often have to make do with limited availability of climate information and limited technical capacity to apply such information for robust decision-making. National teams involved in vulnerability and adaptation studies often allocate most resources in the development of climate change scenarios and impact analysis, but limited attention has been given to the use of climate information to support policy making. The need for guidance in this area became evident through the several Regional Workshops on Second National Communications organized by the National Communications Support Programme (NCSP) in the last two years. Thus, with Global Environment Facility funding and contribution from the Government of Switzerland and the Government of the United States, the NCSP developed this guidance and resource document on Applying Climate Information for Adaptation Decision-Making.

This guidance document intends to provide countries with a practical tool on using climate information in their decision-making processes. A key concern frequently raised by practitioners is designing sound adaptation programmes under the uncertainties commonly associated with climate change. This guide addresses these issues of adaptation planning under uncertainty of observed and projected climate change. It discusses the level of requirement for climate information in the decision-making process and, where possible, it provides examples and practical steps to illustrate the application of climate information. A number of different approaches have been used to guide the adaptation decision process depending on the way climate risks are framed, which in turn requires different levels of information. This document provides information requirements depending on the scope of the analysis, ranging from assessing initial risk screening and detailed risk analysis to assessing risk management options. The document highlights the need to identify non-climate drivers — a critical consideration that must be given due attention to ensure a rigorous decision-making process to address adaptation concerns. Finally, there are sources for obtaining climate observational data and climate model outputs, and a set of questions to guide the requirement and application of climate information in support of adaptation decisions.

We hope the document provides useful guidance to those engaged in climate risk assessment and adaptation planning on making the best possible use of available climate information, even with data constraints, to inform climate risk assessment and adaptation policy decisions. As the National Communications become a more relevant document for strategic decision-making, we certainly hope that the national communications teams can especially benefit from the guidance provided here.

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1 INTRODUCTION

In its latest assessment report, the Intergovernmental Panel on Climate Change (IPCC) reaffirmed, with greater confidence, the "unequivocal" changes in climate system, other natural systems and aspects of human society, in response to increase in anthropogenic greenhouse gas (GHG) emissions. It warned that anthropogenic warming could lead to some abrupt or irreversible impacts, which will affect the world's poor — the least able to cope — the worst (IPCC, 2007a). This, along with the huge body of scientific evidence underlying the IPCC reports, has drawn to a close the debate about the existence and causes of climate change. The challenge now is to take actions to mitigate and adapt. The United Nations Secretary-General highlighted that "climate change is a serious threat to development everywhere" and made "galvanizing international action on global warming" as one of his main priorities(United Nations, 2007b). When in 2007 the Nobel Peace Prize was awarded for work on the science and communication of climate change it signified the prominence of the international climate change[1] challenge.

Despite the considerable public attention to climate change, progress towards the implementation of action is limited. In particular, measures to adapt to impacts on natural environment and human society of projected climate change are still at an early stage. Among other constraints, insufficient availability of and access to relevant climate information has been reported as a barrier to adaptation (Adger et al., 2007; OECD, 2006). To address this, notable efforts are being made to improve the accessibility of data currently available, by regional centres and international organisations. Other requests include restructuring climate research so that relevant information more easily supports decision-making (Stainforth et al., 2007). However, guidance on how to use existing climate observations and model projections to inform adaptation decisions is currently limited, which hinders further progress on integrating climate change adaptation into development policies and plans at different levels. Although there have been guidance documents on how climate information could be derived and applied to climate impacts and adaptation assessments, they tend to focus on the supply side of the equation, i.e., what climate data are available (IPCC-TGICA, 2007; Lu, 2006). These guidance documents fall short in analyzing the context of adaptation decisions and their needs for climate information, hence are of limited help to adaptation practitioners.

This document aims to address this deficit through an overview of the needs for climate information within different stages of adaptation process, observational and projected climate data that can be used to aid adaptation decisions. Although supporting adaptation work in developing countries through the national communication process has been the primary motive for this document, much of the guidance provided here is applicable to industrialised country context as well. Where possible, examples are provided to illustrate how climate information could be used to support different adaptation decisions.

It is worth noting that climate change is only one of the many factors that contribute to the vulnerability of communities. Other non-climate factors could be much more significant. Readers are therefore reminded that due consideration is needed during the adaptation decision process to weigh relevant data and uncertainty issues related to these non-climate factors.

This document is intended for experts engaged in climate risk policy assessments and consultants advising the design and implementation of adaptation policies and projects at national and sectoral levels. Particularly, scientists and consultants/technical advisors involved in the preparation of Second National Communications (SNCs) from non-Annex I parties to the United Nations Framework Convention on Climate Change (UNFCCC) are encouraged to refer to this guidance for the preparation of the 'vulnerability and adaptation to climate change' section of the SNC documents. Users of this guide are expected to have a basic understanding of climate risk assessments, potential uses and limitations of climate information, and the process of adaptation decision-making.

Adaptation decision frameworks and the role of climate information are discussed in Section 2. The needs for climate information are discussed by each of the key components of risk assessment and adaptation planning: initial risk screening, detailed risk analysis and evaluation of adaptation options. Section 3 summarizes available climate information and their potential applications in adaptation decision-making. Section 4 highlights critical questions in guiding the selection and application of climate information with three distinctive decision objectives: to enhance adaptive capacity, to formulate climate resilient development plans, and to invest in adaptive infrastructure development. The document concludes with a set of key messages in Section 5.

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[1] See http://nobelprize.org/nobel_prizes/peace/laureates/2007/ipcc-lecture.html for the Nobel Lecture.

2 ADAPTATION TO CLIMATE CHANGE: DECISION-MAKING UNDER UNCERTAINTIES

In this document, adaptation is defined as strategies, policies, programmes, projects or operations aimed at enhancing resilience or reducing vulnerability to observed or plausible changes in climate. It includes activities implemented to create changes in decision environments as well as actual adjustments to address climate risks (Adger et al., 2007). Developing a national or regional adaptation action plan is a good example of creating positively influential changes in a policy environment. On the other hand, building a sand dam to harvest rain water in arid areas is an actual action taken to reduce vulnerability of communities in times of drought.[2]

To plan for adaptation to currently observed and/or projected climate change, decision makers need to consider both climate and non-climate factors. Adaptation decisions may be directly driven by the need to reduce or otherwise manage anticipated climate risks, based on experience in coping with past and current climate variabilities. For instance, decisions are required to manage the expected consequences of variability in climate (e.g., cold years, flood events, seasonal droughts, storm surges, extreme wind speeds, freezing conditions, heat waves). These are decision areas where climatic factors have long been acknowledged as being a primary consideration in the choice of risk management options. With climate variability and change being the key drivers, these decisions are referred to as climate adaptation decisions (Willows and Connell, 2003). However, there are also many decisions where the outcomes could be affected by climate change, but where climate change is only one of a number of factors. For example, when a farmer in a drought prone area of Africa selects the crop variety, climate change and its potential impacts could be an important consideration. But the market trend and access to seeds of crop varieties are also important factors that need to be taken into account. Such decisions, also considering non-climate factors may be called climate-influenced decisions (Figure 1) (Willows and Connell, 2003).

Due to the cascade of uncertainties associated with climate change and its impacts, and other socio-economic factors, adaptation can be characterized as decision-making under uncertainties. This document addresses issues related to adaptation planning under uncertainties related to observed and projected climate change. To manage climate risks under a changing climate, a critical question for decision-making within this context is: What is the appropriate level of adaptation and on what timeline? This relates to the range of uncertainty in projecting future climate change and its impacts that operate at different spatial and temporal scales as illustrated in Figure 2.

Sources of uncertainties in assessing impacts of climate change include:

- Emissions pathways determined by socio-economic and technological patterns;
- Carbon and other gas cycle and feedbacks;
- Climate model uncertainties (including transient climate sensitivity);[3]

Figure 1: Relative significance of climate risks
(Source: Willows and Connell, 2003)

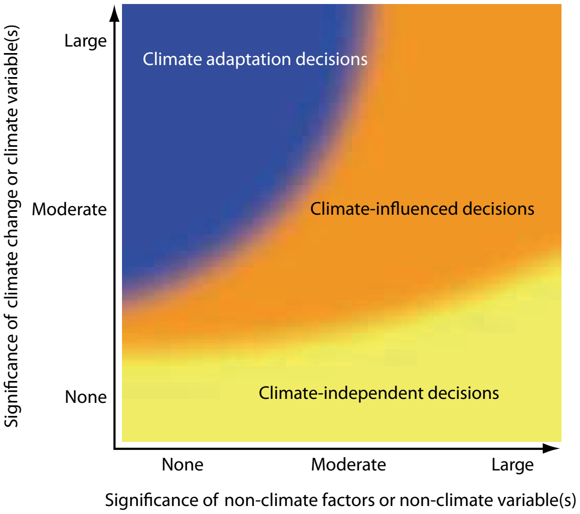
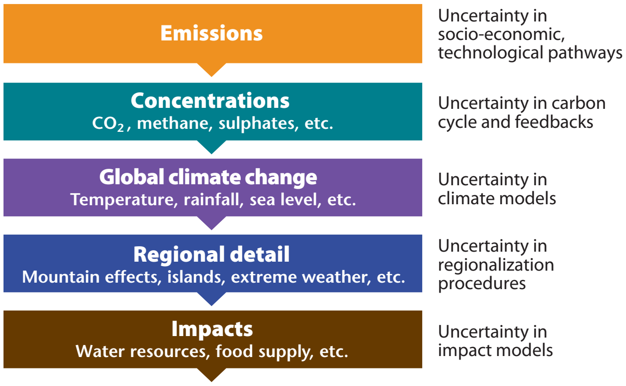


Figure 2: Cascade of uncertainties associated with characterizing future climate change and its impacts *(Source: modified from Jones et al., 2004)*



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[2] See http://practicalaction.org/practicalanswers/product_info.php?cPath=&products_id=60 for details.

[3] The IPCC defines "climate sensitivity" as the equilibrium temperature rise that would occur for a doubling of CO_2 concentration above pre-industrial levels.

- Regionalization procedures; and
- Impact assessment techniques

The degree to which adaptation decisions are sensitive to these uncertainties determines the role of, and the level of requirement for climate information (both observations and projections) in the decision-making process. Dessai et al. (2005) examined the role of climate scenarios in adaptation planning. They concluded that, in addition to the availability of technical and financial capacity to handle climate scenario information, the type of and approach to adaptation have a major bearing on the role climate information plays in supporting adaptation decision.

A variety of taxonomy for adaptation have been proposed (e.g., Adger et al., 2007). To frame adaptation within the context of development efforts, McGray et al. (2007) places adaptation activities in a continuum of approaches, from actions undertaken to address the underlying contributors to climate change vulnerability to measures explicitly directed to address the impacts of climate change (Table 1). Vulnerability-based approach, with its emphasis on underlying vulnerability factors (often non-climate factors), is less dependent on climate projections for adaptation planning. On the other hand, approaches starting with climate change impacts generally require more information on likely changes in key climate parameters to assess potential impacts. However, the nature of adaptation intervention under different approaches and the spatial and temporal scales at which the intervention takes place all have implications for the requirement of climate information. For example, large-scale, broad (qualitative) descriptions of current and future trends in primary climate variables may well be sufficient to "climate-proof" long-term national or regional development strategies (e.g., to restructure the key climatically sensitive economic sectors). But the design of major coastal defence infrastructure at a particular location needs information about changing surge and wave heights (local scale), in additional to global sea level rise projections (broad scale), to aid the design of the defence system. Therefore, a more

Table 1: A continuum of adaptation activities: from development to climate change and examples[4]
(modified from McGray et al., 2007)

1 Addressing Drivers of Vulnerability	**2 Building Response Capacity**	**3 Managing Climate Risk**	**4 Confronting Climate Change**
UGANDA: Providing women with crossbred goats and instructions in graze-free feeding *(Karamoja Agropastoral Development Programme* **BANGLADESH:** Diversification of livelihood strategies in areas vulnerable to flooding (**South***South*North) **CUBA:** Vaccination program to eradicate diseases in low-income areas *(Cuban Ministry of Health)*	**BRAZIL:** Participatory reforestation in Rio de Janeiro's hillside favelas to combat flood-induced landslides *(City of Rio de Janeiro)* **MONGOLIA:** Reinstating pastoral networks to foster appropriate rangeland management practices in arid regions *(National University of Mongolia)* **TANZANIA:** Reviving traditional enclosures to encourage vegetation regeneration and reduce land degradation *(Ministry of Natural Resources and Tourism, Tanzania)*	**TANZANIA:** Monitoring salinization of drinking water and drilling new wells to replace those that are no longer usable (**South***South*North) **MALI:** Teaching farmers to collect climate data and integrate it into their planting decisions *(Government of Mali / Swiss Agency for Development and Cooperation* **BANGLADESH:** Using nationally standardized risk assessment procedures to develop a community adaptation plan of action *(local government)*	**INDONESIA:** Managing coral reefs in response to widespread coral bleaching *(WWF)* **NEPAL:** Reducing the risk of glacial lake outburst floods from Tsho Rolpa Lake *(Government of Nepal)*

Vulnerability focus ← → **Impact focus**

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[4] Refer to Mcgray et al. (2007) for details of these examples.

pragmatic way to examine the need for climate information to support adaptation is to look at the process of adaptation, as described in different adaptation decision frameworks.

2.1 Adaptation decision frameworks

Different frameworks have been developed and applied to assessing climate change impacts, vulnerability and adaptation and subsequently guiding the adaptation decision process (Carter et al., 2007). Examples include the IPCC 'seven-step approach' (IPCC, 1994), UNDP Adaptation Policy Framework (UNDP, 2005), UK Climate Impacts Programme's climate risk decision framework (Willows and Connell, 2003), Australia's climate risk management guide (Australian Greenhouse Office, 2006), and the US Agency for International Development's climate adaptation mainstreaming guidance (USAID, 2007). These frameworks were developed with different end users (academia vs. practitioners), objectives (advancing science vs. improving adaptation decision-making), and overall approaches (top-down vs. bottom-up). Table 2 summarizes the key characteristics of these adaptation decision frameworks.

Table 2: Characteristics of major adaptation decision frameworks

Adaptation decision framework	Objective	Target end-users	Key components/steps
IPCC 'seven-step approach' (Carter et al., 1996)	Guiding the **assessment** of climate change impacts and adaptation	• Researchers	1. Define problem 2. Select method 3. Test method/sensitivity 4. Select scenarios 5. Assess biophysical and socio-economic impacts 6. Assess autonomous adjustments 7. Evaluate adaptation strategies
UKCIP climate risk decision framework (Willows and Connell, 2003)	Facilitating the climate risk **assessment** and **management** through informed decision-making	• National and local governments • Resource managers • Businesses • Professional associations	1. Identify problem and objectives 2. Establish decision-making criteria 3. Assess risk 4. Identify options 5. Appraise options 6. Make decision 7. Implement decision 8. Monitor
UNDP Adaptation Policy Framework (UNDP, 2005)	Facilitating the climate risk **assessment** and management	• Researchers • Decision makers at different levels • Donor agencies	1. Scope and design an adaptation project 2. Assess current vulnerability 3. Assess future vulnerability 4. Formulate adaptation strategy 5. Continue the adaptation process
Australian Greenhouse Office climate risk management guidance (Australian Greenhouse Office, 2006)	Facilitating the **climate risk assessment and management**	• National and local governmental bodies • Businesses	1. Establish the context 2. Identify the risks 3. Analyse the risks 4. Evaluate the risks 5. Treat the risks
USAID guidance on integrating adaptation into development projects (USAID, 2007)	Establishing the **context for adaptation** and guiding the **climate risk screening and climate-proof project design**	• Development agencies	1. Screen for vulnerability 2. Identify adaptations 3. Conduct analysis 4. Select course of action 5. Implement plan 6. Evaluate

There are clear differences in the way climate risk is framed (sensitivity, impacts or vulnerability) and the process (steps) to manage risks within these frameworks, but they share three key components that involve the application of climate information. They are:

- Initial risk screening,
- Detailed risk analysis, and
- Assessing risk management options.

The next section describes these components and their respective needs for climate information.

2.2 Needs for climate information

2.2.1 Initial risk screening

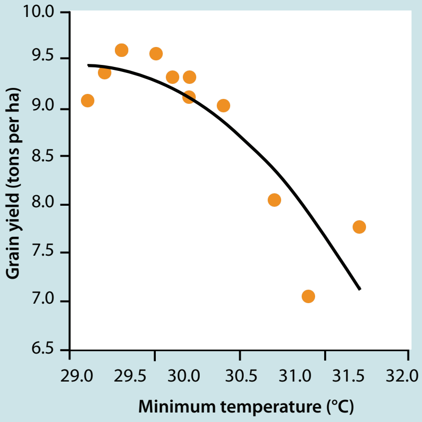
This step establishes whether climate variability and change would compromise the function and services of a system, outcome and effectiveness of an activity and policy decision, or longevity of infrastructure. The premise is that if the key functions or outcome of a system or activity are sensitive to currently observed trends in relevant climate variables, and if there is evidence that these may change in the future, then there are reasons for concern in terms of potential risks or opportunities.

This usually entails a sensitivity analysis and preliminary vulnerability assessment. Observed trends in relevant climate parameters over the past (e.g., 30-50 years) are required. Depending on the adaptation service/project in question, characteristics of extreme weather events (e.g., heavy rainfall events) may be required. The range of relevant climate variables can vary: For some activities the most common indicators, such as temperature and rainfall, are sufficient, while others require more information, such as humidity to assess health impacts. In general, the need for climate information at this stage is moderate, and the required data, to a large extent, exist[5] either in a national meteorology archive and/or provided by international organizations with a data provision and dissemination mandate. Broad directions of change under future climate in key variables are also required at this stage. This is important to determine whether currently observed climate impacts are likely to continue under a changing climate in the future. Details on the possible sources of data are provided in Sections 3.1 and 3.2 below.

Box 1: Using results from sensitivity analyses and broad scale climate information for initial risk screening — a case study on rice production in the Philippines

To evaluate the potential impacts of global warming on rice production, Peng et al. (2004) analyzed the relationship between rice grain yields and temperature trend over the period of 1979 – 2003. They found a close link between rice grain yield and mean minimum temperature during the dry cropping season (from January to April). Grain yield declined by 10% for each 1°C increase in growing season minimum temperature in the dry season (see Figure 3)[6]. With the high level of sensitivity of rice yield to minimum temperature over the dry growing season, broad scale projections for minimum temperature change in the future are helpful in determining the potential risks climate change poses to rice production in the Philippines. Indeed, the multi-model and multi-emission scenarios average projection of minimum temperature over the period from January to April is estimated to be around 2° higher than present day value by the end of the 21st century (http://www. cru.uea.ac.uk/~timm/climate/ateam/TYN_CY_3_0.html). Hence, a potentially significant decline in rice grain yields can be expected and further detailed risk analyses are warranted to examine the extent and nature of the risk.

Figure 3: Link between rice grain yield and minimum temperature over the dry growing period (January to April) in the Philippines *(Source: modified from Peng et al., 2004)*



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[5] Despite the progress made to enhance the global climate observatory system, access to data archives in many developing countries is still limited and in some countries, the number of functional stations is actually in decline (see e.g., WMO, 2005).

[6] However, the authors did not offer any definitive explanation for this correlation between increase in nighttime temperature and rice yield decline while suggesting that increased maintenance respiration (hence reduced assimilation) resulting from temperature rise cannot solely explain the observed trend.

Boxes 1 and 2 illustrate the procedure of initial risk screening using two examples: rice yield sensitivity to nighttime temperature in the Philippines, and national annual GDP growth rate sensitivity to June-July-August rainfall variation in Ethiopia. From sensitivity analyses[7] and consideration of broad scale climate change projections, it is clear that projected climate change poses risk on rice production in the Philippines, and impedes national economic development in Ethiopia. Efforts to further investigate the nature of the risks (i.e., detailed risk analysis) and plan for adapting agriculture sector or the national economy to a changing climate are thus warranted.

2.2.2 Detailed risk analysis

If the initial risk screening points towards possible risks to the objectives or services of an activity or system under projected climate change, detailed risk analyses are often required to further characterize, usually quantitatively, the nature of the risks. Detailed risk assessments sometimes serve to inform whether adaptation is needed under specific circumstances. For example, even though a sensitivity analysis may suggest a significant percentage (e.g., 10%) reduction in rice yield would incur with each 1.0°C of increase in night time temperature in a particular area, if night time temperature rise is unlikely to exceed 0.5°C over the next 50 years, immediate adaptive measures may not

Box 2: Using results from sensitivity analyses and broad scale climate information for initial risk screening — a case study on GDP growth rates in Ethiopia

Ethiopia's national economy is heavily dependent on climate sensitive sectors, for example variability in rainfall quantity during the growing season can have a major impact on the GDP growth rate in Ethiopia. As shown in Figure 4, the trend of GDP growth rate follows very closely that of variability in June-July-August rainfall amount. As shown in Figure 5, Ethiopia is to expect June-July-August rainfall decrease under a changing climate. It is therefore important to further examine the potential impacts of changes in rainfall on climate sensitive economic sectors and consider necessary measures to address them.

Figure 4: GDP growth rate and variation in June-July-August rainfall 1982-2000 in Ethiopia *(Data source: Rainfall anomalies are derived from http://www.cru.uea.ac.uk/~timm/cty/obs/ TYN _CY_1_1.html; GDP data are derived from World Bank data base.)*

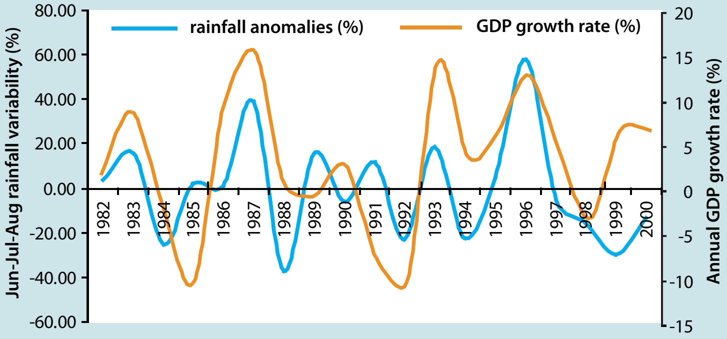
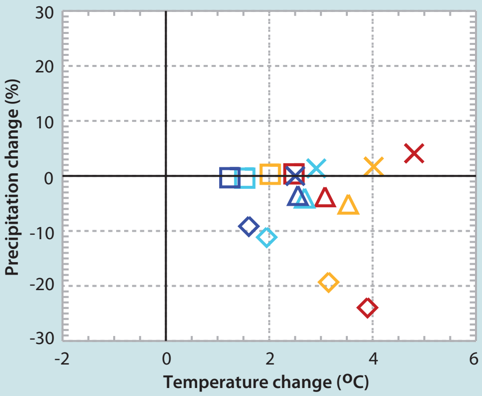


Figure 5: Anomalies of June-July-August rainfall for the 2080s in Ethiopia as simulated by different climate models (denoted by different symbols) and under different emissions scenarios (represented by different colors) *(Source: http://www.cru.uea.ac.uk/~ timm/climate/ateam/TYN_CY_3_0.html)*



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[7] Such sensitivity analyses may already have been undertaken. Efforts should be made to review existing literature (e.g., national communications, IPCC reports, and other published resources) before initiating new sensitivity studies for risk screening.

be necessary. There are different approaches, methods and tools for assessing climate risks (e.g., Jones et al., 2005; Willows and Connell, 2003), but essentially, a practitioner needs to determine and assess:

- Acceptable risk level;
- Impacts of climate change on the activity or system which often involves the application of climate scenarios;
- Impacts of changes in non-climate factors (e.g., socio-economic conditions, land-use change, technological advances, etc.) on the activity or system;
- Cost of climate change impacts; and
- Confidence level of the assessment, which entails detailed consideration of uncertainty.

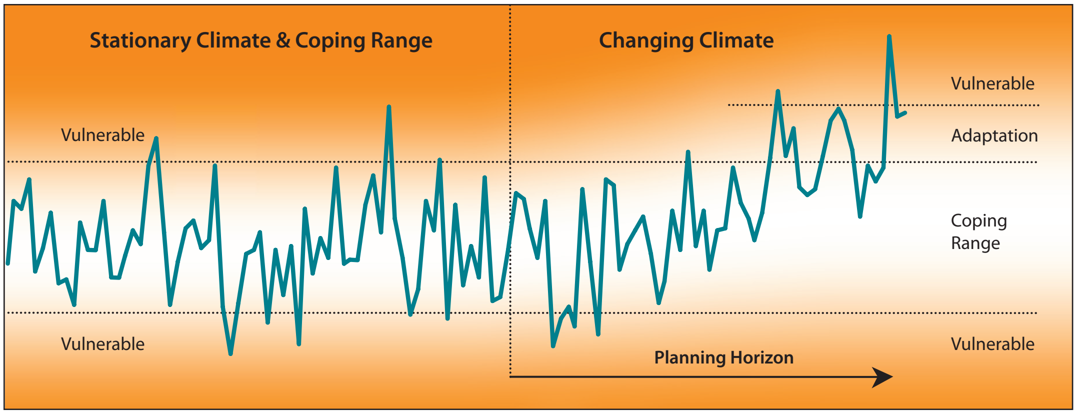
For climate risk assessment and management, ***critical threshold*** is a key concept. A critical threshold refers to the level of magnitude of a system process at which sudden or rapid change occurs. This could be a critical level of climate stimulus (e.g., 40% reduction in annual rainfall) or a critical level of impacts on an activity or system (e.g., loss of biological species by 20%). Critical thresholds are often used to separate a system's coping range from vulnerable state (see Figure 6 below). They are also closely related to the risk attitude of stakeholders, which ultimately determines the significance of climate risks and the need to adapt. Critical thresholds of climate stimuli are usually derived from trend analysis of key parameters of a system and that of climate variables. An example of deriving critical thresholds of climate stimuli for malaria transmission is provided in Box 3.

Box 3: Deriving critical thresholds of climate stimuli for malaria transmission

In order to provide early warning for malaria outbreak in Africa, the International Research Institute for Climate and Society (IRI) developed the Seasonal Climatic Suitability for Malaria Transmission (CSMT) tool (see http://ingrid.ldeo.columbia.edu/maproom/.Health/.Regional.Africa/.Malaria/.CSMT/). Fundamental to this tool is the empirically derived critical thresholds for malaria transmission: monthly precipitation at and above 80mm, mean temperature between 18 and 32°C, and mean relative humidity at least 60% (Hellmuth et al., 2007).

Once a critical threshold is identified, future climate change projections are taken into consideration to measure the significance of climate risks. For the example described in Box 3, if future climate change projections indicate all the critical climatic thresholds will be exceeded (i.e., monthly temperature between or above 18-32°C, rainfall exceeding 80 mm, and relative humidity higher than 60%), the risk of malaria outbreak would be perceived significant.

Figure 6: Conceptual illustration of a coping range showing the relationship between climate change and threshold exceedance, and of how adaptation can establish a new critical threshold, reducing vulnerability to climate change *(Source: Carter et al., 2007)*



In relation to the needs for climate information, the following aspects are important to consider and are contextual to the specific risk analyses:

- Relevant climate variables,
- Temporal scales, and
- Spatial scales.

Relevant climate variables

Identifying the relevant climate variables is an important first step for risk assessments. Depending on the sector or system under consideration, necessary climate variable information can vary widely. In selecting the appropriate variables for risk assessment, a robust physical relationship between the selected variables and the outcome or function of the activity or system being considered should be ensured. Relevant variables may be identified by stakeholders, conceptual models of the system, or through the use of more detailed process models where prior research and experience have revealed the key climate drivers of the system.

Table 3 presents a set of common variables relevant for assessment in different sectors or systems. Data on variables listed in Table 3 can be obtained from direct meteorological measurements or climate model simulations. But risk analyses may also require the characterization of climate hazards or extreme events. Basic variables can be used to derive indicators of these

Table 3: Common climatic variables used for climate impact and risk assessment *(Source: modified from CSIRO, 2007)*

Sector/system	Areas of potential impacts	Relevant climatic variables
Agriculture	• Insect outbreaks • Soil properties • Crop yields • Livestock herds	• Temperature • Rainfall • Solar radiation • Evaporation
Water resources	• Water availability and supply • Water resources reliant on snow melt	• Temperature • Rainfall • Evaporation
Coasts	• Coastal erosion • Coastal flooding • Storm surge return periods and area inundated	• Temperature • Rainfall • Sea level • Wind • Pressure
Human health	• Heat stress and related mortality • Infectious disease	• Temperature • Rainfall • Humidity
Infrastructure	• Road and rail maintenance costs • Building • Energy production	• Temperature • Rainfall • Radiation • Winds • Sea level
Biodiversity	• Primary production • Abundance and distribution of species • Coral bleaching and mortality	• Temperature • Rainfall • Radiation • Sea surface temperature

Table 4: Climatic variables used to characterize extreme climate events *(Source: modified from SEI, 2007)*

Climate hazard	Climate variables
Drought	• Evapotranspiration • Dry spells (number of days with rainfall below a certain dependable amount)
Wind storm	• Maximum daily/hourly wind speed
Heat wave	• Number of consecutive days with high maximum temperature • Maximum temperature
Flash floods	• Hourly or daily rainfall and/or rainfall intensities
Waterlogging	• Precipitation • Soil water content and field soil moisture capacities
Landslide	• Accumulative daily rainfall • Soil moisture
Riverine flood	• Number of consecutive rainy days
Fire	• Onset of rainy season • Number of consecutive dry months • Maximum temperature

hazards and events. Table 4 summarizes a set of common hazards and basic climate variables that can be used to characterize these hazards.

Temporal scales

Time horizon

The objectives/functions of an activity/system are often associated with different time scales, which have implications for the time horizon over which climate information is needed to assess risks.

Adaptation practitioners shold consider changes in both the mean and variability of climatic variables, but the relative importance of changes in the mean and variability in adaptation decision process varies with, among other factors (e.g., governance level), the time horizon of the decision. If an activity (e.g., a policy, programme or project) or system (e.g., an orchard) has long payback times or long-term (decades or longer) consequences, it is more likely to be affected by long-term climate change. If the associated timescales are shorter (a few years or less), the activity or system is more likely to be vulnerable to short-term variations and weather extremes. In these cases, recent climate records or impacts of extreme weather events that have already happened could be used to assess climate risks.

Boxes 4 and 5 provide examples of using climate change and climate variability information to assess climate risks for activities/systems associated with different time horizons.

Box 4: Using seasonal climate forecasts to detect and manage malaria risk in southern Africa *(Source: Hellmuth et al., 2007)*

Under the Roll Back Malaria initiative, a new Malaria Early Warning System (MEWS) was developed. The System includes five components, of which seasonal climate forecasting is an important one. Given the established link between climate and malaria incidence (see Box 3 on critical thresholds of key climate variables for malaria transmission), reliable forecasting can help predict and provide sufficient time to manage epidemics. Seasonal climate forecasts can give several months lead time, allowing effective control and other measures to be put in place. Computer-based software packages are developed to facilitate the detection of potential malaria risks using seasonal climate forecasts.

Box 5: Using long-term climate projections to assess climate risks and plan for adaptive responses *(Source: USAID, 2007)*

As part of its effort to support the development of tourism in Honduran coastal city of La Ceiba, where flooding and storm surge are of great concerns, USAID identified the installation of urban drainage system as a priority adaptive measures to be incorporated into the Agency's assistance programme. To assist the design of the drainage system, climate projections for the next 50 years or longer are required to estimate the intensity and extent of urban flooding and thereafter to evaluate the cost of the engineering work involved under different safeguard specifications of the drainage system.

Time slice or transient

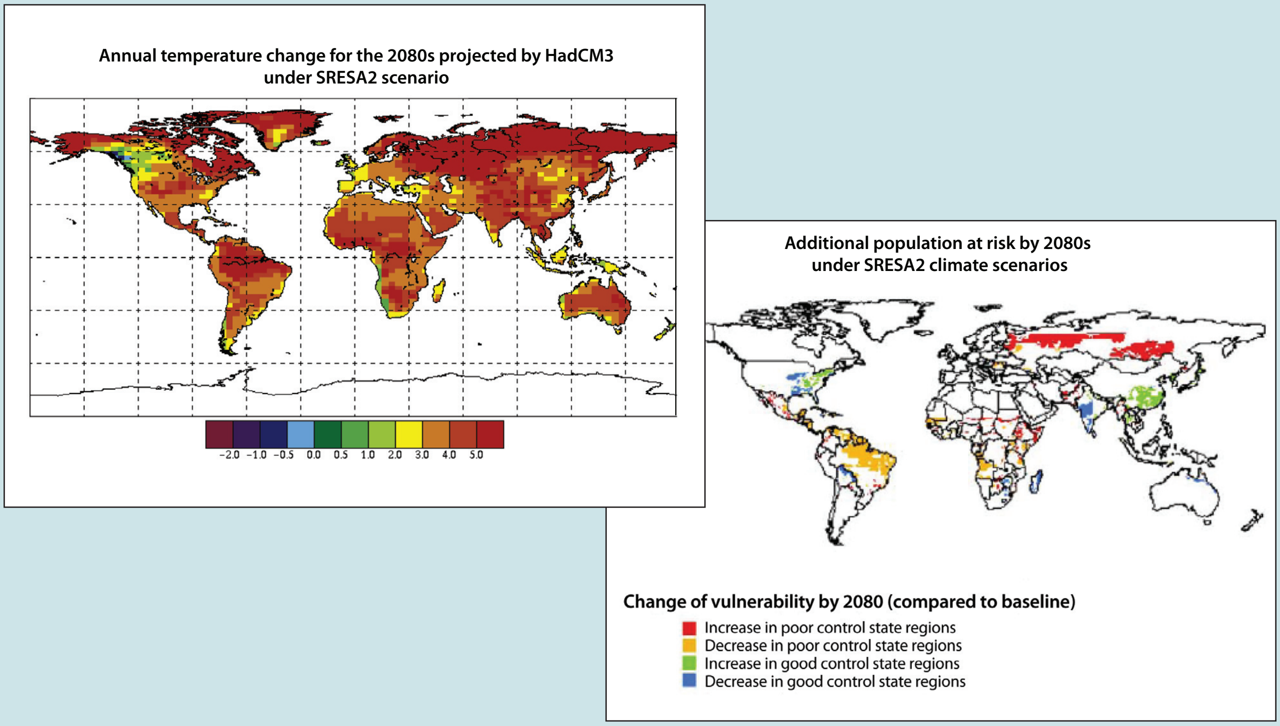
For some sectors or systems, a risk analysis for a particular future time slice might be sufficient to inform the decision on the risk management options. For example, an assessment on the total additional population at risk of contracting malaria by 2050 or 2080 would be helpful to guide the long-term provisions of health care. Multi-decadal average monthly climate change projections are usually used to support such assessments (Box 6).

For other assessments, the time evolution, rather than a snapshot, of sectoral performance or system function is essential. For example, the evolution of vegetation dynamics within a terrestrial ecosystem is important to evaluate the potential risks of climate change. To support such assessments, time series of climate data is required to count for the inter- or intra-annual variability. Box 7 provides an example of using annual time series of temperature and precipitation to assess the impacts on global net ecosystem productivity.

Box 6: Using multi-decadal average monthly climate change projections to assess future populations at risk of contracting malaria

Lieshout et al. (2004) used multi-decadal average annual temperature and precipitation projections and the MIASIAM model to characterize the level of populations' vulnerability to malaria risks at global scale (see Figure 7). In addition to climate variables, socio-economic indicators such as population and malaria control status sharing the same underlying socio-economic storylines as the climate scenarios are also included in the assessment (Lieshouta et al., 2004).

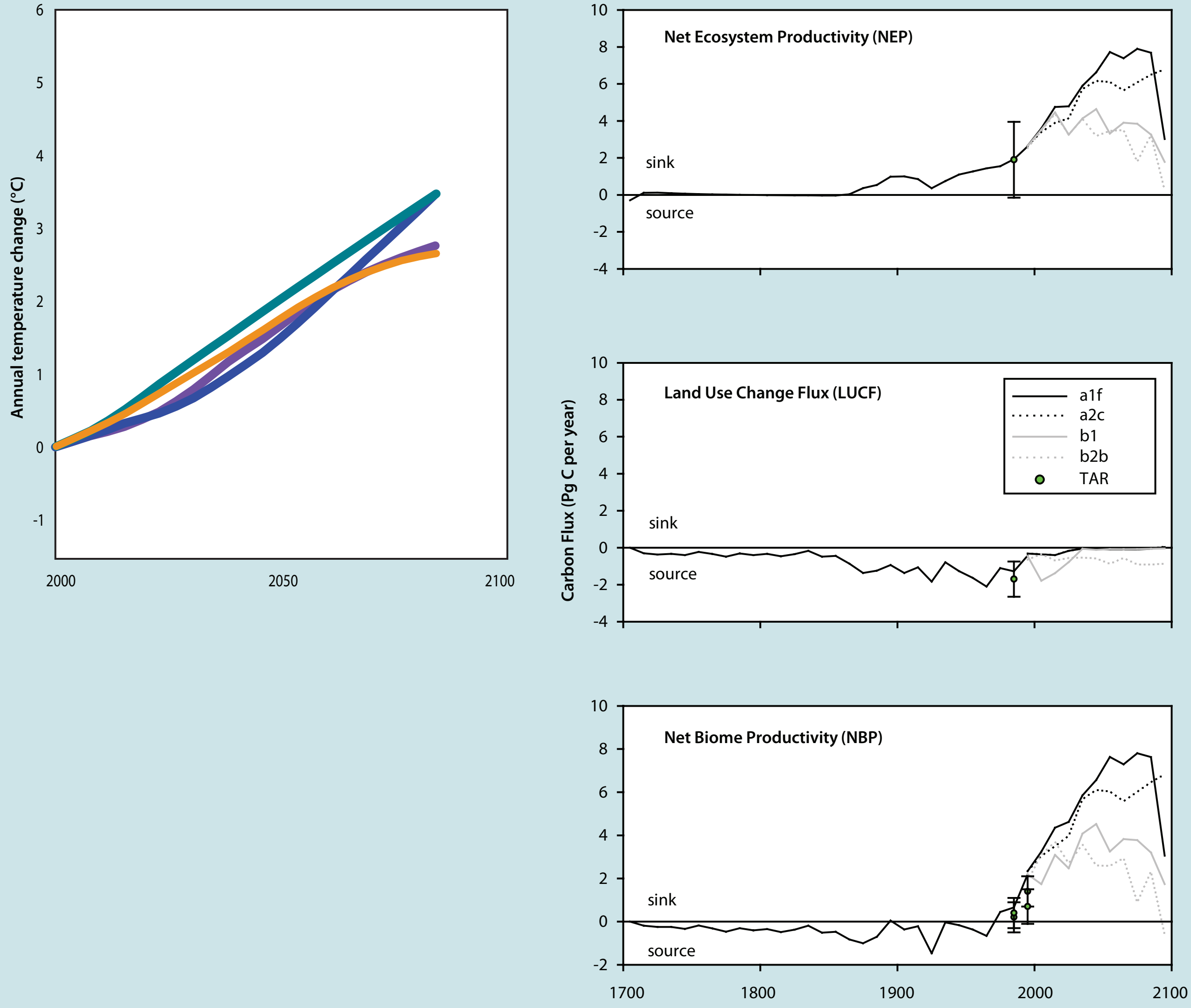
Figure 7: Multi-decadal average climate projections and assessment of potential malaria risks. Climate projection map is obtained from the data visualization tool provided by the IPCC Data Distribution Centre (http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf). The malaria risk map is extracted from Figure 7 of Lieshout et al. (2004).



Box 7: Using time series climate information to assess ecosystem functions and services

To assess the global carbon fluxes (as one of the key features of ecosystems) throughout the 21st century, Levy et al. (2004) used temperature and precipitation time series projections derived from the HadCM3 simulations, CO_2 concentrations and land use scenarios, and the HyLand model (Levy et al., 2004).

Figure 8: Time series climate projections for the 21st century and global carbon fluxes. The left panel is an illustrative example of climate projections (derived here from MAGICC simple climate model www.cgd.ucar.edu/cas/wigley/magicc/); the right panel shows the global carbon fluxes estimates using time series scenarios of climate, CO_2 concentration and land use. *(Source: Figure 3 of Levy et al., 2004)*



Temporal resolution

For some assessments, seasonal or annual average quantities of climate variables will be sufficient (e.g., for assessment of ecosystem function/services; see Box 7). But for other assessments, analysis on daily or sub-daily processes is required. For instance, daily climate data (both from observations as well as projections for the future time period) are needed to derive indicators of extreme events such as heat wave occurrence or peak river flow during flooding events. Although daily climate data are not always readily available from climate model experiments, there are techniques that could be used to generate data at daily or sub-daily scales based on observed statistic relationships between indicators of different temporal scales. Box 8 presents an example of applying daily climate data to analyze extreme events.

Spatial scales

Geographic extent

Depending on the subject of risk assessment, climate information is required for a variety of geographic extents: from a single site (e.g., a farm), a limited area (e.g., a river basin or lake area), to an entire country or continent. For single location assessments, observations at weather station(s) are often used to define baseline climate while downscaling techniques are applied to generate climate scenarios for impact assessments. Gridded climate datasets of different spatial resolutions are used to support assessments covering a larger area.

Examples of applying climate information for impact assessments with different geographic extents are presented in Box 9.

Box 8: Using daily climate information to characterize future rainfall events

To analyze the potential impacts of climate change on the farming practices in lower Mekong River Basin, Chinvanno et al. (2006) used daily outputs from the high resolution (10km x 10km) Conformal Cubic Atmospheric Model to characterize rainfall events under future climate conditions. As shown in Table 5 below, for Paske in Lao People's Democratic Republic, future rainy season is to start earlier and end sooner with a shorter duration, compared with present-day conditions. Meanwhile, total annual rainfall amount is expected to increase. But with shorter rainy season, it is expected that the rainfall will arrive in more intense events, with significant implications for rice farming practices in the area.

Table 5: Characteristics of rainfall events under future climate for Paske, Lao PDR *(Source: Table A3 of Chinvanno et al., 2006)*

CO_2 scenarios	Onset data	End date	Length of rainy season (days)	Annual rainfall (mm)
Baseline	140	336	197	959
540ppm	133	287	155	1027
720ppm	137	312	176	1105

Box 9: Application of climate information to support risk assessments with different geographic extents

A single site

To 'climate proof' the design of the Breakwater for the Western Basin, Avatiu Harbour, Rarotonga, the Cook Islands (see the left hand panel of Figure 9 below), risk assessment was carried out to determine the design water level and waves (including wave height, period and incidence direction) based on climate and sea level change scenarios (Hay et al., 2005). As shown in the right panel of Figure 9, GCM-simulated maximum wind speed data (by the CGCM3 model forced by SRES A2 emissions scenarios) for the grid containing Rarotonga were used to calculate the changes in return period of currently observed strong wind speed associated with extreme wave events.

Since the GCM simulations at grid level represent the average values over a large area (typically 100s km by 100s km), they underestimate the extreme wind speed at a specific location (Rarotonga, in this case). Therefore, GCM output for maximum wind speed was scaled using the observational data and GCM simulation at the same time period (Hay et al., 2005).

Figure 9: An example of analysis on potential changes in extreme wind speed at a single location

Wind Speed (m/sec)	Return Period (yr)				
	Kirk (1992)	Observed Data (1972 - 1998)	GCM Based Maximum Wind Speed Data		
			1961 - 1990	1991 - 2020	2021 - 2050
28.5	2	2	1	1	1
33.9	5	5	2	2	2
37.5	10	11	3	4	4
38.8	13	14	5	5	6
41.9	25	29	18	16	14
44.9	50	57	60	45	31
47.8	100	113	120	95	64

A limited area

To assess the implications of climate change for water resources in Vietnam, the Government of Vietnam carried out impact analyses at river basin level to estimate changes in river runoff under different climate scenarios derived from GCM simulations. As shown in Figure 10, temperature and rainfall scenarios were derived from GCM simulation for different regions/areas in Vietnam, as inputs to the assessment of runoff changes at river basin scale.

Figure 10: An example of impact assessment using climate scenarios at sub-national/river basin scale *(Source: modified from Government of Vietnam, 2003)*

Climate change scenarios

Variable	Region	Season	2010	2050	2070
Temperature change (°C)	Northwest, Northern of North		0.5	1.8	2.5
	Northern plain		0.3	1.1	1.5
	North of Central		0.3	1.1	1.5
	Middle of Central		0.3	1.1	1.5
	South of Central		0.3	1.1	1.5
	High land		0.5	1.8	2.5
	South		0.3	1.1	1.5
Rainfall change (%)	Northwest, Northern of North	Rainy	0	0 – +5	0 – +5
		Dry	0	-5 – +5	-5 – +5
	Northern plain	Rainy	0	0 – +5	0 – +5
		Dry	0	-5 – +5	-5 – +5

Changes in river runoff under climate change projections

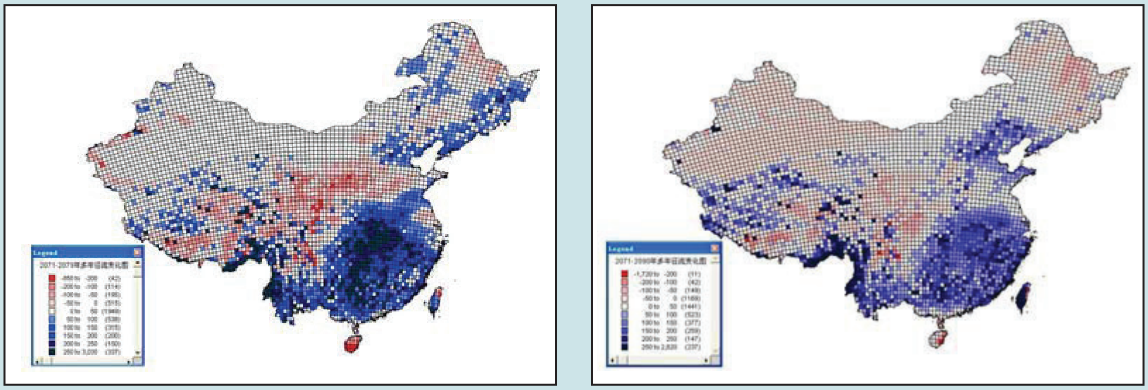
River Basin	Present (mm)	2070 (mm)	Change (%)
Ma & Chu	890	797	-11.5
Hoat	760	758	-2.1
Yen	838	829	-2.1
Lach Bang	788	777	-2.4
Hoang Mai	741	723	-3.5
Bung	725	689	-5.0

Box 9: Application of climate information to support risk assessments with different geographic extents *(cont.)*

An entire country

For most countries, the vulnerability and adaptation assessment under the national communication project is undertaken at the national scale. National level climate information, either as a spatially aggregated average or geographically referenced, is required as inputs to sectoral assessments. Figure 11 below illustrates a national scale spatial analysis undertaken within its Initial National Communication (INC) of China (Government of China, 2004).

Figure 11: Temperature and precipitation changes and their impacts on river runoff in China *(Source: modified from Figure 3.5 of Government of China, 2004)*



SRES A2

SRES B2

Spatial resolution

For many assessments, spatial resolution is often a key consideration. The spatial resolution at which climate information is required is largely determined by the purpose of the assessment. For example, if it is designed to assess the risk of global food insecurity under a changing climate, information at native global climate model resolution (i.e., sub-continental level) may be sufficient. But if the assessment is intended to support adaptation planning at an operational level, for instance, to augment water supply policies or to set a premium for drought insurance, climate information of higher resolution is often required.

Box 10 presents three cases requiring climate information with increasingly higher spatial resolution.

2.2.3 Assessing risk management options

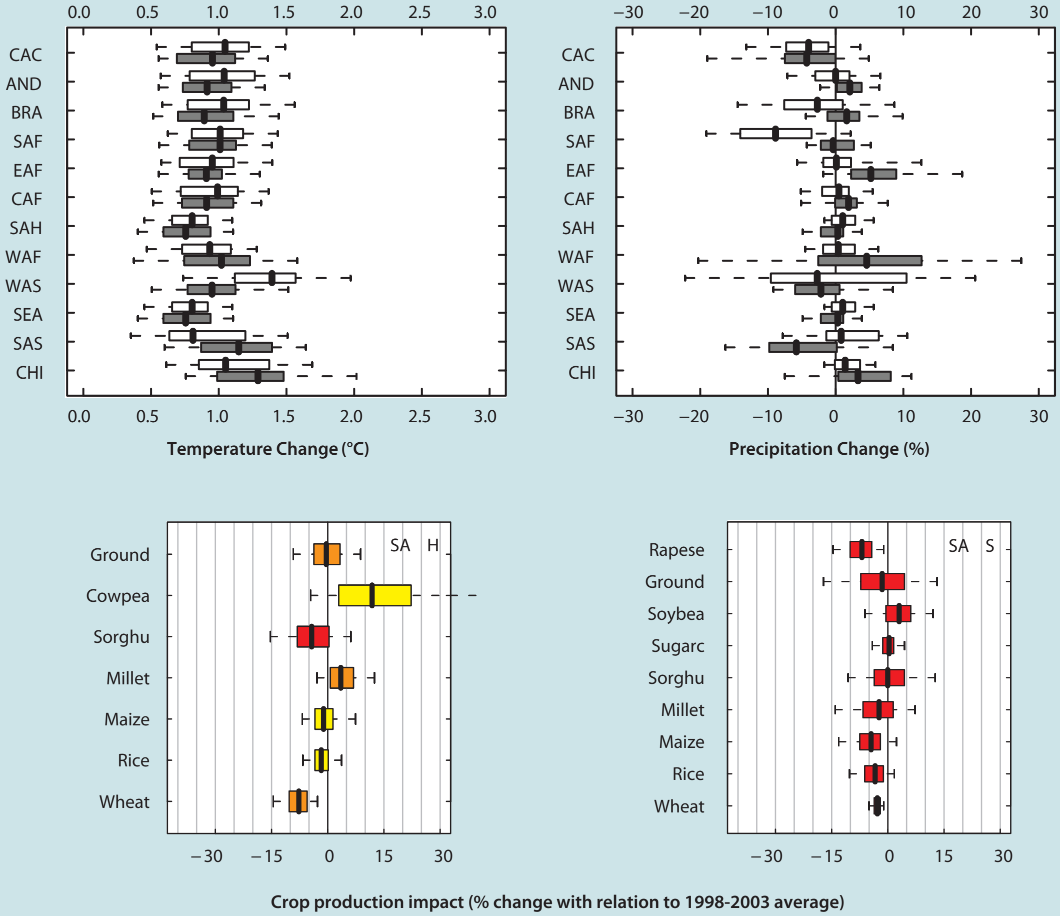
A wide variety of tools and techniques have been developed to evaluate and prioritize options to manage climate risks identified through the assessments (e.g., see Table 15 in Willows and Connell, 2003). One of these tools is scenario analysis. This essentially involves evaluating the efficiency of different options in moderating the risks or enhancing opportunities by re-assessing the risk incorporating the adaptive measures (e.g., through adjusting key parameters in an impact model). Scenario analysis is often conducted in conjunction with other tools (e.g., economic and/or policy analyses,) to assess the economic feasibility and efficiency of alternative adaptation measures under future climate conditions. Therefore, climate information required here is broadly similar to a detailed risk assessment. However, there are two aspects of risk management options that must be assessed that have significant implications for the way climate information uncertainty should be treated: types of intervention and planning horizons.

Box 10: Examples of assessments requiring climate information of increasingly higher spatial resolution

Sub-continental level (GCM skill level)

In order to assess the potential risk of global food insecurity under future climate conditions, Lobell et al. (2008) assessed the impacts of projected climate change on the production of major crops in the world's 12 least food-secure regions. To support the analyses , seasonal temperature and precipitation projections for the 2030s from 20 GCMs under three emissions scenarios were derived (top panel of Figure 12). These changes were used as inputs to crop models to simulate the potential crop production responses (bottom panel of Figure 12). In this case study, climate scenarios at sub-continental scale were derived from GCM experiments (i.e., no downscaling involved). In addition, uncertainty related to emissions scenarios and climate models were represented in the selected climate scenarios. This has resulted in a range, instead of a single value, of changes in crop productions, which is arguably more relevant to adaptation planning.

Figure 12: Climate scenarios (top) at sub-continental scale used to assess the level of potential food insecurity in key world regions *(Source: modified from Lobell et al., 2008)*

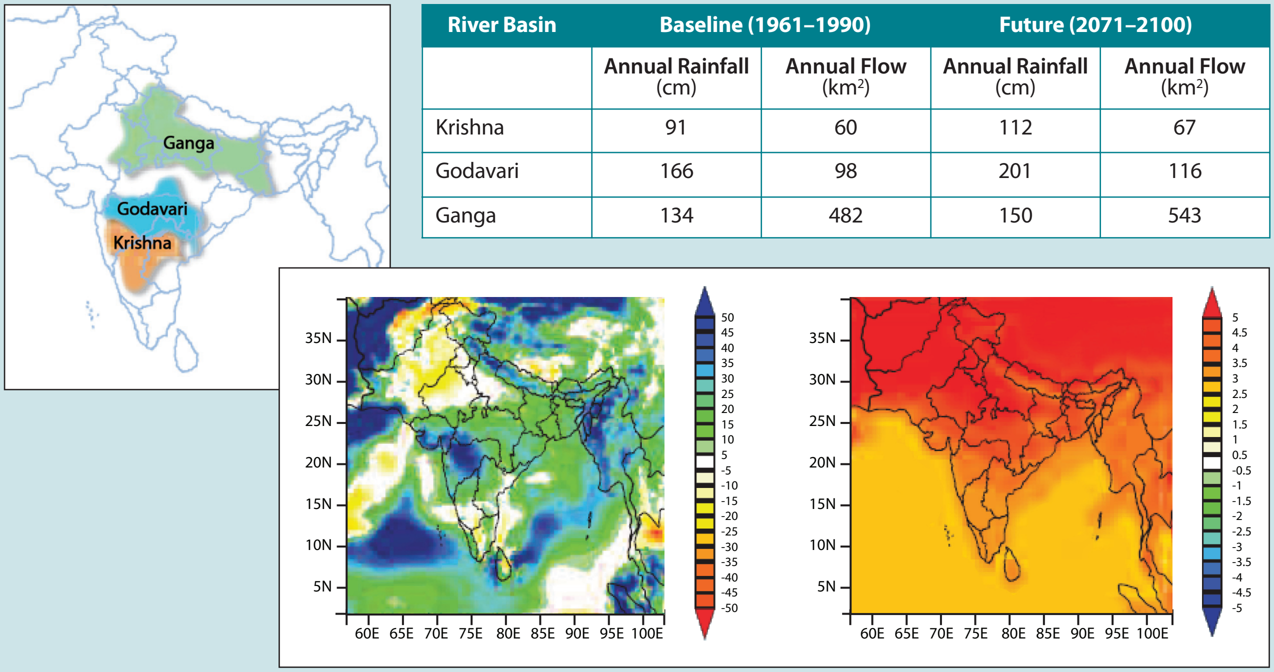


Box 10: Examples of assessments requiring climate information of increasingly higher spatial resolution *(cont.)*

Sub-national level (downscaling often required)

To investigate the impacts of climate change on water resources in the three main river basins in India, Defra (2005b) carried out detailed hydrological modeling (top panel of Figure 13) (Defra, 2005b). To support the analysis , high resolution climate scenarios at 0.44° x 0.44° resolution were developed from outputs of Hadley Centre regional climate model experiments (bottom panel of Figure 13) (Defra, 2005a). Model validation work has suggested that regional climate models show significant improvements over global climate models in simulating surface climate in Indian region. Detailed analyses on the potential changes in river flow and characteristics of extreme rainfall events were made possible with high resolution climate change scenarios.

Figure 13: High-resolution climate change scenarios derived from Hadley Centre regional climate model (bottom) used to assess the impacts on water resources in the three main river basins in India (top)



River Basin	Baseline (1961–1990)		Future (2071–2100)	
	Annual Rainfall (cm)	Annual Flow (km²)	Annual Rainfall (cm)	Annual Flow (km²)
Krishna	91	60	112	67
Godavari	166	98	201	116
Ganga	134	482	150	543

Local level (statistical downscaling often required)

To manage climate risks to farming communities in developing countries, the United Nations has developed and piloted an index-based insurance scheme in Africa and Asia over the past few years (United Nations, 2007a). In general, the premium for such insurance is determined by the expected loss, risk margin and administrative costs:

$$\textbf{Premium} = f\,\textbf{(Expected Loss, Risk Margin, Administrative Cost)}$$

Climate and weather information is required to assess the "expected loss" element of the premium. Within this context, the spatial scale of climate information plays a central role as spatial variation in climate conditions can produce winners and losers: when a drought insurance scheme was piloted in Malawi, the payout was triggered by dry conditions; that is, rainfall over a specified period of time below a preset threshold. The rainfall amount being considered is often representing the precipitation observed at the center point of an area of 20-km radius. But what a farmer would actually receive on his or her plot of land could be higher or lower than that which falls on the center point of the area (Hellmuth et al., 2007).

For this type of applications, global or regional climate model outputs will often need to be downscaled to single locations, using appropriate (often statistical) downscaling techniques and locally observed climate data. See Wilby (2004) for detailed guidance on how to apply climate scenarios generated from statistical downscaling techniques.

Types of intervention

There is a broad range of interventions that could be implemented to manage climate risks. As shown in Table 6, these interventions reflect different ways in which the decision-making process handles uncertainty. No-regret interventions are not affected by uncertainty related to future climate changes, i.e., they deliver benefits greater than costs no matter what happens to the uncertain parameters in the decision-making. Enhancing the provision and dissemination of climate information for farming community in drought-prone areas is an example of no-regret intervention. Evaluation of such interventions does not require the quantification of uncertainties in climate information. To the other end of the spectrum, decisions sometimes have to be made on planning issues (e.g., to plan for the relocation of a large population) or investment (e.g., to select the location, design of the technical specifications for a major reservoir). Given the considerable stake such decisions represent, climate information used to evaluate these interventions needs to treat the wide range of uncertainties to the extent possible. Assessing the potential benefits of interventions falling between these two extreme cases would require some degree of consideration for uncertainty treatment in the climate information used. Table 6 summarizes the varying requirements for uncertainty treatments of different risk management interventions.

Planning horizons

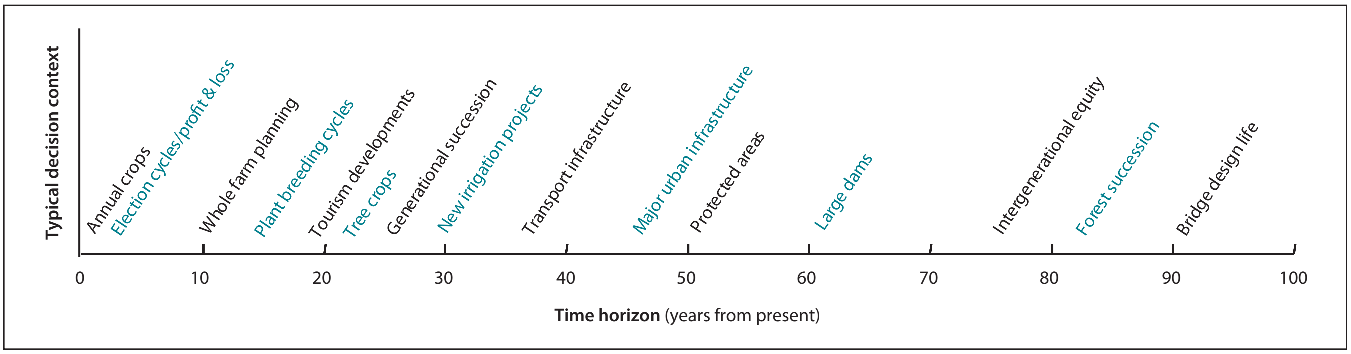
Planning horizons determine how far into the future adaptation invention may be needed. Figure 14 illustrates the varying planning horizons for a range of activities and systems. This has major implications for how climate information uncertainty should be treated, as different sources of uncertainties are associated with different time scales. Table 7 presents the relative significance of different sources of uncertainties for different time horizons.

It is worth noting that uncertainty related to impact assessments are beyond the scope of this guidance hence not discussed here but they can be significant, especially over the near term (see e.g., Wilby et al., 2008).

Table 6: Uncertainty treatment in climate information for assessing risk management interventions

Type of climate risk management invention	Examples	Level of requirement for treating climate information uncertainties
No-regret	Promoting conservation and efficiencies in the use of natural resources	Low
Low-regret	Integrating climate risk and adaptation assessments into business and community planning	Medium-low; Flexible
Win-win	Diversifying sources of income	Medium-low
Flexible/adaptive management	Adopting new crops to suit prevailing climate conditions	Medium
Anticipatory planning or investment	Installing irrigation systems	High

Figure 14: Adaptation decision contexts and their associated time horizons *(Source: modified from Jones, 2007)*



2.2.4 Summary

Common to the various climate change adaptation frameworks, climate information is required to undertake:

- Initial climate risk screening,
- Detailed risk analyses, and
- Evaluating adaptation options.

Depending on the context, the needs for climate information vary widely, with different considerations to be taken into account for each of these tasks. Table 8 provides a summary of the level of climate information requirements and associated considerations for the three adaptation decision components.

Table 7: Planning horizons of adaptation inventions and relative significance of sources of uncertainties associated with climate information

Planning horizons	Relative significance of sources of uncertainties associated with climate information				
	Natural climate variability	Committed climate change[8]	GHG emissions	Transient climate sensitivity	Regional climate responses
Near term (<10 years)	++	++	—	—	—
Medium term (10~30 years)	++	++	—	+	+
Long term (>30 years)	+	+	++	++	++

++ highly significant + quite significant — not significant

Table 8: Key adaptation decision components and their requirements for climate information

Adaptation decision stage	Level of requirement for climate information	Type of climate information required	Key considerations
Initial risk screening	Low – Medium	• Long-term observed climatologies and characteristics of extreme events • Trend in projections of future climate	• Selected climate variables to be physically plausible and appropriate in relation to the key parameters of the system/activity being screened; • Duration of data series to be sufficiently long to derive trends; • Alternative projections of selected climate variables for future time periods to be considered for deriving robust directions of change
Detailed risk analysis	Medium – High	• Observed climatologies and characteristics of extreme events • Climate change projections with varying spatial and temporal details	• Climate variables to be physically plausible and appropriate; • Spatial and temporal scales of climate information to be fit for the objectives and context of the analysis
Evaluating the efficacy of adaptation options	Low, Medium, High	• Climate change projections with varying spatial and temporal details	• Climate information related uncertainties to be adequately treated according to the type(s) and planning horizon(s) of adaptive measures being considered

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[8] Committed climate change refers to climate change as a result of GHG emissions already in the atmosphere.

3 CLIMATE INFORMATION: AVAILABILITY AND ROBUSTNESS

Section 2 above discussed the diverse needs for climate information within the climate risk management and adaptation decision framework. This section discusses the availability and robustness of required climate information. It is not the intention for this document to provide an exhaustive list ,rather, it aims to summarize the broad categories of existing data and information that could be used for climate risk analyses and adaptation planning, and to provide an assessment of their robustness based on the latest IPCC assessment report.

Information on current climate is discussed briefly in Section 3.1 while Section 3.2 focuses on future climate projections derived from climate model outputs. A short summary is presented in Section 3.3.

3.1 Information on current climate

Although there has been a strong international call for investment in improving the resolution and accuracy of climate model projections, current climate information, also termed as climate baseline, deserves equal attention, if not more. Within the context of adaptation decision-making, climate baseline data is needed to serve the following three purposes:

- Establishing the climate relevance of current vulnerability of environmental and socio-economic systems (e.g., to answer the question: Does climate change really matter?)
- Identifying critical climate thresholds in characterizing risks (see Section 2.2.2) (e.g., to address the issue: How much climate change is acceptable?)
- Defining the features of high impact extreme events under present-day climate (e.g., to help address questions such as: How much do we need to adapt?)

The following are four broad categories of data sources that can be used to establish the climate baseline:

- National meteorological archives,
- Supranational and global data sets,
- Climate model outputs, and
- Data from weather generators.

Details on these data sources including their respective advantages and limitations are discussed in IPCC-TGICA (2007). Generally speaking, purposes 1 and 2 of baseline climatology described above are well served by various national and international data provision initiatives. Normally, mean climate quantities will suffice and to a large extent, are readily available in public domain. Data with higher temporal resolution are required to analyze extreme weather events. In comparison, baseline data at spatial and temporal resolutions adequate to support such analyses is patchier but there has been increasing efforts directed to filling in the gaps.

In terms of quality, or robustness, thermal variables (e.g., temperature, radiation, etc.) are generally available with better quality than precipitation. Particularly, practitioners should exercise caution when using spatially interpolated precipitation parameters in mountainous areas or regions with complex topography. When the availability of choices permits, it is advisable to use datasets accompanied by detailed documentation on the underlying technical methods and major caveats of the datasets. Another criterion for selecting baseline datasets is the extent of application in relevant contexts; i.e., the more widely used the datasets are in similar geographic and decision contexts, the higher confidence one could attach to the datasets.

Table 9 summarizes major sources of data representing current climatic trends made available by regional and international institutions. It is worth noting that locally and nationally observed, processed and quality-controlled datasets should be given priority over international sources, as the production of the latter relies on raw data from limited number of observation stations and (often imperfect) interpolation algorithm. Readers are also strongly recommended to read the relevant supporting documents to ensure that the datasets are fit for purpose before deciding to use them.

3.2 Future climate projections

As discussed in previous sections, adaptation practitioners need characterization of future climate conditions, often used interchangeably with climate scenarios or climate projections, to define the nature and magnitude of climate risks with and without adaptation interventions. Different approaches and techniques have been developed to facilitate the construction of climate scenarios (e.g., see Section 3.2 of IPCC-TGICA, 2007; Section 3 of Lu, 2006).

The main data sources for climate scenarios are outputs from General Circulation (or Global Climate) Model (GCM) experiments. GCMs are mathematical representations of physical processes in the atmosphere, ocean, cryosphere and land surface. GCMs are based on well-established physical principles and have been demonstrated to reproduce observed features of

Table 9: Major sources of data representing current climatic trends

Data source	Geographic coverage	Owner institution	Time period	Spatial scale	Temporal scale	Variables	Access	Further details
WorldCLIM	Global land area except Antarctica	University of California, Berkeley	1950-2000	30 arcs (~1km)	Monthly	Pre, Tmp	http://worldclim.com	• http://www.worldclim.com
CRU Global Climate Data Set	Global land area except Antarctica	University of East Anglia	1961-1990	0.5° x 0.5°	Monthly (30-year average)	Tmp, Pre, Dtr, Vap, Spc, Cld, Frs, Wnd	http://www.ipcc-data.org/obs/get_30yr_means.html	• http://www.ipcc-data.org/obs/cru_climatologies.html • Box 4 of the IPCC TGICA guidance document (http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf)
			1901-2002	0.5° x 0.5°	Monthly time series	Tmp, Tmx, Tmn, Pre, Dtr, Vap, Spc, Cld, Frs	http://www.cru.uea.ac.uk/cru/data/hrg/cru_ts_2.10	• http://www.cru.uea.ac.uk/~timm/grid/CRU_TS_2_1.html
				National			http://www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1_cty-table.html	• http://www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1.html
African Climate Atlas	Africa and surrounding tropics	CLIVAR VARC, World Climate Research Programme (WCRP)	1931-1960 1961-1990	0.5° x 0.5°	Monthly (30-year average)	Tmp, Tmx, Tmn, Pre, Dtr, Vap, Cld	http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/ClimatologyIndex.html	• http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/
			1901-2000	0.5° x 0.5°	Monthly time series		http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/AnomaliesIndex.html	

recent climate (Hegerl et al., 2007; Randall et al., 2007) and past climate changes (Jansen, 2007). There is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Given the sound physical basis and global coverage, outputs from GCM simulation are important data sources for developing climate scenario. Issues related to the selection and downscaling of GCM outputs for developing regional climate scenarios are discussed in Section 3.3 of Lu (2006).

Typically, outputs from GCM simulations are used to derive changes in climate variables, which are then combined with baseline data to compute the value of the variable for a future time period or point[9]. The reason that GCM outputs are usually not directly used to describe future climate conditions is that there

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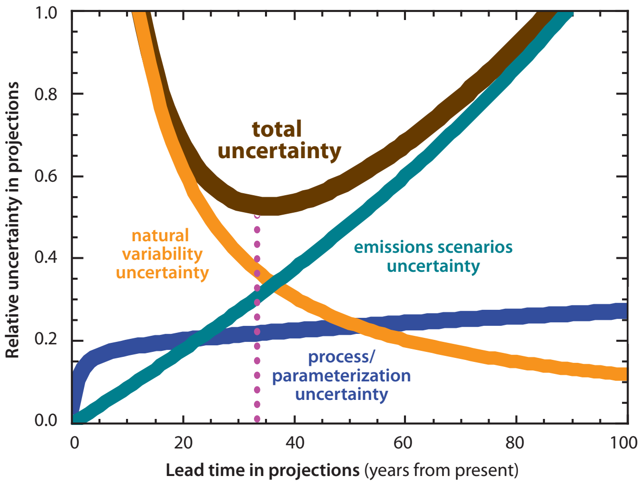
[9] $X_t = X_0 + \Delta X_t$ (for variables such as temperature related to thermal state) or $X_t = X_0 \times \Delta X_t$ (for variables such as precipitation associated with hydrological regimes) are used to combine model simulated change fields for variable (X) at a future time (t) ΔX_t with baseline average X_0 to calculate the (absolute) value for the future X_t.

are biases in model results. Details on how the different components in a climate scenario are calculated can be found in Section 3.4 of Lu (2006).

As discussed in Section 2, climate scenarios derived from model experiments are subject to a range of uncertainties (see Figures 2 and 15). These uncertainties operate at different time scales with contributions to the total level of uncertainty. As shown in Figure 15 below, natural variability accounts for the majority of uncertainties associated with climate scenarios for the next 2-3 decades. GHG emissions pathways become increasingly important in total climate uncertainty over time (particularly after 2050), while overall climate model uncertainty (e.g., parameterization of key processes and feedbacks, climate sensitivity) stay relatively stable over time. Its contribution to total climate scenario uncertainty changes markedly: It is much less significant after 2050 when the total uncertainty is dominated by GHG emissions pathways. As shown in Figure 15, there is a "window of opportunity" between 30-50 years from the present time when climate scenarios derived from climate models are least uncertain (Cox and Stephenson, 2007). Shorter-term predictions will be less accurate because of uncertainty over natural variability (initial conditions of model simulations). For projections more than 50 years into the future, uncertainty levels in model simulations increase because of large uncertainties related to the level of GHG emissions. Therefore, they argue, that between 30 and 50 years from the present is a kind of "sweet spot" in which to target climate policy planning (Cox and Stephenson, 2007)[10].

Figure 15: Indicative level of uncertainties in climate model projections from different sources
(Source: modified from Cox and Stephenson, 2007)



As for the robustness of climate information derived from model experiments, the latest IPCC report asserts, "there is now higher confidence in projected warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and ice" (IPCC, 2007b). Confidence in model estimates is higher for some variables (e.g., temperature) than for others (e.g., precipitation) (Randall et al., 2007). In addition, progress has been made to characterize changes in extreme events. Table 10 below summarizes the likelihood of model-projected changes in a range of extreme weather events/phenomenon.

Table 10: Assessment of projections in trends of observed extreme weather events
(Source: modified from IPCC, 2007b)

Extreme event/ phenomenon and direction of trend	Likelihood[11] of trends based on projections for 21st century using SRES emissions scenarios
Warmer and fewer cold days and nights over most land areas	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Virtually certain
Frequency of warm spells/heat waves increases over land areas	Very likely
Frequency (or proportion of total rainfall from heavy falls) of heavy precipitation events increases over most areas	Very likely
Area affected by droughts increases	Likely
Intense tropical cyclone activity increases	Likely
Increased incidence of extreme high sea level (excluding tsunamis)	Likely

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[10] It is worth noting, though, Cox and Stephenson (2007) do not include uncertainties related to impact assessments and abrupt climate change.

[11] Based on the IPCC uncertainty terminology, "virtually certain', "very likely" and "likely" indicate there is a higher than 99%, 90% and 66% probability of a well-defined outcome occurring, respectively (Manning et al., 2004).

Table 11: Major sources of climate model outputs assessed by the IPCC Fourth Assessment Report (AR4) for developing national and sub-national climate scenarios

Data source	Geographic coverage	Owner institution	Time period	Spatial scale	Temporal scale	Variables[12]	Access modality[13]	Further details
IPCC AR4 climate model outputs	Global	IPCC Data Distribution Centre	1961-2100	Varying – native GCM scale	Multi-year average monthly and daily	Tmx, Tmp, Tmn, Pre, Sph, Slp, Wnd	http://www.ipcc-data.org/ar4/gcm_data.html	http://www.ipcc-data.org/ar4/gcm_data.html
Climate Change Explorer	Africa, Asia	Climate Systems Analysis Group (CSAG), University of Cape Town	2045-2065 2081-2100	Station	Daily and Monthly (30-year average) Monthly time series	Tmp, Tmx, Tmn, Pre	http://data.csag.uct.ac.za/explore/	http://www.wiki-adapt.org/index.php?title=Q%26A_for_the_Climate_Change_Explorer!#What_data_are_available.3F
African Climate Atlas[14]	Africa and surrounding tropics	CLIVAR VARC, World Climate Research Programme (WCRP)	1961-2100	0.5° x 0.5°	Monthly (30-year average) Monthly time series	Tmp, Slp, Sst, Wnd	http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/ClimatologyIndex.html) Online: (http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/AnomaliesIndex.html)	http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/
Climate Mapper[15]	Africa [16]	US Agency for International Development (USAID)	2030s 2050s	0.5° x 0.5°	Decadal monthly average	Tmp, Pre	http://www.iagt.org/servir/servir_viz/climatemapper.asp	http://www.iagt.org/servir/servir_viz/climatemapper.asp
Country Climate Profiles[17]	Developing countries[18]	UNDP-UNEP-GEF National Communications Support Programme (NCSP)	1961-2100	National and GCM grid level	Annual, seasonal	Tmp, Tmx, Tmn, Pre	http://ncsp.undp.org/report_detail.cfm?Projectid=189	
World Bank Climate Change Portal[19]	World	World Bank	1981-2100	20km x 20km	Annual, Seasonal	Tmp, Pre, Forest fire, Runoff	http://sdwebx.worldbank.org/climateportal/home.cfm	http://sdwebx.worldbank.org/climateportal/home.cfm

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[12] Tmx – maximum temperature; Tmp – average temperature; Tmn – minimum temperature; Pre – precipitation; Sph – specific humidity; Slp – sea level pressure; Sst – Sea surface temperature; Wnd – wind speed

[13] Some of the online links to the data sources may change over time but a Google search with the name of the data source should normally be able to locate the correct page.

[14] The Atlas includes visualization tools as well as a suite of analytical tools.

[15] Climate projections can be assessed against 3D visualizations of landscape, which could facilitate vulnerability assessments as development planners consider adaptation strategies.

[16] Climate Mapper will soon be expanded to global coverage.

[17] Results from analyses on changes in extreme temperature and precipitation events are also available. Graphics, underlying data files, summary narratives and tables are provided for each country.

[18] During the first phase of the project, 53 country profiles have been created. Discussions are underway to generate profiles for developing countries not included in the first phase.

[19] Currently datasets are only available from simulations performed by the Japanese Meterological Service climate model.

Table 12: Indicative levels of requirement, availability and confidence of climate information required for risk assessment and adaptation planning

Climate information		Current climate		Model simulated future climate					
				Average			Extremes		
Requirement, availability and confidence level		Average	Extremes	Up to 2030	Up to 2050	Beyond 2050	Up to 2030	Up to 2050	Beyond 2050
Requirement for climate information	Initial risk screening	√	√	√	√	√	√	√	√
	Detailed risk analysis	√	√	√	√	√	√	√	√
	Evaluation of adaptation options			√	√	√	√	√	√
Availability		High	Medium	High	High	High	Medium	Medium	Medium
Indicative level of confidence		High	Medium	Medium	High	Low	Low	Low	Low

A wide range of regional and international initiatives have been undertaken to improve the access to and facilitate the application of climate model outputs. Table 11 provides examples of data sources of analyzed/downscaled climate model outputs assessed by the latest IPCC assessment reports. To make the most appropriate and effective use of climate model outputs for constructing future climate scenarios, the following good practices are recommended.

- Scope of scenarios: Be very clear about what you need, rather than what you want (see Section 4 below for details on how to define what is needed).

- Selection of climate models: Review relevant literature or undertake validation analysis to determine which model(s) perform better in the study area, for the season(s) and variables of interest.

- Uncertainty management: Try to represent as wide a range of uncertainty as possible by selecting projections from different models, different runs of a same model forced with different emissions scenarios.

- Selection of data sources: Consider the availability of documentation on underlying techniques and raw data sources (particularly when working with downscaled products), ease of accessing and processing data (i.e., user-friendly downloading interface and data format, etc.), and availability of technical support.

3.3 Summary

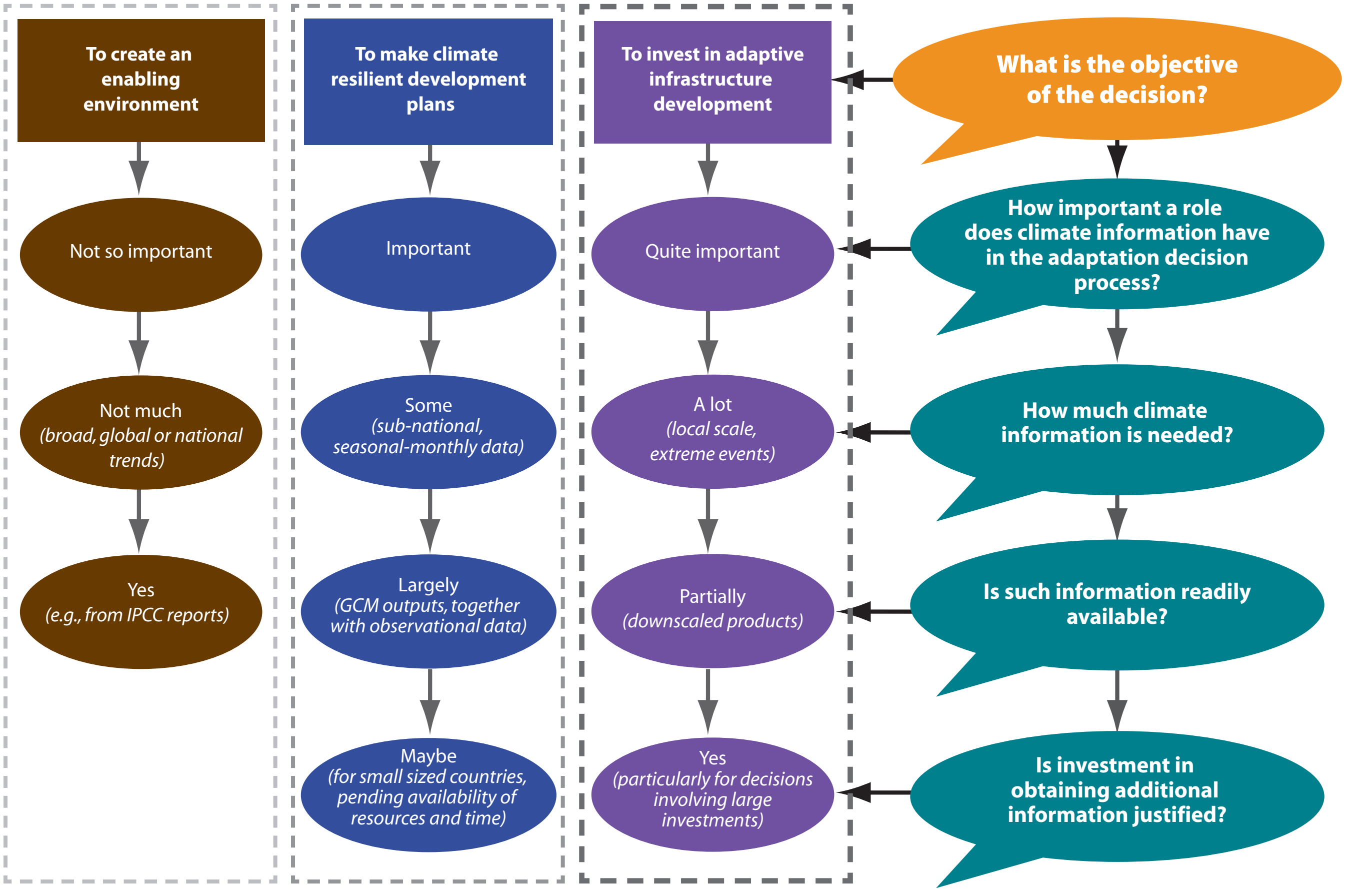
Table 12 provides a summary of indicative levels of availability and robustness of data on current climate conditions and characterization of changes in future climate.

4 APPLYING CLIMATE INFORMATION IN SUPPORT OF ADAPTATION DECISIONS: KEY QUESTIONS TO CONSIDER

As discussed in Section 2, the need for climate information varies widely depending on the context of adaptation decisions. Section 3 outlined multiple sources of data and climate information products. However, it is not always easy to strike a sound balance between ensuring that adaptation decisions benefit from the climate science and information to the extent possible, and at the same time avoiding the acquisition of non-essential climate information. As a recap of discussion in Sections 2 and 3, this section provides general guidance on practical steps for scoping the information needs, selecting the sources of existing information and methods/tools to generate additional information as needed.

As shown in Figure 16, a set of questions can be used to guide the definition and provision of required climate information to support adaptation decisions. As discussed in Section 2, the decision context is central to the scope and features of climate information that is needed to support the decision-making. Therefore, the first question a practitioner must consider in terms of climate information requirements is: What are the objectives of the adaptation decisions? The objective of the adaptation decision will largely dictate what climate information is needed, and the subsequent selection of data sources, methods and tools to obtain or generate them.

Figure 16: An illustrative process to determine climate information needs and course of action to obtain required information in support of adaptation decisions



4.1 Creating an enabling environment

In many cases, adaptation decision aims to design activities for **creating an enabling environment** for adaptation in different ways, such as a public awareness campaign, organizational learning, or implementation of general poverty reduction programmes. In most cases, general illustration of changes in observed climate conditions and associated impacts on natural environment and human society is adequate to sensitize stakeholders and justify "no-regret" actions. Within this context, climate information plays a very minor role in the decision process hence very broad climate trends (at global or national scale, annual or seasonal time step) will be sufficient.

Data requirement here can be met by publicly available resources, either from international organizations (e.g., IPCC Data Distribution Centre, http://www.ipcc-data.org) or national agencies (e.g., national Met Services).

4.2 Making climate resilient development plans

But information on how climate has changed and how it is likely to change becomes more important if the adaptation decision is related to the **planning for national, regional or sectoral climate resilient development.** Typically, this involves:

- First, an *initial risk screening* will determine whether climate change poses any risk to national/regional socio-economic development or sectoral performances.
- If the initial risk screening warrants, *a detailed risk analysis* will identify the magnitude and distribution of impacts and vulnerability from projected climate change.
- Finally, *adaptation assessments* will be carried out to evaluate regulatory, budgetary, management or operational measures as options to reduce vulnerability, and ensure and sustain development outcomes.

Within this context, observed climate data and model simulated future climate change are required to support the different stages of adaptation decision (see detailed discussions on information needs for each of the three stages in Section 2.2 above). Climate information is often required at national or regional scale and at monthly to seasonal time step. Existing observed datasets (Section 3.1), GCM outputs and downscaled scenario products (Section 3.2) can largely meet the needs. However, when resources and technical capacity permit, additional work could be undertaken to produce climate information at higher resolution (both in spatial and temporal terms), providing that the benefits of this information are likely to exceed the costs of producing it. For instance, the development of a five-year national plan in a small island may require climate scenarios more detailed than those from GCM outputs to support fine-scale risk assessment. Investment in producing such detailed climate scenarios is justified to ensure local relevance of information derived from global climate models.

4.3 Investing in adaptive infrastructure development

For adaptation decisions related to **investment in adaptive infrastructure development**, climate information plays an important role, particularly if the design and/or function of the infrastructure is sensitive to key climatic variables (e.g., coastal defence system). The three decision components (i.e., initial risk screening, detailed risk analysis and adaptation assessment) described above will need to be undertaken with great depth.

Within this decision context, climate information is often required at local scale, sometimes site-specific, and at daily or sub-daily time step. In most cases, climate data at this level of details are not readily available hence additional work is often required. Typically, observed daily time series data are used to derive the statistics characterizing extreme weather events (e.g., frequency and intensity of heavy rainfall events and droughts, etc.) under present-day conditions. Daily GCM or RCM outputs are analyzed to derive changes in the frequency, intensity and rate of extreme events.

5 KEY MESSAGES

- Baseline climate data and projections of future climate change are needed to define the nature and magnitude of climate risks, and to evaluate adaptive options required to manage such risks. Consistency between observed and projected climate change, including variability and extreme weather events, and vulnerabilities of natural and human systems are the basis to justify (often additional) investment in interventions to adapt to climate change impacts.

- In recognition of this important role of climate information in facilitating adaptation, there are a growing number of regional and global initiatives aimed at improving the availability of and access to observed climate data and climate model outputs. A notable variety of data products have been made available.

- Currently, the availability and quality of baseline climate data can largely meet the needs of adaptation planning, with the exception of datasets at high spatial and temporal resolutions, particularly for precipitation. As of model projections, the next 30-50 years from now is considered to be the "sweet spot" for which climate model outputs are of least uncertainty. Model projections are most robust at and above the continental scale. There remain large uncertainties in model-projected extreme events.

- However, planning for adaptation cannot be conditional on the availability of accurate and precise climate projections because accurate climate projections are inherently unattainable.

- Indeed, not all adaptation decisions require such "perfect" climate scenarios. It is therefore important, prior to any extensive climate information acquisition exercise, to carefully define what is needed — not what is desired.

- A wide range of adaptation initiatives, (e.g., adaptive capacity building and/or climate resilient national/sectoral development planning), can be planned using currently available climate information.

- For adaptation decisions which place high demand on climate information (e.g., investment in infrastructure, insurance schemes etc.), the focus should be on the sensitivity of adaptation outcomes to climate scenario uncertainties, rather than trying to produce accurate climate scenarios. In other words, greater emphasis should be placed on robust decision-making rather than on defining optimal solutions that are scenario dependent. That said, efforts should be made to create robust climate scenarios, using best available datasets and analytical techniques and tools.

- Climate information is only one part of the crucial components in the adaptation decision framework. Climate risk and adaptation assessments also require robust analytical tools such as impact models, multi-criteria and cost-benefit analyses, etc. Therefore, practitioners making decisions on whether to invest in developing and improving climate information need to consider the importance of climate information related to uncertainties that could result from the use of these analytical tools. For example, a near-term risk of crop yield reduction may vary widely depending on the selection of crop models. Similarly, the cost-benefit analysis may result in a drastically different prioritization of adaptation options depending on the key assumptions made within different analytical tools.

- Finally, climate change is only one of the many stressors vulnerable communities are confronted with. Within the context of development, other non-climate factors — such as access to markets, social networks, etc. — may play a much more important role in determining the vulnerability of communities. Therefore, climate information should be applied in conjunction with other relevant non-climate data within an integrated framework.

ACRONYMS

AR4	(IPCC) Fourth Assessment Report
AOGCM	coupled Atmosphere-Ocean GCM
CRU	Climatic Research Unit
DDC	Data Distribution Centre
CCIAV	Climate Change Impacts, Adaptation and Vulnerability
GCM	Global Climate Model/General Circulation Model
GEF	Global Environment Facility
IIASA	International Institute for Applied Systems Analysis
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
NAI	non-Annex I parties to the UNFCCC
NAPAs	National Adaptation Programmes of Action
NC	National Communication
NCEP	(US) National Centres for Environmental Prediction
NCSP	National Communications Support Programme
NOAA	(US) National Oceanic and Atmospheric Administration
OAR	(US NOAA's) Office for Oceanic and Atmospheric research
PRECIS	Providing Regional Climates for Impact Studies
PSD	(ESRL's) Physical Sciences Division
RCM	Regional Climate Model
SNC	Second National Communication
SRES	Special Report on Emissions Scenarios
TAR	(IPCC) Third Assessment Report
TGICA	(IPCC) Task Group for data and scenario support for Impact and Climate Analysis
UEA	University of East Anglia
UKCIP	UK Climate Impacts Programme
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
UNFCCC	United National Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
WB	World Bank
WMO	World Meteorology Organisation

GLOSSARY OF TERMS[20]

Adaptation

Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities. Various types of adaptationinclude anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

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 of years. The classical period is three decades, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate, in a wider sense, is the state of the climate system, including a statistical description.

Climate Change

Climate change, in this document, refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which 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 Model

A climate model is a numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (i.e., for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions; the extent to which physical, chemical or biological processes are explicitly represented; or the level at which empirical parameterizations are involved. Coupled atmosphere/ocean/sea-ice General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system. There is an evolution toward more complex models with active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal and interannual climate predictions.

Climate Projection

A climate projection is a projection of the response of the climate system to emission or concentration scenarios of *greenhouse gases* and *aerosols*, or *radiative forcing scenarios*, often based upon simulations by climate models. Climate projections are distinguished from *climate predictions* in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions, concerning, for example, future socio-economic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty.

Climate Scenario

A climate scenario is a plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate. A "climate change scenario" is the difference between a climate scenario and the current climate.

Climate Variability

Climate variability refers to variations in the mean state and other statistics (e.g., standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial 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 (10 to 100 km) information from larger-scale models or data analyses. Two main methods are distinguished: *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 or statistical methods develop statistical relationships that link the large-scale atmospheric variables with local or regional climate variables. In all cases, the quality of the downscaled product depends on the quality of the driving model.

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[20] Definitions of terms are taken from (Parry et al., 2007).

Emission Scenario

An emission scenario is aplausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., *greenhouse gases, aerosols*) based on a coherent and internally consistent set of assumptions about driving forces (e,g., demographic and socioeconomic development, technological change) and their key relationships. In 1992, the IPCC presented a set of emission scenarios that were used as a basis for the climate projections in the Second Assessment Report. These emission scenarios are referred to as the IS92 scenarios. In the IPCC *Special Report on Emission Scenarios*, emission scenarios — the so-called SRES scenarios — were published.

Extreme Weather Event

An extreme weather event is an event that is rare within its statistical reference distribution at a particular place. Definitions of “rare” vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called “extreme weather” may vary from place to place. An “extreme climate event” is an average of a number of weather events over a certain period of time, an average that is itself extreme (e.g., rainfall over a season).

(Climate) Impact Assessment

A climate impact assessment is the practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Projection (Generic)

A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized — and are therefore subject to substantial uncertainty.

Radiative Forcing

Radiative forcing is the change in the net vertical irradiance [expressed in Watts per square meter (Wm-2)] at the tropopause due to an internal change or a change in the external forcing of the climate system, such as a change in the concentration of CO_2 or the output of the sun. Usually radiative forcing is computed after allowing for stratospheric temperatures to readjust to radiative equilibrium, but with all tropospheric properties held fixed at their unperturbed values.

Scenario

A scenario is 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-related stimuli. 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*).

Stakeholders

Stakeholders are persons or an entity holding grants, concessions, or any other type of value that would be affected by a particular action or policy.

Vulnerability

Vulnerability is the degree to which a system is susceptible to, or 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 variation to which a system is exposed, its sensitivity, and its adaptive capacity.

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