TOPIC GUIDE:

Adaptation: Decision Making under Uncertainty

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EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
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- Provide an overview of a topic
- Present the issues and arguments relating to a topic
- Are illustrated with examples and case studies
- Stimulate thinking and questioning
- Provide links to current best 'reads' in an annotated reading list
- Provide signposts to detailed evidence and further information
- Provide a glossary of terms for a topic.

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- Send an email to the Evidence on Demand Editor at enquiries@evidenceondemand.org with your recommendations for other Topic Guides.

About this Topic Guide

The purpose of this Topic Guide: *Adaptation Decision Making under Uncertainty* is to stimulate thinking about two major issues: first, how climate change may alter the long-term outcomes of development interventions today and second, how such interventions can be better designed from the outset to have outcomes that enhance climate resilience and are themselves robust and adaptable to long-term stresses, like climate change.

The Topic Guide is written for DFID staff, but is relevant to all development professionals. It is suitable for both non-experts and experts on climate change. It is not a comprehensive manual, but aims to provide sufficient information to enable development professionals to take some practical steps in their day-to-day work, as well as know where to look for more information.

The Topic Guide offers an overview of the latest thinking on how to manage the changing and uncertain climate in development decisions today. The key premise is that climate change will affect the long-term outcomes of many development interventions. Indeed, interventions that are beneficial today may prove to be damaging in the long term if they do not take account of climate change. This gives a strong rationale for ensuring that programmes and projects are robust and adaptable to climate change. Importantly, climate change and its uncertainties should not be an after-thought in development interventions – they must be addressed from the outset of the process and throughout the project cycle.

The specific challenge addressed in this Topic Guide is that the future climate is deeply uncertain. This is not just a scientific issue – it has real implications for DFID. If uncertainty is not tackled properly from the outset today, there is a significant risk of taking not enough, too many or the wrong types of interventions. This could mean a lower value for money of investments, or in extreme cases, wasted investments or adverse outcomes.

The central message from this Topic Guide is that accounting for the changing and uncertain climate need not be complicated and should not paralyse action. This Topic Guide introduces a range of concepts and tools for dealing with the changing and uncertain climate in designing and implementing development interventions – many are suitable for all development professionals, but in the final chapter we also include a set of more involved methods for those interested in quantitative options appraisal.

The Topic Guide begins with a brief introduction to the main issues concerning climate change adaptation and climate-resilient development from a DFID perspective. Section II then introduces climate uncertainty and explains where this is important in development interventions, giving a number of **case studies**. Sections III and IV then consider what practical steps development professionals can take to address the changing and uncertain nature of climate in their work. The first part discusses the design and implementation of policies and programmes that are robust to uncertainty. The second part focuses on more technical issues for quantitative options appraisal. Below is a document map to help direct readers to appropriate points in the Topic Guide.

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About the author

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Executive summary

Climate change will affect the long-term outcomes of many development interventions. This Topic Guide aims to help development professionals consider how interventions can be designed today to promote climate-resilient development and to have outcomes that are robust to the uncertainties over future climate risks. The concepts and tools introduced are relevant to managing all long-term risks and uncertainties in development interventions.

Adaptation is the only way to safeguard gains in development and poverty alleviation from the damages of unavoidable climate change. The poorest and most stressed people tend to be worst affected by climate impacts and have the least capacity to respond to climate change. Without effective adaptation and climate-resilient development, the poor could be driven deeper into poverty and the development gains achieved by organisations like DFID will be short-lived. The sustainability of progress against the Millennium Development Goals is under threat.

Climate change is not just an additional risk that can be managed separately, but affects many, if not all, of DFID's strategic priorities. Climate change and climate-resilient development are recognised as crucial issues for development organisations and will have implications at all levels of planning and implementation, from operational plans to individual projects. It is relevant not only for programmes where adaptation is a specific goal, but for any development programme that has one of the following characteristics:

- Where climate shocks or climate change could affect the outcomes of an intervention. Many of DFID's strategic priorities are climate-sensitive – for example, improving food security in Sudan.
- Where the programme could affect the vulnerability and resilience of local communities, either directly (for example, improving the management of shared water resources across Africa) or indirectly.

Studies suggest that the proportion of development portfolios that are at risk from climate change could be large. For example, the OECD estimated that US$0.5 billion in international aid to Bangladesh and Egypt are at risk. A review by the World Bank estimated that 25% of its portfolio across six countries is at significant risk from climate change.

Activities today can have long-lasting impacts, which are difficult to reverse. The wrong types of interventions today can lock societies into a more vulnerable development path. In addition, a failure to account for uncertainties related to climate change can lead to wasted investments; for example, if new infrastructure like irrigation systems needed to be replaced or expensively retrofitted before the end of their useful lifetime, or could put more people at risk. For DFID, this could mean the failure to achieve its objectives, a lower value for money of investments and reputational damage. This gives a strong rationale for ensuring that programmes and projects are robust to climate change. DFID has committed a budget of £2.9 billion to the International Climate Fund (ICF), of which around half is allocated to adaptation. Yet this represents only around 3% of the UK's Overseas Development Assistance (ODA). There is a need to ensure that the other 97% is climate-resilient too.

Tackling climate change and its uncertainties will require a more forward-looking, pro-active, flexible and progressive approach to programming. A resilient intervention is not

only one that is able to achieve its objectives today, but also one that is *robust*, meaning that it performs well under a wide variety of futures, and *adaptive,* meaning that it can be adapted to changing (unforeseen) future conditions.

Uncertainty over future climate will not necessarily be a factor in many development decisions. Development professionals deal with high levels of uncertainty every day. The difference here is perhaps that we know enough to be able to design interventions that are resilient to long-term changes. Uncertainty over future climate could be an important factor where an intervention is long-lived, inflexible (not adjustable) and high-stakes (with high costs and benefits). This will include, for example, interventions concerning buildings and infrastructure, urban development, sectoral growth strategies or land-use planning.

There are many places where it makes sense to invest early in adaptation, even though the benefits will not be felt until later. Similarly, in some cases, the most rational cause of action will be to wait until more information is available. The timing of adaptation interventions is an important consideration and will not only be determined by the risks to be avoided and the uncertainty, but also by the costs of delay (linked to the lifetime, reversibility of the intervention or its absence). The most urgent measures tend to be where not acting today can commit us to greater costs and risks in the future, for example: long-lived infrastructure and urban development.

We can draw out four priority areas for adaptation today:

- **Measures with early and robust benefits:** ‘Low-regrets’ measures, like climate-resilient development, early warning systems and insurance, for example.
- **Acting to avoid locking-in long-term risks:** taking action to account for changing risks in long-term decisions such as critical infrastructure, urban development, land-use change or sectoral development strategies.
- **Capacity building:** building the capacity for implementing development programmes that are resilient to the changing environment.
- **Low-regrets measures with long lead times:** for example, investing now in long-term agricultural research programmes to increase future options.

Adaptation and climate-resilient development are not substitutes – both are needed. Development and poverty alleviation themselves can help to reduce vulnerability to climate impacts. But, there are a number of arguments for prioritising some specific and additional adaptation measures to cope with future climate today, such as accounting for climate change in long-lived infrastructure and urban development planning, tackling immediate risks from climate, and preparing for transformational adaptation where necessary.

There is evidence of a general lack of forward-looking interventions that anticipate future risks and act to reduce them ahead of time. A number of recent reviews of development portfolios suggest that the majority of so-called ‘adaptation’ interventions today focus on low-regrets measures and capacity building, and are failing to address the need to avoid locking-in risk. In addition, the application of tools to screen climate risks appears to be ad hoc and, as a result, climate risks are sometimes neglected in development programmes.

Implementing progressive and flexible interventions may raise institutional challenges for development organisations like DFID, where project timescales are relatively short and value for money must be demonstrated quickly. In addition, monitoring and evaluation frameworks may need to evolve from a backward-looking process, to become an integral part of the management of the project.

New capacities, both human and institutional, will be needed to help us adapt under uncertainty. We know what robust adaptation should look like, but we need to build capacity in applying the building blocks within development programmes. For example:

- In conditions of deep uncertainty, our conventional economic appraisal tools break down – alternative tools are available but require new skills, as well as resources to develop practical experience.
- We will need to better communicate the role of 'robustness' alongside conventional 'optimisation'.
- Institutions and decision making processes will also need to evolve to deliver more long-term, incremental interventions, which can be adjusted over time as new information is gathered.
- There are several practical challenges to communicating and acting on uncertainty on the ground. For example, officials tend to be less willing to prioritise investments where the uncertainties are high and the options more disputed. Also, historically, planning and policymaking are often slow to react to, learn from and foresee change.

Frequently asked questions

1. Isn't adaptation just good development?

Adaptation *should* be just good development, but in practice traditional development alone is unlikely to meet short-term adaptation needs. Therefore, there is a rationale for investing in specific adaptation measures now. For example:

- Firstly, in an ideal world, investments in core development will build the capacity to adapt to climate change, but in practice there are many barriers to be overcome;
- Secondly, traditional development and growth, without considering climate change, could commit a society to a more vulnerable development path
- Thirdly, some specific adaptation measures are needed, for example, retrofitting some public infrastructure, building sea walls or investing in agricultural research; and
- Finally, some adaptation is urgent and there are high costs associated with delay.

These issues are discussed in more detail in Sections I.1 and I.3.

2. How do I know if future climate uncertainty should be an important factor in my decision?

There are generally three types of interventions where future climate uncertainty is likely to be an important factor in design and implementation:

- Firstly, where the intervention aims to support climate change adaptation;
- Secondly, where an intervention has outcomes that are climate-sensitive (for example, particularly those relating to agriculture, water, forestry, disasters or ecosystems); and
- Thirdly, where an intervention could directly or indirectly adversely affect the long-term vulnerability or resilience of a community, region or country (for example, urban development, natural resource management, land use change or sectoral development).

But, for each of these, climate change is only likely to be a factor if:

- The lifetime of the decision is long (where the lifetime is the full duration of influence, not just the length of the project);
- The decision is difficult or costly to change later (for example, a building may be difficult to retrofit later and urban development may be impossible to change); and

- Where the intervention is costly or has significant implications, for example, in terms of the number of people affected.

These topics are covered in Sections I.2 and II.2.

3. How can we adapt while projected future changes remain so uncertain?
This is a common question in response to the emphasis on uncertainty in the scientific literature and to a focus on distant future impacts. In fact, long-term uncertainty is rarely an important factor in the decisions we make today because:

- Firstly, compared with normal weather variability or other factors in development decisions, such as political decisions or exchange rates, short- to medium-term climate is not so uncertain;
- Secondly, our attention should be focused on decisions being made in the near future and these types of decisions can be far more certain, even where there is uncertainty over the long-term climate. When the adaptation challenge is reconceptualised in terms of its implications for near-term decisions, many decisions are not so greatly affected by climate change;
- Thirdly, even where decisions are sensitive to assumptions about future climate, like long-lived infrastructure, there are many well-known approaches for reducing the risks in decision making; and
- Finally, not all adaptation needs to be done now – adaptation is not a one-off. Adaptation is a process in which decisions can be updated and improved as the future unfolds, and as more information is gained.

Therefore it is quite possible to make decisions in the face of uncertainty anyway. Further details are given in Sections II.2 and III.1.

4. I have limited resources. How do I ensure that my programme is resilient to climate change?
The first stage is to identify if climate change and uncertainty are important factors in the design of the programme, either qualitatively (Section II.2) or quantitatively (Section IV.2). In many cases, climate change will not be important. If climate change is an important factor, consider approaches to reduce the impact of uncertainty on the outcomes of the intervention (Section III.1). Decision analyses are then used to estimate whether a strategy meets certain criteria and to weigh up different options. These analyses need not be complicated – they can start with simple sensitivity testing and scenario analyses. Complex and resource-intensive decision analyses will generally only be needed when the decision is highly sensitive to uncertainties – e.g. for long-lived, high-stakes and irreversible decisions like the design of a new dam – and where the costs of delaying action are high.

SECTION I Climate change, adaptation and climate-resilient development: an overview

"If we are serious about development we need to be serious about climate change", Mark Lowcock, Permanent Secretary, DFID, 2011

"The two defining challenges of the 21st century are overcoming poverty and avoiding dangerous climate change. If we fail on one of them, we will fail on the other", Lord Nicholas Stern, I G Patel Professor of Economics and Government, London School of Economics and Political Science, 2009

Development and climate change adaptation are intimately linked. The poorest and most stressed people tend to be worst affected by climate impacts and will have the least capacity to respond to climate change. Today, the climate already has a material impact on the development prospects of the poorest countries. Since 1980, weather catastrophes alone have caused almost 1.2 million fatalities and led to direct damages amounting to US$610 billion in low and lower-middle income countries[1].

Climate change will affect climate 'shocks', like droughts, floods and storms, but will also lead to more gradual changes in climate (climate 'stress'). Firstly, climate change is expected to increase the intensity of climate shocks. For example, the global land area affected by drought is expected to rise and tropical storms are likely to become more intense (IPCC 2012). Secondly, more gradual changes in climate will increasingly stress poverty alleviation and development goals through their direct and indirect impacts on human health, food systems, water supplies and ecosystems (World Bank, 2010a).

Climate impacts will interact with other threats and pressures, such as population growth, increasing resource scarcity, environmental degradation, conflict and instability, magnifying their impacts. The 2013 Global Risk Report of the World Economic Forum ranked a failure to adapt to climate change as the greatest environmental risk faced by humanity, and amongst the top 10 most interconnected global risks (Fig. I.1). This risk has strong interdependencies with the risks of food and water crises, unsustainable population growth, global governance failures, volatile commodity prices, mismanaged urbanisation and species overexploitation (WEF, 2013).

Without appropriate interventions, climate change will create a vicious circle of growing vulnerability and impacts. The poor could be driven deeper into poverty and the development gains achieved by organisations like DFID may be short-lived. The progress made against the Millennium Development Goals is under threat (OECD, 2009)[2].

The only way to limit future climate change is to substantially reduce global greenhouse gas emissions. But the world is already committed to further warming and climatic change over the next 30 years or so due to past emissions. Adaptation is the only option to safeguard development and poverty alleviation gains from the effects of this unavoidable climate change.

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1 Data supplied by Munich Re.

2 See Table 1.1 in OECD (2009) for further details (pg. 29).

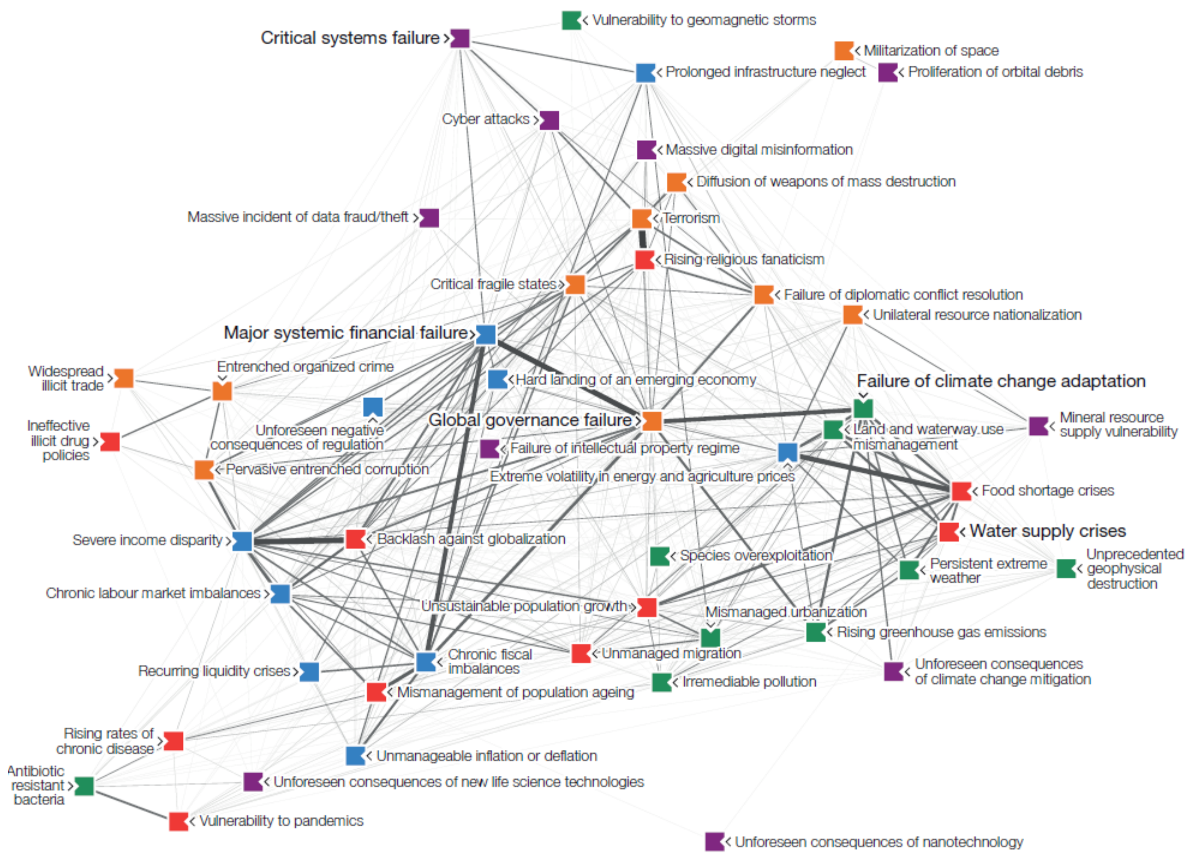

Figure I.1: Interdependencies between global risks. 'Failure of climate change adaptation' is rated as one of the top 10 most interconnected risks. Source: WEF (2013)

Many experts agree that the international goal to limit global warming to 2°C above pre-industrial levels[3] is now looking increasingly remote (UNEP, 2010), suggesting that society may need to cope with much larger levels of climatic change for longer. The lack of progress in abating global emissions has led some experts to suggest that, while we should aim to limit the temperature rise to 2ºC, we should plan to adapt to a rise of 4ºC (New et al. 2009).

A global warming of 2°C alone could threaten water and food systems in many tropical regions, and place thousands of people at risk from coastal flooding in the small-island states. It is difficult to predict what a 4ºC warmer world would look like as this is so far outside human experience. Modelling suggests that many millions of people could be at risk from coastal inundation, particularly in South and Southeast Asia, tropical rainforests could die back, a large proportion of tropical corals could be lost and we could see large decreases in crop yields in the Sahel and across most of Southern Africa (New et al. 2011 and Case Study 1)[4]. The World Bank (2012) described it as a world in which communities, cities and countries would experience severe disruptions, damage and dislocation.

Climate change adaptation brings a unique challenge for development professionals that have implications for the way in which interventions are designed (Fig. I.2):

Firstly, the risk environment is changing over time – stress is gradually building.

3 The Cancun Agreements of the UN Framework Convention on Climate Change (UNFCCC) http://cancun.unfccc.int/

4 See, for example: http://rsta.royalsocietypublishing.org/content/369/1934.toc

- This means that if we don't take account of changing risk in our decisions today, the impacts of climate change on people and systems will continue to rise. This will erode the gains from development interventions and the value for money of investments will decline.
- A solution is to **adopt a more forward-looking and long-term approach in designing our development interventions and managing risks**. A challenge is that this is contrary to the way most development interventions proceed, where projects are short (three to five years) and the incentive is for rapid impact and return on investment (Jones et al. 2013). **We need to look ahead because in some cases, like long-lived fixed infrastructure, it is often cheaper and easier to take account of long-term risks upfront today than to make costly retrofits later**. In addition, **focusing only on the near-term could also commit us to greater and difficult-to-reverse risks down the line.** For example, mismanaged urbanisation, continuing to overexploit the natural environment and not tackling rising water demand today, lock us into a more vulnerable future.

Secondly, the speed and scale of changing risk could be greater than seen before.

- To date much of our climate risk management has been reactionary. For example, the Thames Barrier in London was built only after more than 300 people lost their lives in the 1953 floods. The consequences of not acting ahead of time are much greater where risk is increasing.
- **It is well known in the disaster risk management community that ex-ante action, acting ahead of time, not only saves lives but is cheaper in the long run** (IPCC, 2012). **Climate change strengthens the economic and social case for pro-active action.** Actions such as relocating people, changing behaviour, agreeing regulatory frameworks, building institutional capacity or diversifying our markets and supply chains will take time and so we need to think and act ahead.

Finally, future risks are deeply uncertain.

- While we know a lot about how the climate will change in the future, we cannot predict exactly how climate change will affect the risks to a particularly community, or the outcomes of a particular intervention. If we do not account for uncertainty fully and properly in decisions today, it can lead us to take the wrong choices – for example, too many, not enough, or the wrong types of risk management measures, which will lead to greater costs, wasted investments and bigger risks down the line. These would occur, for example, if new infrastructure like roads, irrigation systems and reservoirs needed to be abandoned, replaced or expensively retrofitted before the end of their useful lifetime. Such maladaptation can have long-lasting and difficult-to-reverse impacts on the people they are intended to help (Barnett and O'Neill, 2010).
- **Uncertainty means that we need an approach to development that is as robust and adaptable to current and future climate as possible** – this means designing plans that are flexible and progressive.

It is these three challenges that we aim to address in this Topic Guide. Specifically we explore how to design interventions that reduce vulnerability and build resilience (Fig. I.2) in ways that are more forward-looking, pro-active, flexible and progressive (Section III.1). We also consider the implications for the timing of adaptation (Section III.2), the appropriate resource allocation between adaptation and climate-resilient development (Section I.3), the prioritisation of different investments (Section III.3) and the appropriate tools for options appraisal (Section IV).

The remainder of this section aims to address the following questions:

1. *Why are the least developed countries typically more vulnerable and less resilient to climate shocks and stresses, and what are the main drivers?*
2. *What are the relationships between development, disaster resilience and adaptation?*
3. *What are the practical implications for aid organisations like DFID?*

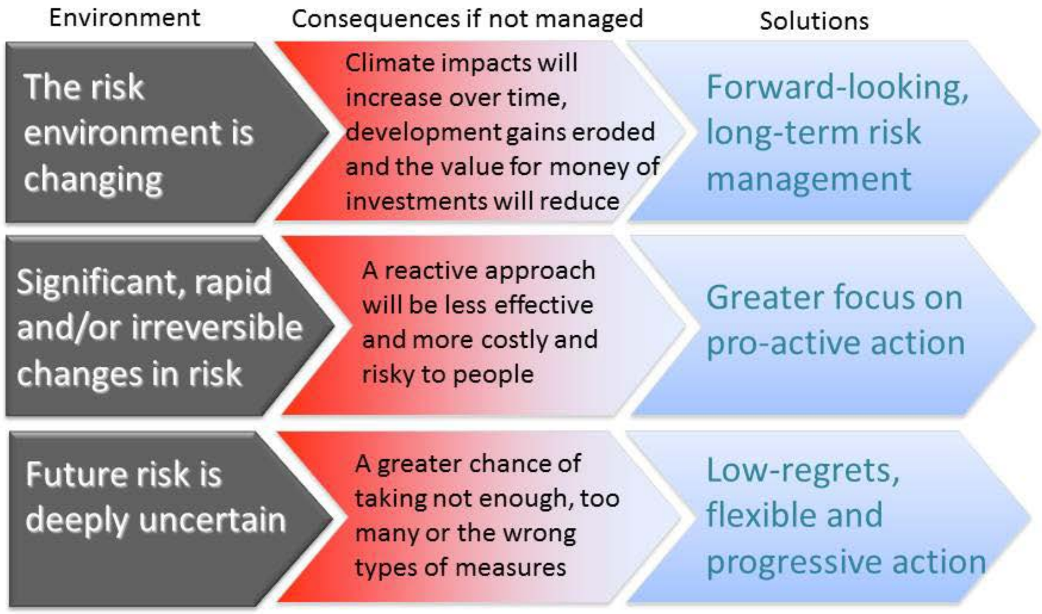

Figure I.2: The challenges of adaptation decision making. Source: based on Ranger and Garbett-Shiels (2012) and Fankhauser et al. (2013)

Case Study 1: Agriculture in Sub-Saharan Africa (SSA) in a 4ºC-plus warmer world

Agriculture is an economic mainstay of many SSA countries, employing on average about 60% of the workforce. The prevalence of malnourishment has declined, but very slowly, to around 30%. In the future, SSA will see the combined pressures of changing food demand and a more hostile climate.

The complexity in climate–crop systems, together with the limits to the predictability of the climate, lead to significant uncertainties in predictions of future yields. One study predicts that the average length of the growing season could decline across much of SSA (except East Africa). It suggested that by the 2090s in Southern Africa nearly all rain-fed agriculture is likely to fail one year in two. This prediction appears relatively robust (except in the south west). Yields of key crops like maize and beans could decline across SSA by, on average, 24% and 71% respectively by the 2090s, but there is much uncertainty about the exact scale of declines. The implications for food security are more difficult to predict, requiring predicting the interactions with broader development and market trends.

Adapting to these impacts will require radical shifts in agricultural systems, rural livelihood strategies and food security strategies and policies. Despite the uncertainties, there are a number of robust adaptation programmes that could be implemented in the short term. These include, for example, empowering vulnerable local communities, strengthening institutional support for innovation, access to markets and agricultural extension, improving meteorological services and enabling diversification. Other valuable activities include research and monitoring; exploiting global stocks of crop germplasm and livestock genes; and addressing the social, economic and political processes that contribute to food insecurity, including international reforms. However, by the 2090s it is possible that some areas could come up against physical or social limits to adaptation. Further research is needed to map out where these hard limits lie and explore the implications for decisions we make today.

Sources: Thornton et al. (2011) and references therein

I.1. Introduction to vulnerability, resilience and adaptation

The impacts of climate shocks and stresses are driven not just by the characteristics of climate to which a society is exposed, but also, more importantly, its vulnerability and resilience to climate. The terms vulnerability and resilience are defined in different ways by different people and are sometimes used interchangeably. Most experts would agree that the impact of a given climate shock or stress is driven by four factors: the sensitivity, exposure, recoverability and adaptive capacity of a society or system, as described in Fig. I.3.

We define *vulnerability* as the overall susceptibility to harm at a given point in time, which is determined by the social, demographic, infrastructural, environmental, institutional, economic and cultural state of a society or system and underlying development and risk management trajectory (Matyas and Pelling, 2012). By contrast, *resilience* is the capability to withstand sudden shocks, recover from crises when they occur and adapt to changing circumstances (Howell, 2013). The terms are therefore interrelated but resilience is more concerned with the ability to take action, rather than the current state of a system or society, and is linked with governance and capacity (human, technical, institutional and financial).

The poorest communities tend to be more vulnerable and less resilient to shocks and stresses (climate or otherwise). For example, poorer communities tend to be located in more marginal areas, such as low-lying areas or areas with poorer growing conditions. They may also have livelihoods that are more dependent on climate-sensitive production, such as rain-fed agriculture, forests and fisheries. Hence their exposure to climate is greater. Poorer communities also tend to be more sensitive to climate as, for example, investments in risk reduction are lower, governance is weaker, and public services, such as public health care and social safety nets, are less comprehensive. People may also already be under stress from other factors, such as poverty, environmental degradation, resource scarcity, food insecurity, water stress and conflict. There is less capacity to respond to events when they occur and to adapt to future climate due a lack of available resources and governance capacity (e.g. IPCC [2012] and references therein).

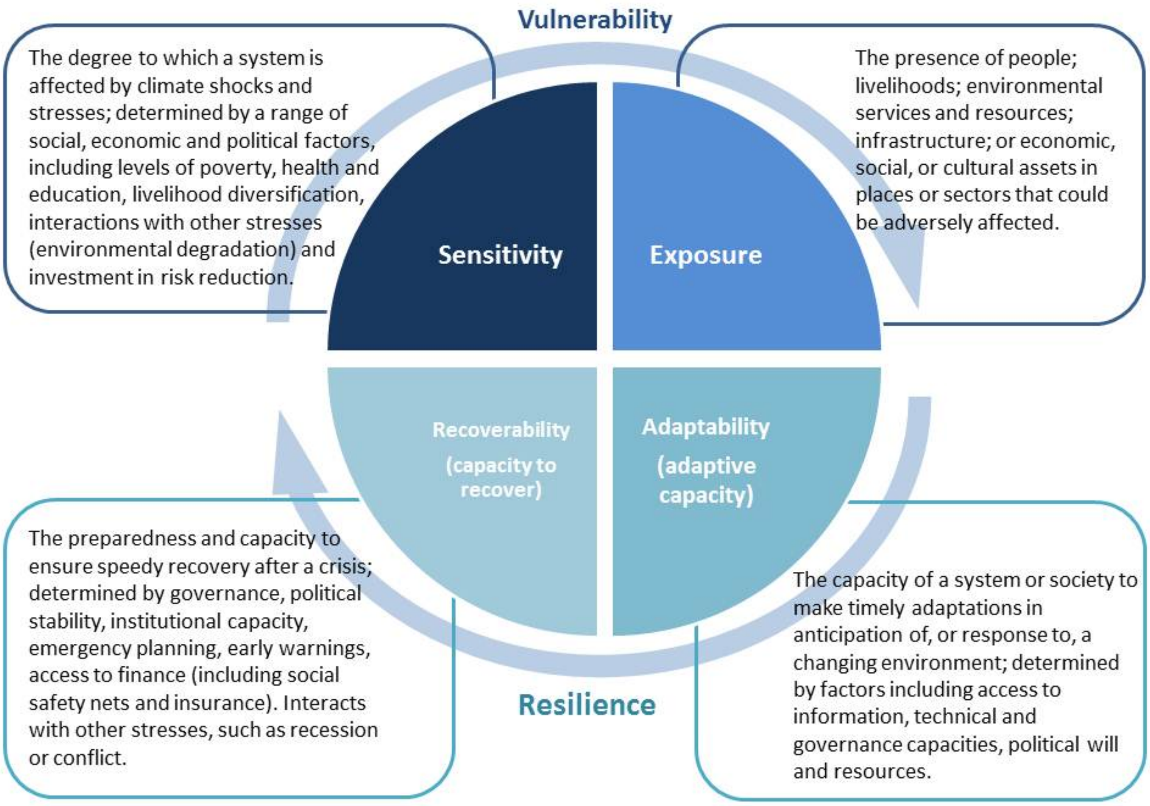

Figure I.3: The four components of vulnerability and resilience to climate. Based on Adger et al. (2007), IPCC (2012) and Howell (2013)

Adaptation aims to lessen the impacts of climate stresses and shocks through reducing the vulnerability of human and natural systems to its effects, enhancing resilience and through capturing any opportunities (Fig. I.4).

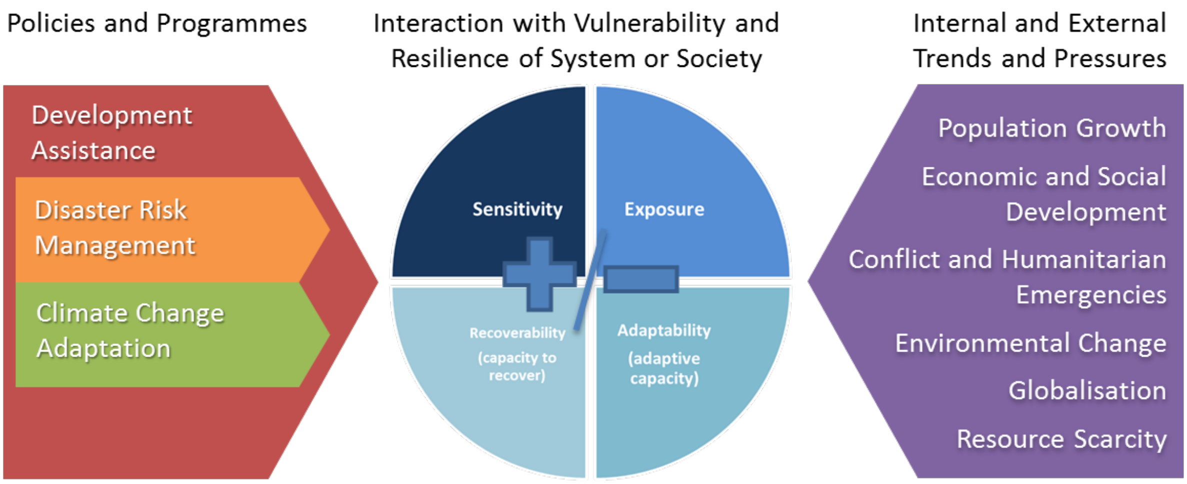

Figure I.4: The influence of development, adaptation and disaster risk management, and external and internal change factors, on the vulnerability and resilience of a system or society

However, vulnerability and resilience are dynamic and are influenced by many internal and external factors over time. For example, conflict may reduce the capacity to recover from shocks and prepare for climate change; environmental degradation and resource scarcity may increase sensitivity to climate; and population growth could increase exposure.

Development and poverty alleviation can also reduce vulnerability and build resilience to climate change. For example, traditional development programmes, such as those improving health care, diversifying livelihoods and supporting education, can reduce sensitivity, while strengthening governance and institutional capacity enhances the capacity to recover from climate shocks and adapt to climate change (World Bank, 2010a). Disaster risk management, a core component of development, is largely synonymous with adaptation[5].

Development, disaster risk management (DRM) and climate change adaptation can therefore be considered to be three interdependent and mutually reinforcing policy goals (Fig. I.5). Development is an enabler of adaptation and DRM and vice versa (Mitchell, 2012).

But there can be trade-offs between these policy goals. Not all development will necessarily reduce vulnerability. The wrong types of interventions today can lock societies into a more vulnerable development path for decades to come. For example, an intervention that promoted water-intensive agriculture would be detrimental if the climate became drier over time, but could be difficult to reverse (e.g. if indigenous knowledge and technologies were lost). Similarly, an intervention that incentivised migration to cities in coastal regions could put more people at risk from coastal flooding. Building schools and hospitals that were not adapted to climate change could increase vulnerability in the future.

5 The difference is that adaptation concerns reducing the impacts of climate shocks and gradual climate change, whereas DRM concerns only shocks and encompasses all disasters.

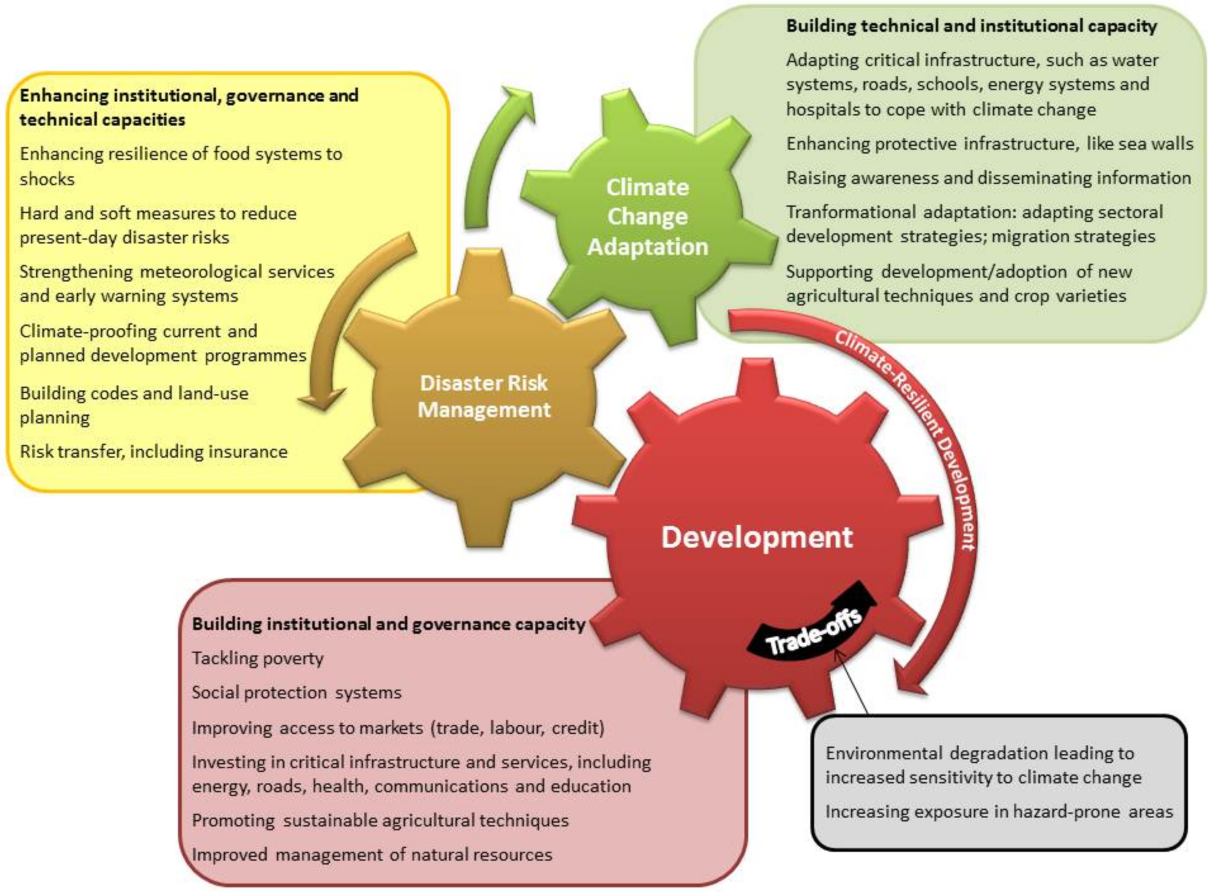

Figure I.5: Development, adaptation and disaster risk management as three interlinked policy goals, with examples of policies and programmes for each

Studies have identified a number of ways in which development strategies may need to change to facilitate adaptation (Vivid Economics, 2010):

- **Greater focus on management of natural resources**, including water, soils, air and ecosystems, with emphasis on promoting long-term sustainability and resilience;
- **Increasing emphasis on DRM**, to reduce current and future vulnerability to climate variability and shocks;
- **More awareness of near-term and long-term risks in policy making, including recognising potential maladaptations.** This would involve mainstreaming DRM and adaptation into all development activities, from national planning to local-level projects. Examples include recognising that policies to incentivise businesses to maximise productivity and growth can expose poor people to unacceptable risks (e.g. over-intensive agriculture), and that urban developments in hazard-prone areas lock in vulnerability to climate shocks and climate change;
- **Institutional capacity building** to support development that is robust and adaptable to changing climate conditions, including appropriate leadership, training, champions and institutional structures and processes;
- **Regulation and price incentives to encourage climate-resilient development in the public and private sector,** for example, regulation of building standards, engineering standards for new public infrastructure, enhanced land use planning, water efficiency programmes and regulation of utilities companies to ensure they include climate change in their long-term planning; and

* **Providing public goods with co-benefits for DRM and adaptation** (Cimato and Mullan, 2010), such as emergency services, investing in meteorological services, social safety nets and research into new medicines and agricultural technologies.

These policies reflect the more forward-looking and pro-active approach to development and risk management that is needed for adaptation (Fig. I.2).

Collectively, these policies build the foundations for *climate-resilient development,* which means ensuring that development proceeds in a way that enhances the resilience of a society and does not inadvertently increase vulnerability of communities in the long run. This is synonymous with *sustainable development,* which is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987).

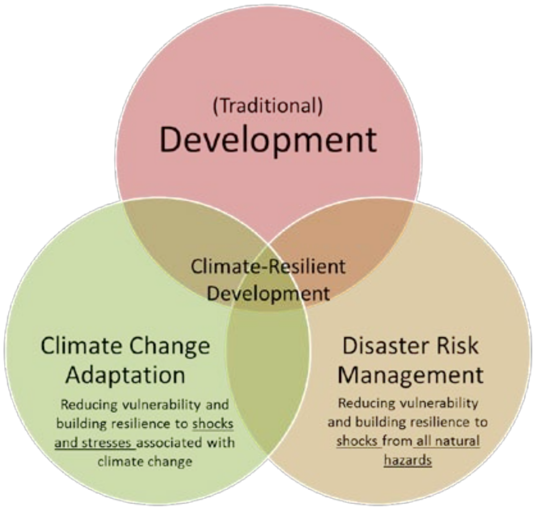

Figure I.6: The relationships between development, adaptation and disaster risk management

Climate-resilient development could be considered to be the overlap between traditional development, climate change adaptation and DRM (Fig. I.6). The separation between these three activities in Fig. I.6 is somewhat artificial, as adaptation and DRM *should* be part of ‘good’ development. However, their separation reinforces the important point that effective adaptation is more than just traditional development. Measures to deal explicitly with climate shocks and climate change will be required (OECD, 2009).

Many other development policy goals (or cogs in Fig. I.5) have synergies and trade-offs with adaptation. For example, there is evidence that empowering women in developing countries can help to reduce their vulnerability to climate shocks; while ignoring gender concerns in adaptation can reinforce the greater vulnerability of women (Adger et al. 2007). Economic growth literally buys options to reduce sensitivity, including better protection, natural resource management and institutional capacity (OECD, 2009), but can have trade-offs if it is not climate resilient, sustainable and pro-poor (Dercon, 2012).

I.2. Adaptation and climate-resilient development in practice

Climate change and climate-resilient development are recognised as crucial issues for DFID. DFID has committed a budget of £2.9 billion to the International Climate Fund (ICF) between April 2011 and March 2015, of which around half is allocated to adaptation.

This follows an investment of £1.5 billion to Fast Start Finance for 2010 to 2012 pledged under the UN Framework Convention on Climate Change (UNFCCC). The overarching vision for the UK's approach to adaptation is *that "vulnerable people in poor countries are prepared and equipped to respond effectively to existing climate variability and the magnified impacts of climate change".*

Yet the ICF finance represents only 3% of the UK's Overseas Development Assistance (ODA). There is a need to ensure that all ICF investments and the remaining 97%, or roughly £8.4 billion per year of ODA, is also climate-resilient. Climate change will be a relevant risk and uncertainty for many development interventions, not just those labelled as adaptation. It is central to achieving many of DFID's strategic priorities. There are two dimensions to this (Box I.1)[6].

1. **Climate shocks and climate change will affect the success, and broader outcomes, of some development programmes**. Many of DFID's strategic priorities outside of the ICF are 'climate-sensitive'. For example, the long-term success of programmes designed to support the strategic goal to increase food security in Sudan may partly depend on how the climate of the region evolves over the next decade or more. Programmes must therefore be designed such that this goal can be met irrespective of how the climate changes (Fig. I.7); and
2. **Development programmes could enhance or inadvertently constrain the resilience of local communities.** DFID programmes are likely to influence the sensitivity, exposure, recoverability and adaptive capacity (Fig. I.2) of local people, either directly (e.g. improving the management of shared water resources across Africa) or indirectly (enhancing access to credit in Tajikistan).

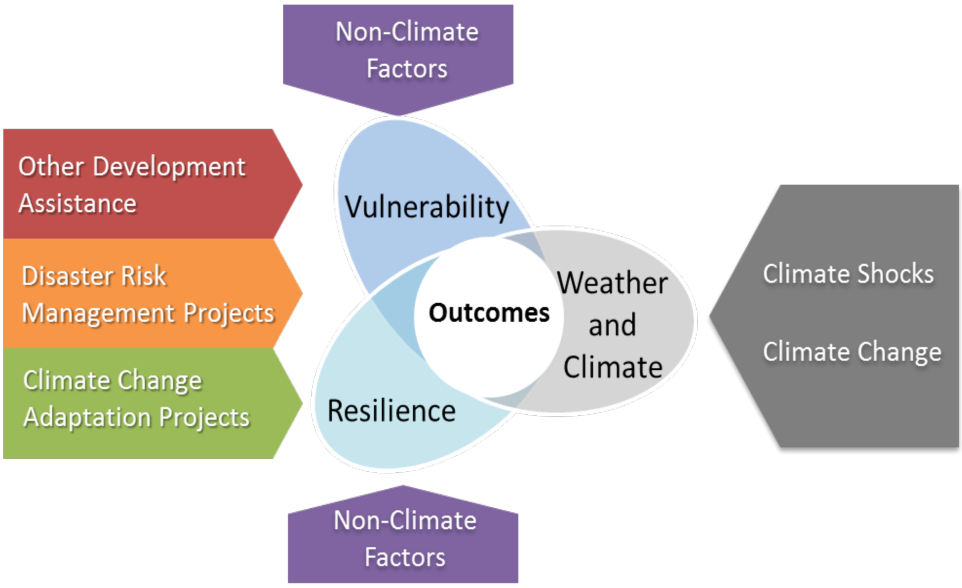

Figure I.7: Interplay of development programmes, climate and non-climate factors (like urbanisation and resource scarcity) in determining the vulnerability and resilience of a society and the outcomes of development programmes. Adapted from IPCC (2012)

6 Examples from the Sudan, Africa Regional and Central Asia Operational Plans 2011-2015.

Box I.1: Typology of decisions

We have explained that development interventions may influence vulnerability to climate change in two main ways. Firstly, the intervention can affect the vulnerability or resilience of local people to climate shocks and climate change. Secondly, climate change can affect the success or value for money of an intervention. The table below illustrates how this might come about.

For example, restoring mangroves is ‘positive’ against the first category (horizontal in table), because it enhances the resilience of local communities to shocks and climate change. It is also ‘positive’ against the second category (vertical in table) because climate change could actually increase the value for money of the investment.

Conversely, introducing rain-fed agriculture in a region of declining future rainfall could be ‘negative’ against the first category, because it could make people less resilient to rainfall variability, and ‘negative’ in the second category, because the value for money of the investment would decline if rainfall levels reduced.

Effect of intervention on vulnerability and resilience to climate shocks and climate change

Effect of climate change on success or value for money of an intervention

	Negative	Negligible	Positive
Negative	The introduction of rain-fed agricultural strategies in a region of declining rainfall		Access to drought-resistant crops enhances resilience, but in regions expected to see fewer droughts will have a lower value for money
Negligible	Urban economic development that encourages poor workers into vulnerable informal settlements	Implementing earthquake building codes to new buildings in Nepal	Reducing corruption will enhance economic efficiency and governance capacity and so increase resilience to climate
Positive	Afforestation programmes that reduce flood risks to farmers downstream but reduce groundwater supplies to upland farmers		Restoring mangroves reduces the sensitivity of local people to storm surges. This protection will have a higher value for money as storm intensity increases

A number of studies have reviewed the climate change risks to the portfolios of development agencies retrospectively (Gigli and Agrawala, 2007; Klein et al. 2007). For example, the ORCHID project identified a large number of DFID projects with climate-sensitive outcomes and where there were opportunities to build in greater climate resilience [7]. Burton and van Aalst (1999) estimated that up to 62% of the World Bank’s investments in six countries were sensitive to climate change. A later review of projects concluded that 25% of World Bank projects are at significant risk from climate change (World Bank, 2006). An OECD analysis (van Aalst and Agrawala, 2005) assessed all official aid flows from all donors to six developing countries and found that US$0.5 billion in flows to Bangladesh and Egypt, and about US$200 billion to Nepal and Tanzania over 1998 to 2000 were at risk from climate change.

[7] The ORCHID project was a DFID-funded research programme that developed applied screening tools to identify the climate vulnerability of DFID country programmes, including India, China and Bangladesh. See: http://www.ids.ac.uk/climatechange/orchid

These risks associated with climate change will need to be managed or 'mainstreamed' at multiple levels of decision making and development programming: from national-level policies and plans, to sectoral development plans, local-level governance and community action and specific projects (OECD, 2009). Figure I.8 illustrates potential entry points for climate change to be mainstreamed into decision making within a country. The interventions appropriate at each stage of the policy cycle will be very different – from ensuring the climate resilience of long-term policy at the national level to climate-proofing specific project proposals at the local level.

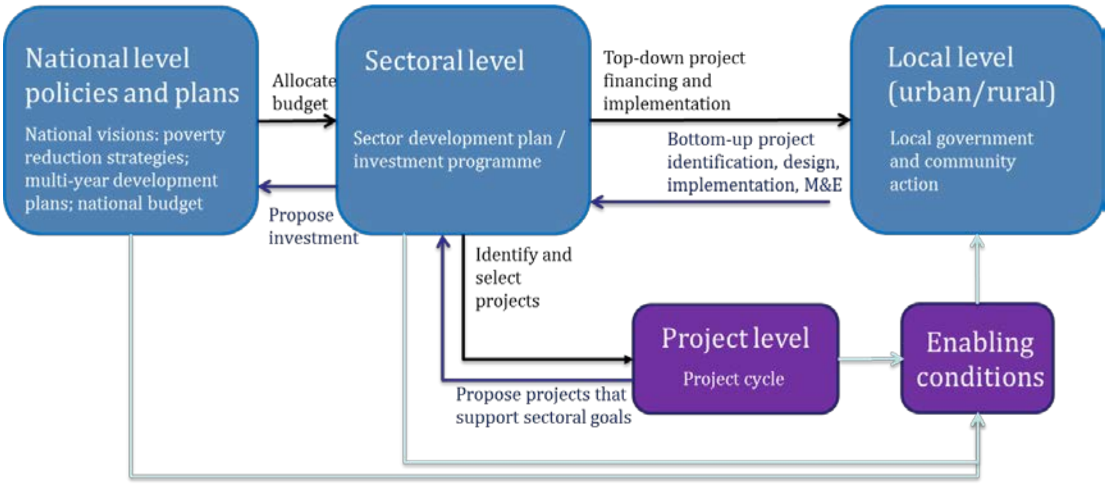

Figure I.8: Decision levels influenced by climate change. Source: reproduced from OECD (2009)

For a development organisation like DFID this means that climate change will influence:

- *Operational plans:* operational plans set out what results will be achieved and when by spending departments. In country offices these are developed in consultation with recipient countries. Climate change will influence who, what and where development assistance is most needed, as well as the achievability of other development objectives (concerning, for example, food security), so could influence the strategic priorities set out in the plans;
- *Country-level portfolio management*: portfolio management concerns the allocation of resources across programmes and projects to meet the targets laid out in the operational plans. Climate change could impact the allocation of resources, for example, targeting greater investment towards priority adaptation needs (Section III.3);
- *Specific projects/interventions*: to design interventions that are effective and robust to future climate conditions, climate change must be considered at the start of the *business plan* process (Section III). Climate change and uncertainty will also have a bearing on the way that interventions are implemented, and the role and design of the *monitoring and evaluation* process (Sections III.1 and III.2);
- *Relationships with other funders and MLFIs:* DFID has an opportunity to influence the UK ODA delivered through multilateral finance institutions (MLFIs), such as the World Bank and regional development banks, including the prioritisation of investments, budget allocations and project design to ensure that interventions are robust and adaptable to climate change. It can also share good practice in risk screening and monitoring and evaluation; and
- *Policy:* climate change impacts will be a risk to the success of policy frameworks, like the Post-2015 Development Agenda. But if designed well, such policy frameworks can support reductions in climate-change risks through promoting appropriate action.

Climate change and climate-resilient development will be relevant at all levels of DFID decision making, from project management, to programme business cases, to portfolio level allocations of resources. This is not limited to decisions where climate resilience is a strategic objective. Officials should ask whether their policy or intervention might affect the vulnerability to climate change, or whether climate change could affect the outcomes of the project, at the outset of the process[8].

I.3. Balance of effort between adaptation and climate-resilient development

An issue of much debate is the appropriate allocation of resources between climate-resilient development and *specific and additional* adaptation. Climate-resilient development is often easier to 'sell' to policymakers, as it has co-benefits that meet short-term priorities of eradicating poverty, enhancing food security and economic growth. It also has the advantage of treating the *underlying drivers of vulnerability*, rather than its symptoms. Some experts have argued that, for the poorest countries, the main focus should be on climate-resilient development (Fig. I.9).

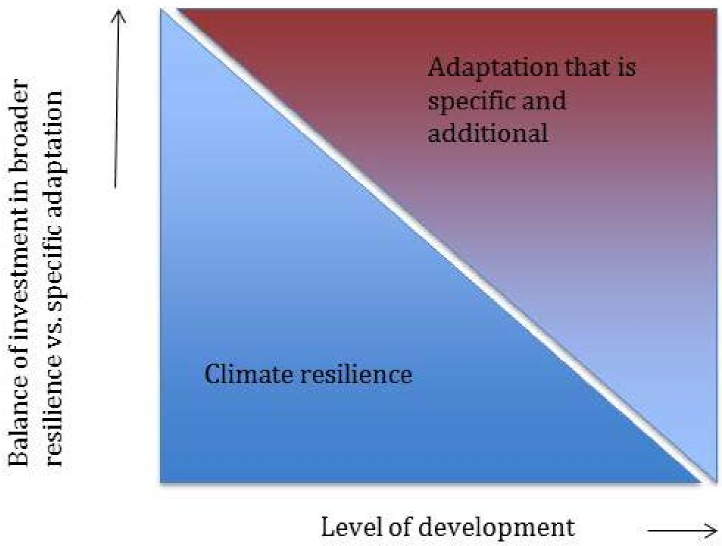

Figure I.9: The 'balance of effort' model. Source: Tanner et al. (2012)

Yet there are a number of arguments for prioritising some *specific and additional* adaptation measures to cope with future climate today (Stafford-Smith et al. 2011; Ranger and Garbett-Shiels, 2012). Climate-resilient development, as defined here, primarily focuses on reducing social and economic sensitivity to climate as well as building recoverability and adaptive capacity for a range of shocks and stresses through advancing development. But to adapt effectively to climate change will require a more forward-looking and pro-active approach to risk management (Fig. I.2). This will include some specific measures, like retrofitting infrastructure, providing climate information, raising defences and investing in research.

Arguably, investments in development will increase the capacity of countries to implement such programmes in the future. However, in some cases there are advantages to acting now

8 DFID has a corporate compliance commitment to assess all interventions for their relevance to climate change and environment. See DFID's 'Climate and Environment – How to Note' for further information (available on Insight).

to address the challenges outlined in Section I.2 by making specific and additional adaptation investments:

- Firstly, for investments that are long-lived or have long-term consequences, it is often cheaper and easier to account for long-term climate up front, or within the natural replacement cycles, rather than retrofitting later;
- Secondly, if climate change is not accounted for specifically in development decisions today then they risk committing societies to a more vulnerable development path;
- Thirdly, in some areas there are already significant climate-related risks that require response. For example, in Nepal action is needed to avoid and protect against potentially catastrophic glacial lake outburst floods that are already a major risk and where risk is expected to increase with rising temperatures (Agrawala et al. 2003); and
- Finally, adapting to significant changes in climate could require transformational changes in social and economic systems (Stafford-Smith et al. 2011), such as diversifying away from some sectors, and this can require decades to plan and implement.

There are many other open questions about implementing adaptation in practice. The remainder of this Topic Guide focuses on the particular challenge of climate uncertainty. In this Topic Guide, we argue that this uncertainty need not be a barrier to implementing effective development programmes today. Development programmes deal with risk and uncertainty every day and in only a few cases will climate change uncertainty be an important factor in the decision. Even in such cases, it is normally possible to design programmes in ways that make them robust to uncertainty. This is discussed in Section III. In the following section (Section II), the Topic Guide provides an overview of the types and sources of uncertainty and the implications for decisions today.

Key messages from this section

- **Climate change adaptation brings a number of unique challenges for development professionals, requiring a more forward-looking, pro-active, flexible and progressive approach in development programmes.**
- **Climate change and climate-resilient development are recognised as crucial issues for development organisations and will have implications at all levels of planning and implementation, from operational plans to individual projects.** It is relevant not only for programmes where adaptation is a specific goal, but for any development programme that has one of the following characteristics:
  - Where climate shocks or climate change could affect the outcomes of an intervention. For example, experts have concluded that the progress made against the Millennium Development Goals is under threat.
  - Where programmes could affect the vulnerability and resilience of local communities, either directly or indirectly.
- **Development is an enabler of adaptation and vice versa but there can be trade-offs between these policy goals.** Development, disaster risk management and climate change adaptation can be considered to be three interdependent and mutually reinforcing policy goals. But the wrong types of interventions today can lock societies into a more vulnerable development path for decades to come. Climate-resilient development aims to ensure that development proceeds in a way that enhances the resilience of a society and does not inadvertently increase vulnerability of communities in the long run.
- **Adaptation and climate-resilient development are not substitutes – both are needed.** Climate-resilient development is often easier to ‘sell’ to policymakers, as it has co-benefits that meet short-term priorities of eradicating poverty, enhancing food security and economic growth. Some experts have argued that, for the poorest countries, the main focus should be on climate-resilient development. But there are a number of arguments for prioritising some specific and additional adaptation measures to cope with future climate today, such as accounting for climate change in long-lived infrastructure and urban development planning, tackling immediate risks from climate, and preparing for transformational adaptation where necessary.

Where can I find more information?

DFID resources:

- DFID Practice Paper "Climate-Resilient Growth: preparing growth strategies for climate change – how to note". November 2010.
- ICF Thematic Paper on Adaptation.

External papers:

- *"World Development Report 2010: Development and Climate Change"* World Bank (2010). Good introductory text. An accessible account of the linkages between climate change and development, and a detailed discussion of the implications for development interventions today from the local level to international finance and policy.
- *"Integrating Climate Change Adaptation into Development Cooperation"* OECD (2009). A detailed but accessible report on the role of climate change adaptation in planning at the project, sector and national levels, including specific and detailed guidance on incorporating climate change into development cooperation. It also provides useful descriptions of the linkages between adaptation and development and the potential implications of climate change for developing countries, including the achievement of the Millennium Development Goals. This report is linked with an online course.
- *"Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*" Agrawala and Fankhauser (2008). An accessible but slightly more technical report on the economic costs and benefits of adaptation and the policy toolkit available.
- *"Stock taking of progress on integrating adaptation to climate change into development cooperation activities"* (Gigli and Agrawala 2008). A review of the status of development agencies' process on adaptation.
- World Resources Report: http://www.worldresourcesreport.org/wrr-2010-2011

Online lectures and courses:

- Vicki Arroyo: "*Let's prepare for our new climate".* Basic introduction video to climate change adaptation with examples from both developing and developed countries. http://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate.html
- Institute of Development Studies interactive briefing on "*Learning to Tackle Climate Change*" http://www.ids.ac.uk/publication/learning-to-tackle-climate-change
- OECD online training on integrating climate change adaptation into development planning: http://www.oecd.org/environment/environment-development/integratingclimatechangeadaptationintodevelopmentplanningapractice-orientedtrainingbasedontheoecdpolicyguidance.htm

Knowledge-sharing platforms and archives of case studies:

- Climate and Development Knowledge Network: http://cdkn.org
- Adaptation Learning Mechanism: www.Adaptationlearning.net
- WeADAPT: www.weadapt.org
- World Bank Climate Change Knowledge Portal: http://sdwebx.worldbank.org/climateportal/index.cfm

SECTION II Climate change and uncertainty and their implications for development decisions today

"Doubt is not a pleasant condition, but certainty is absurd", Voltaire

This goal of this Topic Guide is to raise awareness about how to manage the changing and uncertain climate risks in development programming today. Many of the tools and concepts here are relevant to managing uncertainty about other long-term trends and risks.

If climate change and its uncertainties are not managed well from the outset of development programmes, this could mean that they fail to achieve their objectives, have a lower value for money or could create reputational damage. In Section I, we learnt that climate change implies a fundamental change in the environment in which development inventions operate. This means that climate change needs to be accounted for properly in decisions today (not just in adaptation programmes but in all decisions that have a climate-sensitive component or that could alter societal vulnerability). Otherwise, the development gains from interventions could be short-lived or, in some cases, could lead to wasted investments or adverse outcomes – where their long-run impacts are more harmful than helpful.

This is not a cause for hopelessness: in many cases future climate uncertainty need not be an important factor in decisions today. In this section, we show a number of case studies where uncertainty is and isn't an important factor in decisions today.

However, it does mean that we need to take care to identify if and how future climate uncertainty is a factor and to design and implement interventions in such a way as to make them robust and resilient to the changing climate.

In reading this Topic Guide, it is important to remember that uncertainty itself is common across all development programmes. Development professionals deal with high levels of uncertainty every day. As the 18th-century philosopher Voltaire said, it is the idea that we have certainty that is absurd. The difference with climate uncertainty is that it is perhaps better understood and better characterised than other types of uncertainty, such as future political conditions or global trade patterns, and so we have the opportunity to design **more robust, adaptable and therefore, resilient development programmes.** The tools and concepts introduced in this guide will be relevant to managing all types of uncertainty.

In this section, we aim to address the following questions:

1. *How uncertain are climate and impact projections and where does this uncertainty come from?*
2. *Where will climate change be an important factor in development decisions today?*
3. *Where will climate uncertainty be important today?*

In this section, we focus on characterising the uncertainty, but the design of development interventions themselves can help to reduce uncertainty. This is the subject of Section III.

II.1. What do we know about future climate change and its impacts?

There is much that we currently do know about how the climate will change over the coming few decades. For example, we know that the increase in greenhouse gas (GHG) levels in the atmosphere caused by human emissions will lead to warming across most of the Earth's surface. It is also clear that this will cause sea levels to rise and will change rainfall patterns, with wet areas tending to get wetter and dry areas tending to get drier. We also expect an increase in the intensity of many types of extreme weather.

But we do not know exactly by how much temperatures will rise over the coming decades, or exactly how weather conditions will change at the local level. The uncertainties become larger the further we try to predict into the future.

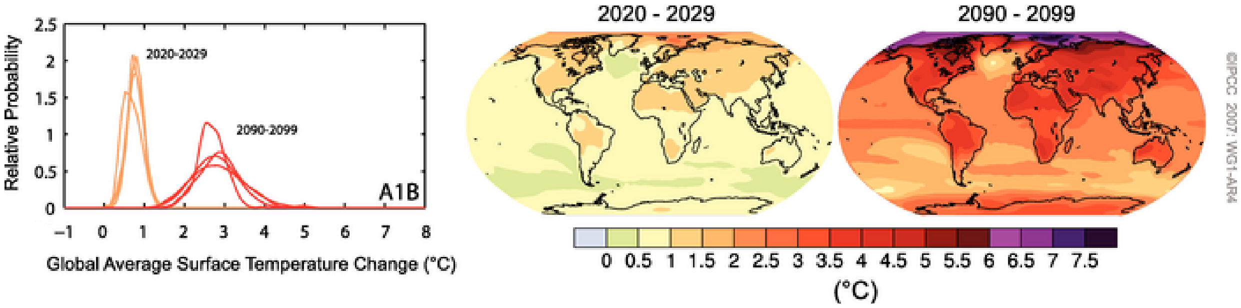

Figure II.1: Projected surface temperature changes for the early (2020-2029) and late (2090-2099) 21st century relative to the late 20th century (1980-1999). The left panel shows the uncertainty in global projections based on several different models. The right panels show the average level of warming projected by models across the globe. All projections are for a central emissions scenario (SRES A1B)

For example, the left panel of Fig. II.1 shows that by the 2020s, the Intergovernmental Panel on Climate Change (IPCC) concludes that globally temperatures are *likely* to rise by up to about 1.5°C above the levels observed at the end of the 20th century (1980 to1999). In IPCC terminology, *likely* implies more than a two-thirds chance (>66%). Much of this warming is already locked in due to our past emissions so is insensitive to our assumptions about future GHG emissions (Solomon et al. 2007). As we look further ahead in time, the range of projections increases, as emissions scenario uncertainty and climate model uncertainty increases (Box II.1). For example, for the 2090s the IPCC projects that global temperature could increase to between 1.1°C and 6.4°C above 1980 to 1999 levels. About half of this range is due to uncertainty in the climate response and the other half due to the uncertainty about how GHG emissions will change over time[9].

Uncertainties are greater for changes in rainfall and for predicting changes in extreme events, like flooding, droughts and storms. For example, Fig. II.2 gives the seasonal average rainfall projections that correspond to Fig. II.1. The white regions show areas where less than two-thirds of climate models agree even on whether rainfall will increase or decrease. Such areas of high uncertainty cover large parts of Africa, Asia and South America. For example, Ghana models predict anything from a 20% increase in rainfall to a 30% decrease (Hallegatte et al. 2012). This range of projections would raise fundamental problems for a hydraulic engineer trying to design a dam in Ghana or for a farmer trying to decide whether to invest in an irrigation system.

9 The business-as-usual emissions scenarios attempt to project how global emissions of several gases will change, assuming no specific policies to mitigate greenhouse gas emissions. For more information, see IPCC (2000).

Box II.1: Why are future climate projections so uncertain?

Climate projections are generated from climate models. These are computer models that attempt to simulate the physical processes of the climate system. They are similar to the models used to create weather forecasts[10]. Climate uncertainty can be divided into three types:

- **Forcing (or scenario) uncertainty:** uncertainties in our assumptions about how human emissions, GHGs and others (particularly aerosols), will evolve over time in response to changing population, technologies and socioeconomic developments, and changes in natural forcing, such as solar radiation and emissions from volcanoes;
- **Model uncertainty:** uncertainty that stems from gaps in our understanding of how the climate operates or in our ability to model processes sufficiently[11]. This is an epistemic (or systematic) uncertainty, and could (in theory) be reduced as more is learnt and models become more powerful. Yet it is unlikely that we will see a narrowing of the uncertainty range in the next 10 years. The range of uncertainty is also impossible to quantify at present; for example, current climate models share a number of systemic uncertainties and this means that we cannot be sure if the ranges of projections they produce can really be considered the 'true' range of uncertainty. For example, the range of sea level rise projections of the Fourth Assessment Report of the IPCC were known to systematically underestimate sea level rise because none of the models represented dynamic changes in ice sheets (Solomon et al, 2007); and
- **Internal variability:** uncertainty that stems from the chaotic nature of weather and climate. This is an aleatory uncertainty, which means that it is irreducible but can be quantified.

See Fig.II.4 for an estimate of how much each of these uncertainties contributes to total uncertainty in global average temperatures and how this changes over time.

Sources: Stainforth et al. (2007)

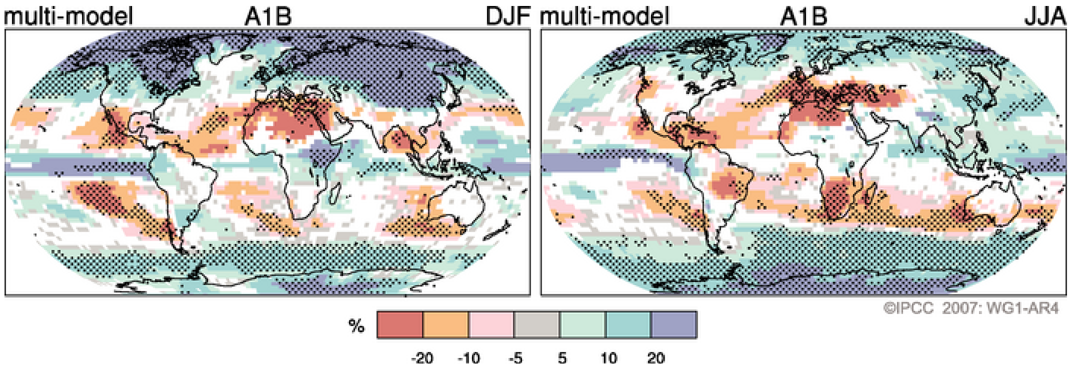

Figure II.2: Projected changes in rainfall (in per cent) for 2090-2099 relative to 1980-1999, for December to February (left) and June to August (right). The values shown are averages across a suite of models for a central emissions scenario (SRES A1B). The white areas are where fewer than two-thirds of models agree on the sign of the change. Stippled areas are where more than 90% of models agree on the sign of the change.

10 Climate models are much simpler than weather forecasting models in some ways, and more complex in others. For example, they have a much lower resolution to allow them to simulate climate over much longer time periods (centuries rather than days), but they include many more physical processes, such as ocean circulation and biological systems.

11 Computing constraints, which means that we are limited in the resolution of our models and the breadth of processes that can be represented (*structural* model uncertainty). This also means that we have to make simplifications, for example in the way that we represent clouds (*parametric* uncertainty).

There are a number of additional steps that one must take to understand how this physical climate change translates into impacts on people and livelihoods at the local level – this is illustrated in Fig. II.3. The uncertainty in future climate cascades down through this chain and at each step more uncertainty is incorporated (Fig. II.3). Few of these uncertainties can be meaningfully quantified. This situation is often referred to as 'deep uncertainty' (Box II.2).

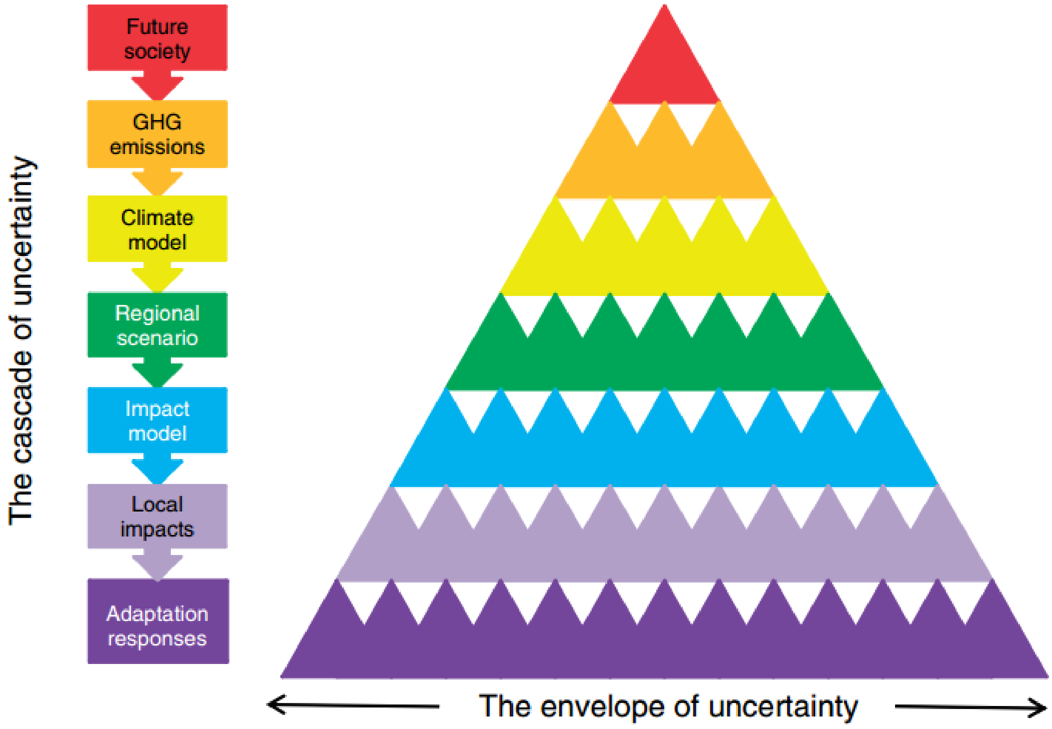

Figure II.3: The 'cascade of uncertainty' along the prediction chain from future societal conditions to projections of local impacts and adaptation responses. Source: Wilby and Dessai (2010).

In most cases, the largest source of uncertainty will not be changes in physical systems but in how these interact with social, ecological, economic, institutional and political systems and factors at the local scale. The vulnerability and resilience to climate (described in Fig. I.2) is itself uncertain and is changing considerably over time as a result of development progress, *autonomous adaptation*[12], changing social, economic and political circumstances, but also shocks and other pressures. These relationships are complex, rapidly changing and almost impossible to predict ahead of time. For example, the profile of vulnerability to climate in Africa is likely to change radically over the next few decades as the population continues to grow, more people move into urban areas, wealth (for most people) increases and new technologies, like new agricultural techniques, are adopted.

This final aspect of uncertainty, while arguably at least on a par with the influence of physical climate change in terms of scale[13], is the least well studied and so is often neglected. However, it can have a considerable bearing on how adaptation strategies are designed today. For example, a recent OECD study estimated that two-thirds of the increase in

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12 Many communities have a high ability to adapt to changing climate conditions, though barriers are present and limits will be reached at higher levels of warming (Thornton et al. 2011).

13 Studies have demonstrated that socioeconomic change is often on a par with the influence of climate change in driving risk, and will be particularly so over the coming 30 years (Warren et al. 2006).

population exposed to coastal storm surges in the world's largest cities by the 2070s would be due to urbanisation and population growth and only one-third due to climate change (Hansen et al. 2011). Ignoring socioeconomic change would mean that adaptation plans would neglect to see the enormous benefits of urban development planning.

Some of these uncertainties will be reducible over time as more is learnt about the science of climate change and local vulnerabilities and resilience (Box II.1). But it is unlikely that they will be substantially reduced within the next 10 years or so. In some cases, we cannot wait for better information (high costs of delaying adaptation, Fig. II.3). This means that we need to learn how to make decisions under deep uncertainty about the future climate today.

Box II.2: Risk versus uncertainty – the challenge for decision making

Uncertainty itself is not necessarily a problem. Decisions are made under uncertainty every day. For example, engineers routinely make decisions about the design of infrastructure, like reservoirs, roads and flood defences, to cope with local weather conditions, which by their nature are chaotic and uncertain. In this type of situation, the planner or engineer will typically have a probability distribution, based on historical observations of the climate, and will optimise the design of a project using standard tools, like cost–benefit analyses. In economics, this situation is sometimes known as decision making under risk – that is, where the uncertainty is quantifiable.

However, the uncertainty in climate impacts is different. In making adaptation decisions, a decision maker can no longer rely on historical observations, but is forced to use model-based climate and impact projections, which inherently come with unquantifiable uncertainties (Box II.1). In this situation, traditional cost–benefit analyses can break down (see Section IV). This type of uncertainty is known as Knightian uncertainty, ambiguity or deep uncertainty.

Deep uncertainty is common across many long-term forecasts, including exchange rates, population growth, commodity prices and economic growth. Arguably, the problem is worsened in this case because of the large scale of the potential impacts.

Continued research to better constrain projections is important. However, it is highly unlikely that further research will significantly reduce uncertainties in future climate risk for the timescales in which many adaptation decisions need to be made.

II.2. Where is the uncertainty important in decisions?

We have seen that there are large and unquantifiable uncertainties in our understanding of the future impacts of climate change on people and societies. The important question is: does this really matter for the development and adaptation decisions that we make today? We argue that in many cases it will not matter. There are three reasons for this.

1. **Many of the development and adaptation decisions that we make today are not sensitive to future climate.** For example, building institutional capacity, promoting more resilient agricultural techniques and investing in early warning systems can have positive outcomes regardless of how the climate changes;
2. **Many decisions we make today are short-lived or can be adjusted over time**, so are not dependent on long-term climate change. For example, crop varieties and planting times can be changed every year; and
3. **Short- to medium-term climate is not as uncertain as long-term climate and can be more easily quantified.** This uncertainty due to climate change on these timescales will usually be small compared with normal weather variability or other factors in development decisions, like political conditions or exchange rates. Short- to medium-term climate variability will mainly be driven by natural weather processes and climate variability, which have uncertainties that are easier to quantify based on historical information (Fig. II.4).

Even where decisions are sensitive to assumptions about future climate, like long-lived infrastructure, there are many well-known approaches for reducing the risks in decision making, for example, by building in safety margins or designing infrastructure that can be adjusted over time to accommodate climatic changes. Such strategies are discussed in detail in Section III.

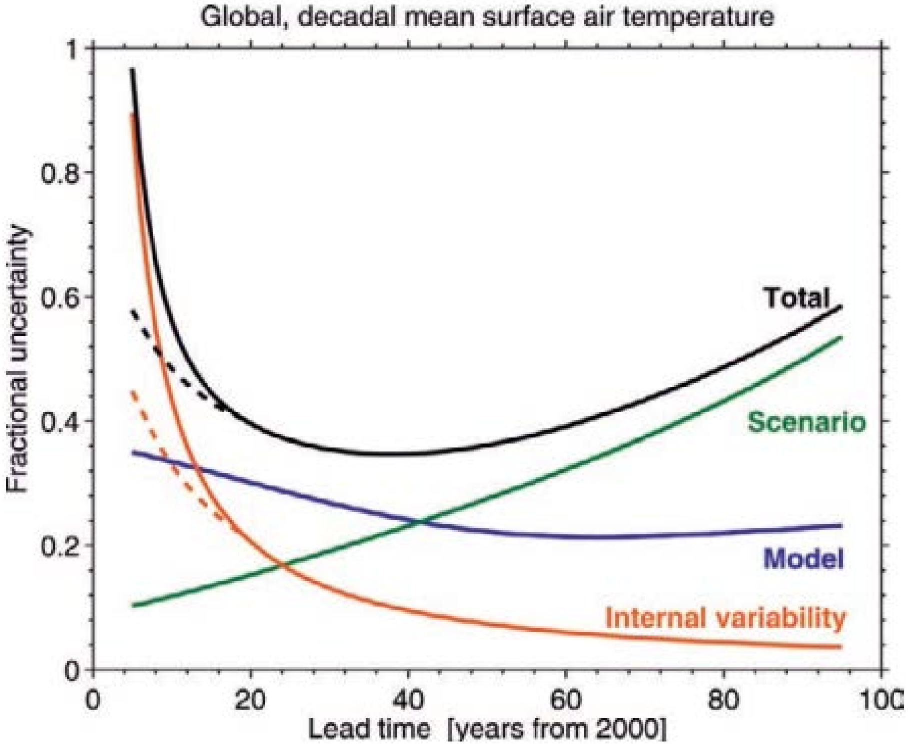


Figure II.4: Estimates of the relative importance of different sources of uncertainty in a climate model projection of global temperature[14]. The 'internal variability' is natural weather and climate variability ('aleatory uncertainty' in Box II.1). The scenario uncertainty is the contribution from the uncertainty about how global emissions will change – these scenarios don't tend to diverge until around 2040. The model uncertainty is the systematic uncertainty stemming from gaps in our understanding of how the climate operates or in our ability to model processes sufficiently (Box II.1).

Case studies 2 to 5, which are presented below, illustrate the implications of climate change in five regions, three in Sub-Saharan Africa (SSA), one in Asia and the other in South America. In each of these cases – which cover agriculture, water resources and flooding – the system is sensitive to climate. In each case, there is also uncertainty about future climate. Together this results in divergent views of how communities will be affected by climate over time.

But the importance of climate change in a decision is determined not only by the sensitivity of the system to climate, but also by the characteristics of the decision itself. Where an intervention is short-lived, low-cost or adjustable over time, long-term climate change is less likely to be important in development interventions today. Similarly, if an intervention has benefits for resilience irrespective of climate change, then uncertainty over long-term climate is unlikely to be important in the decision today.

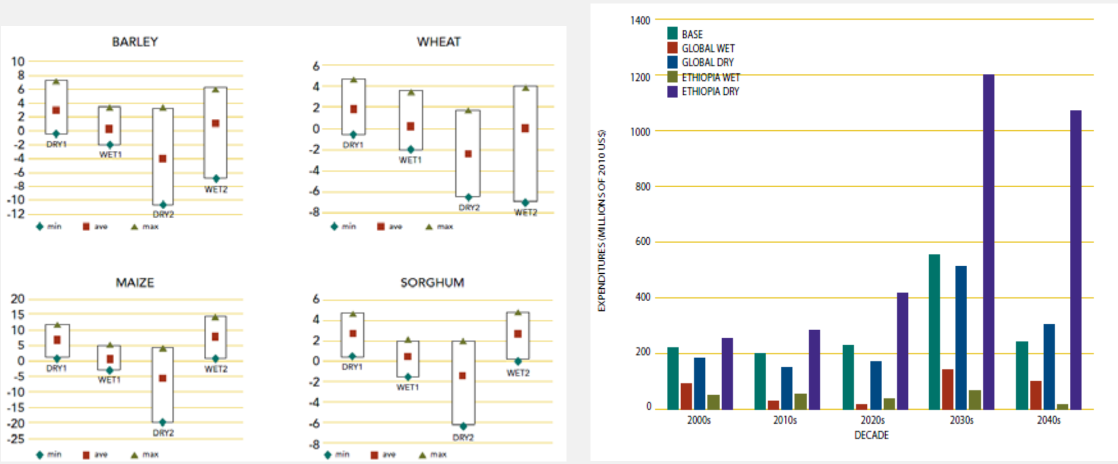
[14] The quantity shown is the decadal average surface air temperature. The fractional uncertainty is the 90% confidence level divided by the mean prediction. The dashed lines indicate how uncertainty in internal variability could be reduced through improved modelling techniques.

This is demonstrated in the case studies. For example, despite the uncertainty in the Maharashtra case, a range of cost-effective adaptation options are found to be available (such as drip irrigation, watershed management and insurance) which can be scaled up over time as the climate changes. These options are all relatively low-cost, short-lived and adjustable. Similarly, for agriculture in SSA (see Case Study 1 in Section I) there are many options available that have significant short-term benefits regardless of how the climate changes.

But the case studies give a glimpse at some harder choices down the line. For example, in Ethiopia, rainfall projections are starkly divergent and so decision makers would need to make a choice between investing in irrigation systems (to tackle an increasing risk of drought) or drainage systems (to tackle a rising risk of waterlogging) sometime before 2050. In this case, assuming the costs of delaying this decision are low, new information gathered over the next decade should help to pin down the right choice. A tough decision in SSA (Case Study 1) is whether and how to prepare for the chance that some communities will need to migrate if agriculture becomes unsustainable.

Case Study 2: The impacts of climate change on agriculture in Ethiopia

Agriculture contributes just under half of Ethiopia's gross domestic product (GDP). There is large uncertainty over how agricultural yields will change due to climate change, which stems partly from the divergence in climate model projections of future June–August rainfall. The impacts also vary by crop type and region. In the most damaging climate scenario, 'dry 2', yields of barley, wheat, maize and sorghum decline by, on average, between 1.5% and 5% by 2050, but year-to-year variability increases significantly more due to the rising frequency of droughts. Under the more optimistic 'wet 2' scenario, average yields rise by around the same amount, but variability continues to rise.



(Left) Ranges of projected yield variations compared with the 'no climate change' baseline and (right) Projected annual expenditure on drought relief by the Ethiopian government for four climate model scenarios and a baseline scenario.

For a dry scenario, drought expenditure increases to more than US$1 billion per year in the 2030s and 2040s, while for a wet scenario drought expenditure remains well below US$100 million per year. This implies starkly different allocation of resources for adaptation interventions. For example, under the driest scenario, the study proposed an investment of US$50 million in irrigation systems before 2050; whereas for the wettest scenario an investment of around US$37 million would need to be made in drainage systems for waterlogged areas[15].

Source: World Bank (2010b), Ethiopia case study

15 Two measures were identified that were relevant in each scenario: research and development and farm and watershed management.

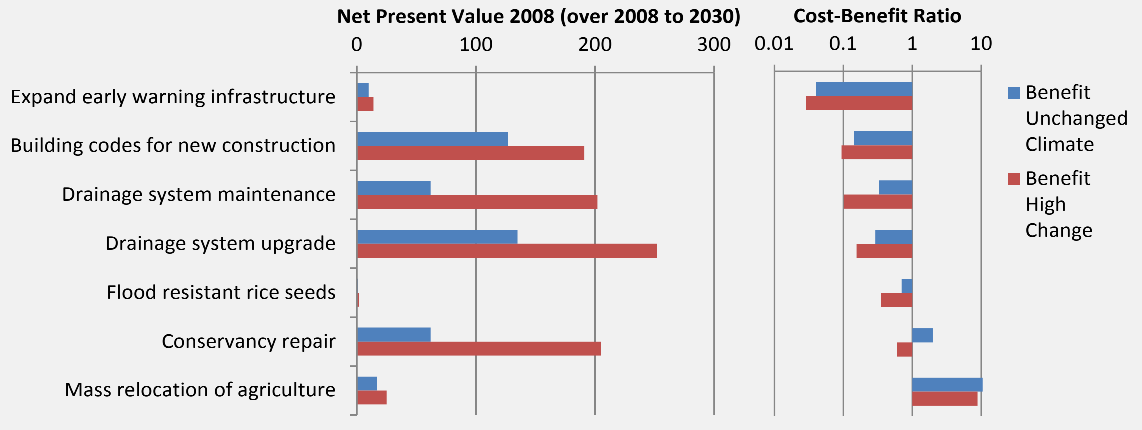
Case Study 3: Averting losses to agricultural output in Mali

Mali already experiences the highest rainfall variability in the world. Farmers in Mali cope with this using a variety of autonomous adaptation strategies, including diversified crop types. Over the coming decades, the climate could change significantly. Based on current models, average rainfall could rise by around 8% or fall by more than 10% by 2030, and temperatures could rise by between 0.9°C and 1.4°C. The result would be a fall in agricultural yields, with a loss of US$120 million per year by 2030 in an optimistic scenario, and US$300 million per year in a pessimistic scenario. Autonomous adaptation may avert a portion of losses – this would likely entail a migration into regions best suited for agriculture and appropriate crop types. This could be encouraged through appropriate policy and infrastructure development, but intervention would also need to address the possible adverse effects of migration, such as competition and conflict over land and resources. Despite this, it is likely that some residual loss will remain in the worst affected areas. Soil techniques, such as low tillage, and irrigation systems could help to maintain yields in these areas and are estimated to be cost-beneficial and feasible options in some parts of Mali, even in a worst-case scenario. There could also be opportunities to increase revenue through cash crops or agroforestry.

Source: Economics of Climate Adaptation Working Group (2009)

Case Study 4: Reducing the risks from flash flooding in Georgetown, Guyana

Guyana's geography makes it prone to flooding. Much of the population and agricultural production lies in a narrow strip of land along the coast, which is prone to flash flooding from rainstorms. Guyana has high levels of poverty and a lack of flood protection. 'Moderate change' climate projections are for a reduction in rainfall of around 5%, though in a worst-case scenario ('high change'), rainfall could increase by 10% by 2030. Under this scenario, expected annual losses from flooding could rise from US$130 million (in a unchanged climate scenario) to US$200 million by 2030 due to climate change. A wide range of measures were found to be cost-beneficial under both a moderate change and a worst-case ('high change') scenario (see Figure below), including expanding early warning infrastructure, introducing building codes for new construction and upgrading the drainage system. The only measure where climate uncertainty is shown to have a material impact on cost-efficiency is repairs to Guyana's water conservancy (flood storage) system – this is found to be cost-beneficial only under the more pessimistic ('high change') climate scenario. Subsequent analysis by the World Bank suggests that if sea level rise is accounted for, upgrades to this system become cost-effective.

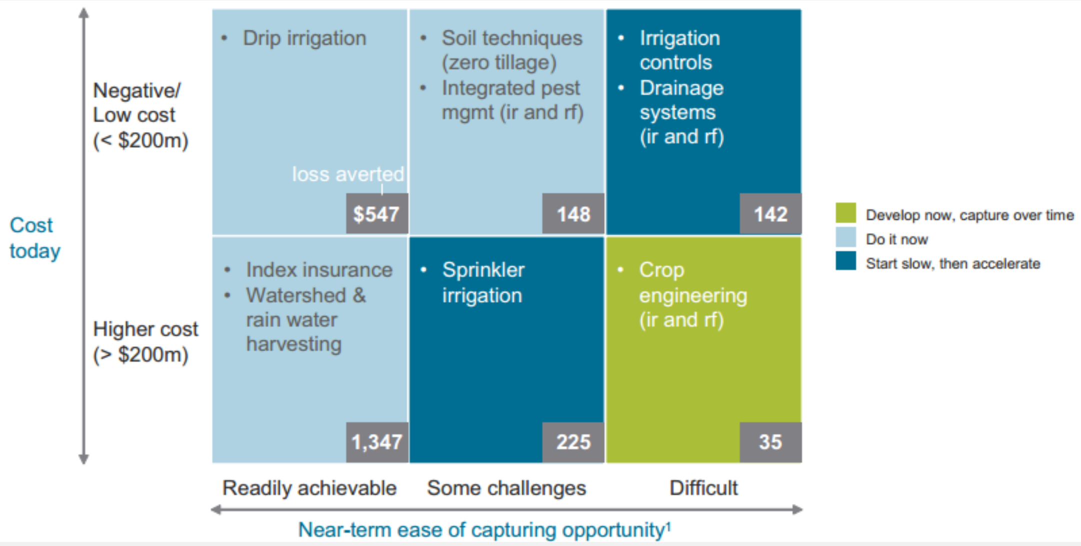


The benefit of a set of adaptation measures for flood risk management in Georgetown, Guyana, expressed in net present value (US$ million 2008), and the cost–benefit ratio, estimated for two climate change scenarios (unchanged and a 'high change' climate scenario).

Source: Economics of Climate Adaptation Working Group (2009)

Case Study 5: Managing drought risk in Maharashtra, India

Maharashtra suffered three years of crippling droughts between 2000 and 2004, with severe impacts on the two-thirds of farmers who depend on agriculture for their livelihoods. One study showed that average climate projections indicated little change in rainfall conditions by 2030, but that in a worst-case scenario annual rainfall could decline by 8%, resulting in a several-fold increase in the frequency droughts (a one-in-10-year drought could become one in three). The study evaluated a wide range of measures for enhancing the climate resilience of agriculture in Maharashtra. They concluded that Maharashtra can avert the bulk of their expected drought losses to 2030 through measures whose economic benefits exceed or approximate their costs, including drip irrigation, drainage systems, soil techniques, watershed management, insurance and irrigation controls. These measures could be implemented incrementally over time, as illustrated below, as more is learnt about the climate.



Source: Economics of Climate Adaptation Working Group (2009)

Based on these simple concepts, Fig. II.5 provides a general guide for screening whether a decision is likely to be sensitive to climate change and uncertainty. The first two factors relate to characteristics of the system and are the same as those given in Section I (Box I.1). The other three factors are characteristics of the intervention itself. For a long-lived, high-cost and inflexible (non-adjustable) intervention, such as those encompassing infrastructure and buildings, uncertainty about future climate is more likely to be an important factor in the decision today. For example, a building will often last a hundred years and so will have to cope with quite radically different climate conditions over its lifetime (Hallegatte et al. 2012).

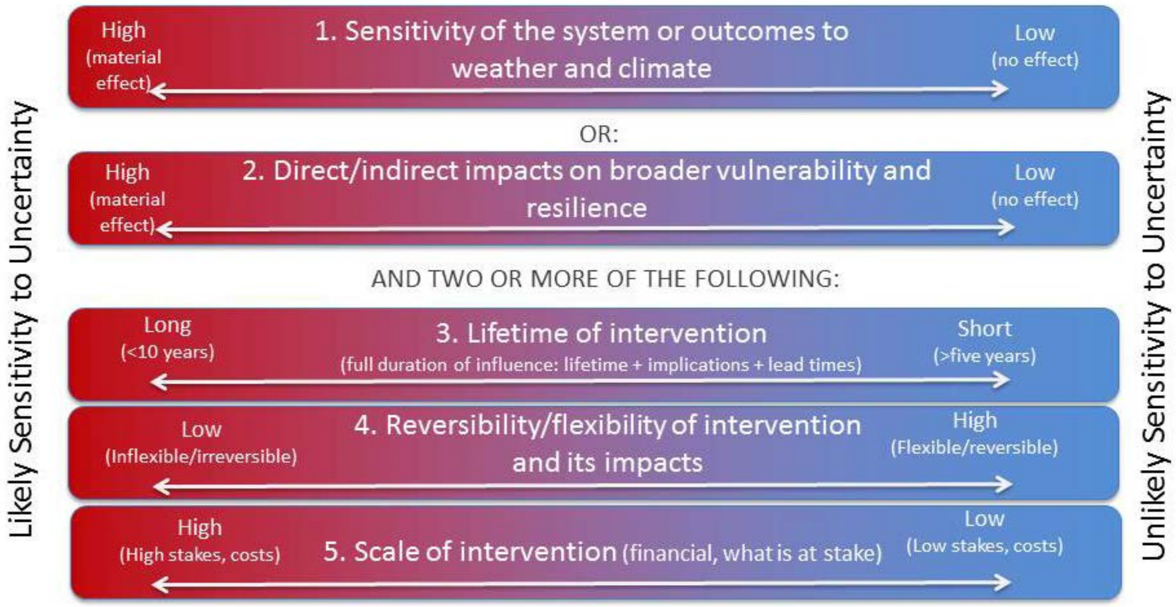


Figure II.5: Guide for identifying decisions that could be sensitive to climate uncertainty[16] (based on Ranger and Garbett-Shiels [2012] and the UK Green Book Guidance [HMT/Defra 2009])

16 In using this guide it is important to remember that the full duration and influence of a programme or project will very likely be longer and deeper than the original intervention. For example, a DFID-funded project may last only three years or so, but it could influence the development prospects and climate resilience of a community or entire region for a decade or more.

Box II.3: Risk screening tools

Several organisations have developed and begun to apply climate change risk screening tools in their projects and programming. These vary in complexity. Below is one example proposed by Burton and van Aalst (2004). A more sophisticated tool, that incorporates climate change projections, is the World Bank's Assessment and Design for Adaptation to Climate Change (ADAPT) tool[17]. Arguably, an advantage of simple tools is their transparency and ease of use. Several summaries of risk screening tools are available, for example, the United Nations Framework Convention on Climate Change (UNFCCC) compendium[18] and the upcoming review by PROVIA[19]. DFID has its own tool in its Climate and Environment Assessment.

A recent review by the World Bank's Independent Evaluation Group (IEG, 2012) concluded that adequate guidance is still lacking on when and how to incorporate climate risks into project design and appraisal. They suggest that current procedures are ad hoc and as a result climate risks are sometimes neglected. They recommend that the Bank develop reference guidelines for incorporating climate risk management into project and programme design, appraisal and implementation.

Ranking	Direct risk	Effect on external risk	Effect on indirect or secondary risk
1: High	Large components of the project are subject to climate risks facing a country or region (e.g. infrastructure and agricultural projects located in flood- or drought-prone areas)	The project could have a strong effect on the climate risks to which a country or region is exposed (e.g. development projects that trigger development in dangerous areas)	
2: Medium	Some elements of the project are subject to direct risks, but the risk to the project as a whole is limited or only indirect		The project may have indirect effects on the vulnerability of the country
3: Low	The project is not sensitive to climate risks at all	The project does not (negatively) affect external vulnerability	

A risk screening matrix for an intervention. OECD (2009) based on Burton and van Aalst (2004). The first column 'direct risk' maps onto the first component of the guide presented in Fig. II.5, while the second and third columns relate to the second component of Fig. II.5 (the tool also requires the user to make implicit assumptions about the other three factors in Fig. II.5).

Fig. II.6 illustrates how the guide (Fig. II.5) might be applied to screen whether an intervention is likely to be sensitive to future climate uncertainty, using a simple ranking (1 to 10). In this example, urban planning scores highly against most of the five factors – indicating that future climate is likely to be a factor in decision making. Both low-tillage agriculture and institutional capacity building score low against each of the three intervention factors (shaded in Fig. II.6), so uncertainty over future climate is unlikely to be a factor. This provides only an initial screening of the role of future climate uncertainty. The Ethiopia case illustrates that the range of uncertainty in future climate will also be a factor. Box II.3 gives a brief overview of some of the many other screening tools available.

17 http://siteresources.worldbank.org/INTCC/Miscellaneous/21315775/Poster_of_ADAPT.pdf

18 http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5457.php

19 http://www.unep.org/provia/Portals/24128/PROVIA_Draft_Guidance_on_Assessing_VIA-For_Review.pdf

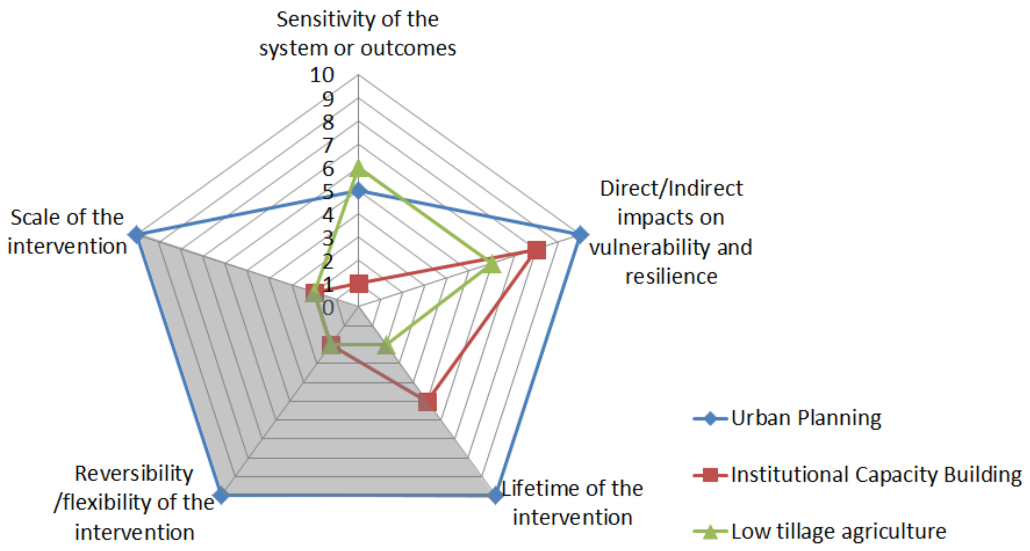


Figure II.6: Illustrative application of the rubric (Fig. II.5) to three interventions concerning urban planning, institutional capacity building and low-tillage agriculture

The interventions most likely to be dependent on climate change and uncertainty are those normally involving the public sector, such as public infrastructure, dams, coastal defences and urban and land planning decisions – these tend to have the longest lifetimes.

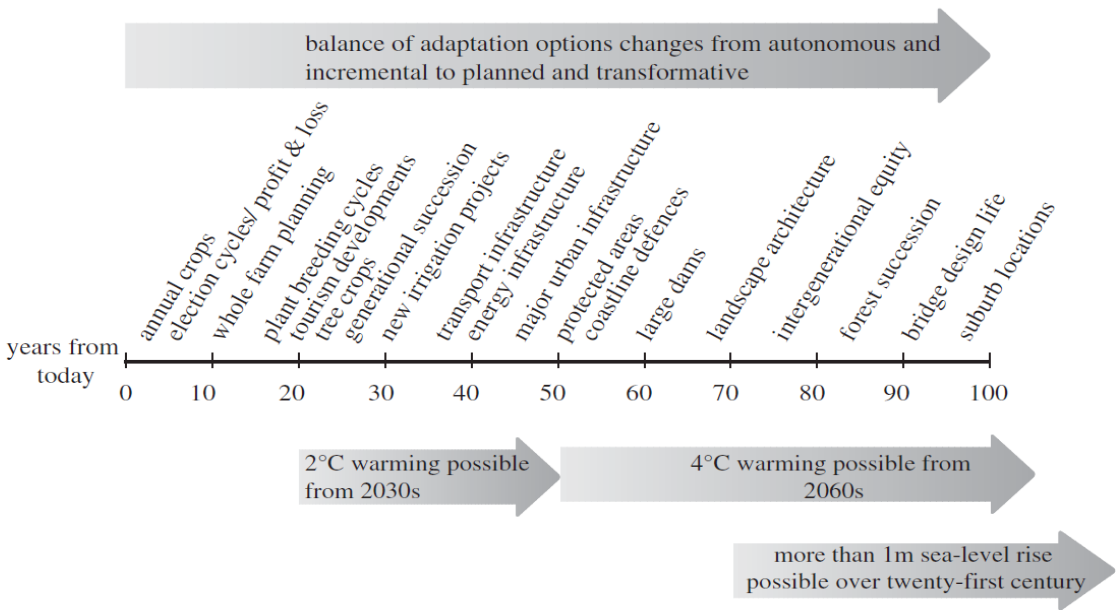


Figure II.7: The timescale of different types of intervention compared with the timescales of climate change. Source: Stafford-Smith et al. (2011)

Government policies, such as growth strategies, land use planning and sectoral planning can also be sensitive to climate change and uncertainty. These types of policies have long-lived implications and can have far-reaching and complex consequences that may inadvertently lock a society into a more vulnerable development path (i.e. the second, third, fourth and first factors in Fig. II.5).

For example, a growth policy that encourages rural-to-urban migration may have benefits for economic growth and poverty alleviation, but may result in the concentration of the urban poor in informal settlements, which tend to be more exposed and vulnerable to climate due to their location and socioeconomic circumstances. Every year 25 million people move into informal settlements in vulnerable dwellings around the world's largest cities, in many cases in hazardous areas, such as along unprotected rivers and coasts (UNISDR, 2009).

Government policy also affects social norms, sectoral development, welfare and social policy, health, education and standards for infrastructure and buildings – all of which will have long-lasting effects on vulnerability. Table II.1 gives examples of national-level decision-making processes, and specific decisions, which are likely to be affected by climate change.

Table II.1: Examples of sectoral decisions affected by climate change. Source: WRI (2011), augmented by HMT/Defra (2009) and Hallegatte (2009)

Sector	Example of national-level decision-making process	Examples of sectoral, local or project decisions
Agriculture	• National agricultural plan • Crop management plan	• Choice between irrigation and rain-fed cropping • Introduction of new crop varieties • Relocation of farm communities
Energy	• National energy policy/strategy	• Choice of power generation • Choice to extend grid vs. distributed generation • Siting of new energy infrastructure
Natural Resources Management	• Coastal zone management plan • Forest management plan • Protected areas plan • National invasive species management plan	• Planning for endangered/protected species • Establishment of protected areas • Determination of maximum fish catch • Choice between hard/soft coastal protection • Control of disease, pests and invasive species
Land, Urban Planning and Infrastructure	• National transport plan • Road maintenance finance plan • National highway plan • Spatial (land use) planning policy	• Urban development planning • Location of mass transit • Construction of bridges and highways • Local of schools and hospitals
Water	• National water policy • Integrated water resource management plan	• Expansion of watershed restoration • Development of river basin cooperation • Repair/redesign of aging infrastructure • Enhancing flood control infrastructure
Tourism	• National tourism plan	• Creation of ecotourism destinations
Cross-Sectoral	• Five-year national development plans • National adaptation programme of action • Civil contingency/emergency response planning	• Identification of adaptation, development and disaster risk management priorities • Prioritisation of sectors and populations • Sectoral development/investment strategies • Preparedness planning for disasters

Fig II.5 provides only an initial screening to identify where uncertainty may be important. This can be followed up by further analysis to assess the extent of the sensitivity of outcomes to climate change and uncertainty (Sections III and IV). In some cases, planning for adaptation to climate change reveals that systems are not adapted to current climate conditions. The Guyana case study provides an example of such *adaptation deficit* – i.e. the gap between current practice and what would be considered a well-adapted system.

The next section (Section III) will explore how interventions can be designed such that the impact of uncertainty in future climate on the outcomes is reduced.

Key messages from this section

- **Future climate and its impacts are deeply uncertain.** This means that predictions come with unquantifiable uncertainties. The level of uncertainty increases with time.
- **If climate change and its uncertainties are not well-managed from the outset of development programmes, this could mean that they fail to achieve their objectives, have a lower value for money or could create reputational damage.** Uncertainty over future climate increases the chance of taking not enough, too many or the wrong types of interventions, leading to wasted investments and higher risks for local people. This means that we need to take care to identify if and how future climate uncertainty is a factor, and to design and implement interventions in such a way as to make them robust and resilient to the changing climate.
- **Uncertainty is common across all development programmes.** Development professionals deal with high levels of uncertainty every day. The difference with climate uncertainty is that it is perhaps better understood and better characterised that other types of uncertainty, over for example future political conditions or global trade, and so we have the opportunity to design more robust and resilient development programmes.
- **Uncertainty over future climate will not necessarily be a factor in many development decisions.** Uncertainty could be an important factor where an intervention is long-lived, inflexible (non-adjustable) and high-stakes (high costs and benefits). This will include, for example, interventions concerning buildings and infrastructure, urban development, sectoral growth strategies or land use planning.
- **A range of tools is available to screen the climate change risks to development projects.** A recent review by the World Bank suggested that the application of tools is still ad hoc and, as a result, climate risks are sometimes neglected in development programmes.

Where can I find more information?

Climate and impact projections:
There are several publicly available sources of climate projections online, including those specifically designed for development professionals. See, for example:

- The World Bank Climate Change Knowledge Portal: http://sdwebx.worldbank.org/climateportal
- The Climate Information Explorer of the University of Cape Town: http://www.csag.uct.ac.za/unitar-cie/
- CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) http://www.ccafs-climate.org/

Sources of information on the impacts of climate change are widespread in the academic and grey literature. As a starting point, we would recommend:

- The Fourth Assessment Report of the IPCC: http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html
- The World Bank study on the "Economics of Adaptation to Climate Change". This report contains a series of short case studies that evaluated the risks from climate perils and adaptation options. The method was simplified – focusing on single hazards, a limited range of socioeconomic factors and short time horizons, yet the findings can be instructive. http://climatechange.worldbank.org/content/economics-adaptation-climate-change-study-homepage

Risk screening, or vulnerability and impact assessment:

- DFID 'Climate and Environment – How to Note'
- ORCHID: screening development cooperation for risks and opportunities. Good introduction to the specifics of where climate change is a factor in DFID programmes. This includes a series of papers, such as a screening of DFID development cooperation in India, Bangladesh and China to identify (1) where outcomes are climate-sensitive, and (2) opportunities to enhance climate resilience. http://www.ids.ac.uk/climatechange/orchid
- UNFCCC Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change: http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5457.php
- PROVIA Guidance on assessing vulnerability, impacts and adaptation (VIA). http://www.unep.org/provia/Portals/24128/PROVIA_Draft_Guidance_on_Assessing_VIA-For_Review.pdf

SECTION III Designing policies and interventions that are robust to climate change and uncertainty

"By definition, a robust strategy is insensitive to our uncertainty about the future. It would perform reasonably well, at least compared to the alternatives, even if confronted with surprises or catastrophes", Robert Lempert and Michael Schlesinger, 1998

"To face decision making challenges in a context of limited resources, governments can follow a strategy used by businesses in times of uncertainty – reserving the right to play in the future by establishing policies and measures that can help to keep options open", Carolina Zambrano-Barragán, Climate Change Advisor, Ecuador[20]

Given the uncertainty inherent in many development decisions, a *resilient* programme or project is not only one that is able to achieve its objectives today, but also one that is "*robust,* meaning that it performs well under a wide variety of futures and *adaptive* meaning that it can be adapted to changing (unforeseen) future conditions" (Walker et al. 2013). This principle is equally relevant at the national, sectoral, local and project scales.

In this section, we hope to convey that designing such programmes and projects is not necessarily complicated. We address the following issues:

1. *The three pillars of building robust and adaptive interventions: progression, flexibility and low-regrets;*
2. *Tackling climate change and uncertainty within the project cycle; and*
3. *Practical challenges of dealing with uncertainty.*

The focus on this section is on understanding what actions need to be taken today. This is the chief concern of most development professionals. In addition, when the adaptation challenge is reconceptualised in terms of its implications for near-term decisions, we find that many decisions are not so greatly affected by climate change. Indeed, well-designed interventions can actually reduce the level of uncertainty in future climate impacts, both directly, through investing in research, and indirectly, through reducing vulnerability.

Robustness and adaptability are not only relevant to addressing climate uncertainty, but can be applied to any uncertainty involved in development interventions, such as future population growth, migration, or global food prices. Importantly, robustness does not necessarily mean adapting to the worst-case scenario now – for example, building a sea wall that could cope with a worst-case sea level rise[21]. In practice, it means designing an intervention that is flexible enough to cope with or adjust to changing conditions.

There is now a very good understanding of the principles of robust and adaptive strategies (Fig. I.6) and a growing body of real case studies. However, the majority of adaptation in practice so far has focused on so-called low-regrets interventions, like climate-resilient development, capacity building or restoring mangroves in Vietnam (WRI, 2011). There are

[20] Quotation from WRI (2011).

[21] This may be a suitable strategy where the incremental cost of adapting to the worst-case is very low. In many cases, adapting to the worst-case would increase the cost of the intervention.

as yet few practical cases studies where a decision maker has had to make a tough choice in the design of an intervention that is sensitive to climate uncertainty[22].

III.1 Building interventions that are robust to uncertainty

Although many development professionals are aware that they are facing deep uncertainty over the future, evidence suggests that they still often develop plans based on the assumption that the future can be predicted (Walker et al. 2013, pg. 957). For example, they develop an 'optimal' plan based on a single 'most likely' future or a static 'robust' plan that will produce acceptable outcomes across a small number of scenarios. If the future turns out to be different to their hypothesised future, then the plan is likely to fail. This was a conclusion, for example, of the recent World Bank review (IEG, 2012).

Studies suggest that there is a **general lack of forward-looking, pro-active interventions that anticipate future risks and act to reduce them ahead of time** (IEG, 2012). The majority of development and humanitarian work on managing risks also tends to be reactive – managing events as they happen, or deliberative – learning from the recent past and adapting to it (Jones et al. 2013). This backward-looking approach brings considerable risks in a changing risk environment (Fig. I.2).

A common question is: "how do we design and implement forward-looking and pro-active interventions when there is so much uncertainty over future climate?". Walker et al. (2013) suggests that there are broadly four ways of dealing with deep uncertainties in plans:

- *Resistance:* planning for the worst possible case;
- *Resilience:* ensuring that whatever happens in the future, the system can recover quickly;
- *Static robustness:* reducing the sensitivity of the outcomes to the widest possible range of future conditions; and
- *Dynamic robustness:* adopting plans that can change over time, in case conditions change.

Each of these approaches has its advantages and disadvantages (Walker et al. 2013). We suggest that in practice, robust and adaptive development interventions may adopt a number of these strategies, as appropriate to the situation. There are three attributes, or interlinked approaches, to designing robust and adaptive development interventions[23] (Fig. III.1), as described in detail below. They should be considered not only for adaptation interventions, but any development intervention that has outcomes that could be sensitive to climate, or influences broader vulnerability and resilience. These attributes are relevant to tackling all forms of deep uncertainty in decisions, not just climate change.

22 It is unclear if this is because climate uncertainty is ignored or if cases are unrecorded. There is a growing number of such cases in developed countries, such as the Thames Estuary 2100 project (Reeder and Ranger, 2011); or adapting water systems in southern California (Groves et al. 2008).

23 These are based on guidance from the UK Government (HMT/Defra 2009), Ranger et al. (2010) and Fankhauser et al. (1999).

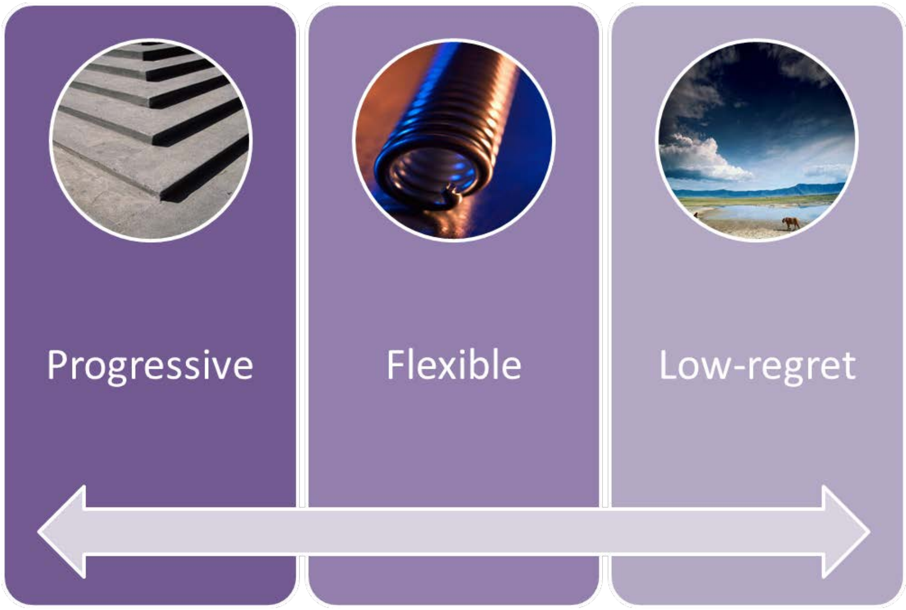


Figure III.1: Three attributes of designing robust and adaptive development interventions

Pillar 1: Progressive – forward looking, adapting incrementally over time
Adapting incrementally should be the cornerstone of the majority of inventions that have a strong climate-sensitive component. In practice, the deep and multiple uncertainties involved mean that development programmes should be a continuous, forward-looking process of planning, implementation, learning and adjustment (Willows and Connell, 2003).

Integral to this process is monitoring and evaluation. As time progresses, more will be learned about the effectiveness of different adaptation measures, the key tipping points in vulnerability and the future climate. This information must be fed back in to the decision process to adjust or refine the strategy, to enhance its performance and reduce the chance of adverse effects. The outcome of this approach should be the progressive reduction in risks associated with climate, while avoiding foreclosing options to ramp up or adjust action if necessary. Case Study 6 gives an example of incremental adaptation in managing coastal flood risk[24].

An important question is *how can such a long-term process of incremental adaptation fit within the relatively short project lifetime of most development interventions?* One approach would be to see the role of development professionals as providing assistance in developing the structures, capacities and resources to implement the long-term process. This could include for example: technical assistance in designing the adaptation pathway and management process; finance for initial adaptation measures; supporting the development of appropriate monitoring systems; and building human and institutional capacities to implement the plans.

Pillar 2: Building flexibility into interventions – keeping options open
Where there is uncertainty, programmes should avoid implementing inflexible measures – those that are suitable only over a narrow range of climate conditions and are costly and difficult to adjust. For traditionally inflexible measures, like infrastructure and urban planning, the solution is to design these measures in a way that builds in flexibility from the start through, for example:

24 See also the Maharashtra, India, case study on drought risk to agriculture developed by the Economics of Climate Adaptation Working Group (2009), and the case studies of World Bank (2010b), which each consider the timing of adaptation options;

- *Building in safety margins:* for example, adding 30cm to the height of a bridge at the outset is relatively low-cost, but enables it to cope with a wider range of possible changes in river flow. Safety margins are appropriate where the additional costs are low.
- *Making it adjustable:* employ measures that can be adjusted or scaled up over time to cope with a climate that is more or less severe than anticipated. For example, building a reservoir so that its capacity can be increased inexpensively if needed, or a flood defence so that it can be raised. The current Thames Barrier that protects London can be over-rotated to cope with higher-than-expected extreme water levels;
- *Obsolescence:* employ less expensive measures or measures with shorter lifetimes that can be easily replaced or abandoned if necessary (for example, temporary structures); and
- *Creating future options:* invest in low-cost measures that will increase the range of adaptation options in the future. For example, supporting agricultural research to develop new types of crops, or buying land that may be needed in the future to build a reservoir.

The objectives of building in flexibility are to prevent costly over-adaptation today, while also avoiding foreclosing options that may be needed in the future (see Case Study 6 that follows).

Pillar 3: Incorporating low-regrets measures
Low-regrets measures have relatively low costs relative to their benefits (and co-benefits) both today and under a wide range of possible future climates – this means that their outcomes are relatively *insensitive* to climate uncertainties. A wide range of measures could meet this criterion:

- *Measures with short lifetimes and reactive measures*: for example, emergency response, changing crop varieties in response to natural year-to-year variability in weather;
- *Reducing vulnerability to current weather and climate variability*: for example, implementing social safety nets and insurance initiatives, and investing in early warning systems and improved weather prediction;
- *Reducing other stresses and risks that will increase vulnerability to climate*: for example, avoiding building on flood plains, reducing leakage from water systems and reducing practices that cause environmental degradation and soil erosion, such as deforestation and over-intensive agriculture. This may also include better managing other risks, like pests and diseases to crops, and reducing risks from malaria and water-borne diseases;
- *Adopting measures with strong co-benefits:* for example, ecosystem-based flood protection through restoring mangroves or coral reefs, which both reduces flood risk and supports livelihoods and ecosystems;
- *Measures to reduce general vulnerability and increase resilience to shocks:* for example, reducing social vulnerability through, for example, better health care and education, enhanced transport and communication networks, capacity building within institutions (e.g. on the use of climate information in decision making) and protecting ecosystem services. Increasing resilience through, for example, diversifying livelihoods; and
- *Measures to remove barriers to autonomous adaptation:* for example, reforming any regulatory frameworks that may inhibit adaptation and lead to maladaptation (for example, subsidies for rain-fed agriculture in a region becoming more drought-prone) and increasing adaptive capacity through strengthening education and disseminating climate-change projections and guidance.

Even if a measure falls into one of the categories above, it is still important to consider the effects of climate change and uncertainties on the outcomes of the intervention and consider the available evidence on whether such an option really meets the criteria for a low-regrets measure. The intervention may still affect or shift long-term vulnerability to climate directly or indirectly.

In practice a mixture of all of the three approaches will be needed. For example, low-regrets measures are not always substitutes for more inflexible measures – enhancing education is not a substitute for a flood wall or improved drainage system, though it is an important component of reducing social vulnerability and building long-term capacity.

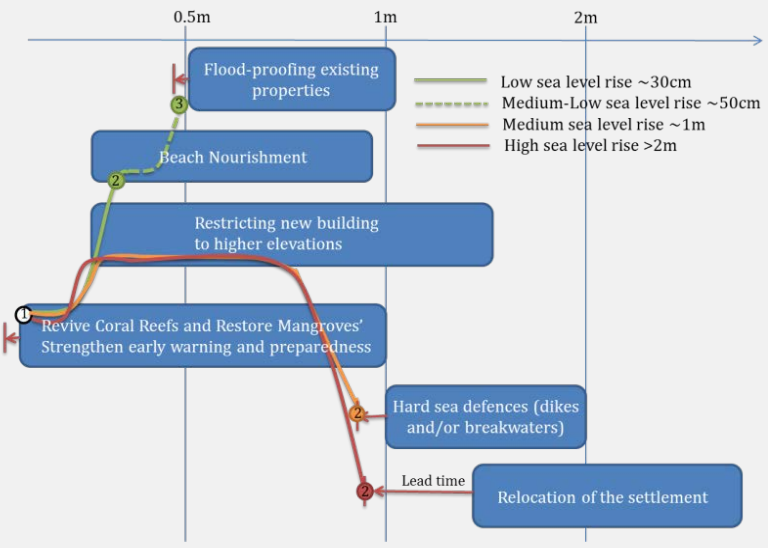
A growing number of case studies demonstrate how this simple framework can be used to construct adaptation plans that are robust to uncertainty; see, for example, a case studies for Yemen (Dessai and Wilby, 2011) and the UK (Ranger et al*.* 2010).

Case Study 6: Incremental adaptation to sea level rise for a low-lying settlement

The Thames Estuary 2100 project (TE2100) has become the classic example of a progressive approach to adaptation (Reeder and Ranger, 2011). The lessons gained from that case study are readily applicable to a broader range of interventions. Here, we show an illustrative example of how the ‘adaptation pathways’ approach applied in TE2100 can be used to explore the sequencing of a coastal storm surge flood management plan for a highly exposed settlement in a small-island state.

For this settlement, sea levels are expected to rise by between 30 cm and 1 m by 2100, but in a worst-case scenario, could rise by more than 2 m. Local consultations lead to the development of a number of potential options, which are effective over different ranges of sea level rise (as shown by the positions of the blue boxes below). From here, it is possible to design packages of measures that perform best for different future scenarios. For example, if sea levels were known to follow a medium-low scenario (green dashed line), then the optimal package would include reviving coral reefs and restoring mangroves; strengthening early warning and preparedness; beach nourishment; and flood-proofing new and existing properties. In the high scenario (red solid line), the best strategy would be to begin a gradual relocation of the settlement to higher land.

A challenge for the advisers is that it is difficult to switch between these ‘optimal’ packages as more is learnt without incurring significant costs. For example, while it would be easy to scale up from a low to a medium-low scenario by flood-proofing properties, moving from this to a high scenario plan would mean abandoning those properties. Similarly, taking the worst-case scenario only would not be appropriate due to its high social and cultural impact.



The adaptation pathways diagram, shown above, can help an adviser to consider ways to build in flexibility through adapting incrementally over time. The **aim is to develop an adaptation plan that reduces risk progressively, while avoiding foreclosing options prematurely or taking action that could mean wasted investments or unnecessary cost.**

The four pathways mapped out above each involve waiting and learning before making the inflexible and costly choice between flood-proofing existing properties, building hard sea defences and relocating the settlement. But there is a cost to this delay as the settlement faces a growing danger from storm surges. To reduce this risk, the plan proposes to implement a number of low-regret measures, including reviving coral reefs, restoring mangroves, and strengthening early warning systems and preparedness. But new properties continue to be built and this will lock in increasing vulnerability – to rectify this, the plan recommends a temporary restriction on development in the flood-prone area.

From this plan it will be possible to define appropriate *decision points* where the decision must be made to switch to a set pathway (decisions at these points are numbered from 1 to 3). The decision point will depend on (a) the sea level rise at which an intervention becomes effective; (b) the rate of sea level rise; and (c) the lead time of the intervention. The plan requires regular monitoring and review to reassess the pathways and decision points.

Source: author's calculation, with adaptation options taken from the Economics of Climate Adaptation Working Group (2009)

III.2 Incorporating climate change and uncertainty through the project cycle

The project cycle describes the whole process of a project, from inception and scoping to monitoring and evaluation. To tackle climate change effectively, and incorporate robustness and adaptability into the intervention, these goals must be addressed from the outset and at each stage of the project cycle.

There is now extensive guidance on approaches to address the changing and uncertain climate in the project cycle. Over the last decade, the literature has evolved significantly, as climate change moved from a science-led concern to a practical issue for planning and policymaking (Box III.1). There is now increasing agreement that climate change and uncertainty can and should be addressed using the tried-and-tested methods and tools for project appraisal and risk management, employed routinely in government and elsewhere (HMT/Defra, 2009). However, within this, we need to dust off those tools in toolbox aimed at dealing with uncertainty. Here, we review the project cycle outlined in the Green Book and highlight where climate change and uncertainty fit in, drawing on guidance including HMT/Defra (2009) and Willows and Connell (2003)[25] (Fig. III.2).

[25] See also OECD (2009) Chapter 9 and Ranger et al. (2010).

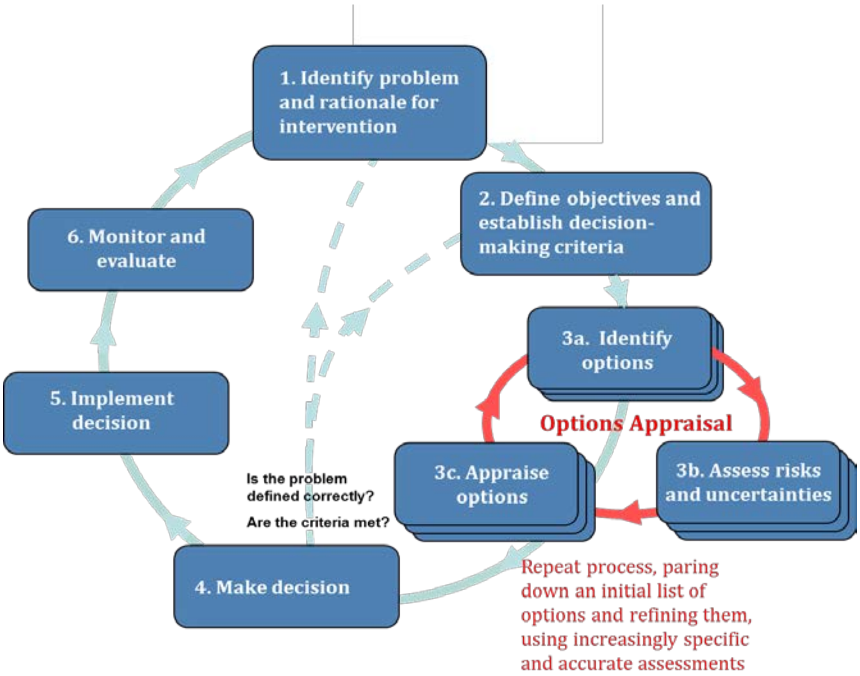


Figure III.2: The project cycle. This version is a combination of the Green Book ROAMEF[26] cycle (HMT, 2003) and the climate change risk management approach outlined by Willows and Connell (2003)

Setting the stage ***(>> the DFID Strategic Case)***

The first stage of the project cycle is to *identify the problem and the rationale for intervention*. This stage clarifies the problem to be addressed by an intervention and outlines the justification for public action (Box III.2). It is here that the potential role of climate change should be identified and categorised, using the criteria laid out in Section I; for example:

1. *Adaptation is a central feature of the problem to be addressed*. This is where the intervention specifically aims to reduce the impacts of climate change that the private sector or individuals would, if left to their own devices, not sufficiently either avoid or adapt to. That is, the presence of one or more 'market failures' justifies the public intervention, for example, raising a sea wall (a public good) or where private measures to reduce the impact of flooding in an area may far worsen the problem for others (a negative externality);
2. *Climate change could materially affect the outcomes of an intervention*, within or beyond the project lifetime (for example, an irrigation project or an agroforestry project). This will often be the case where the outcome is climate-sensitive and the intervention is long-lived and inflexible (Fig. II.5); and
3. *The intervention could affect the climate resilience of the community or region.* This is more likely to occur if the intervention is long-lived and inflexible (Fig. II.5). But short-lived and flexible interventions could also have long-lasting impacts on climate resilience, for example, if they altered habitual behaviours. For example, insurance schemes can lead to farmers taking less action to prevent losses, increasing long-term vulnerability (Warner et al. 2009). Guidance warns that it is important not to consider the implications of an intervention too narrowly. Any intervention that affects the social or economic vulnerability and resilience to shocks could inadvertently decrease or increase vulnerability to climate, or displace vulnerability.

[26] ROAMEF stands for Rationale, Objectives, Appraisal, Monitoring, Evaluation and Feedback.

A decision maker should consider if a project falls into any of these categories at the start of the planning process as it could have a bearing on decisions over the objectives as well as on what resources and expertise are required to design and appraise the intervention. Some guidance recommends undertaking an initial *risk scoping or risk screening* exercise to help identify this (Metroeconomica, 2011). In practice, this might initially just be a *'what if'* thought experiment, for example *'what would happen if the risks from coastal flooding increased?'* or *'what would happen if rainfall patterns and drought occurrence changed?*' and could be developed through discussion with an expert if climate is a possible factor. There are many screening tools available, each generally designed for a specific organisational or sectoral context. More in-depth tools are available (see Box II.2), but may not be necessary at this early stage in the process[27].

The second stage is to *define objectives and establish decision-making criteria.* Clearly defined objectives are the crucial framing for the analysis required. Until you are clear *what* is meant to be achieved and how, it will be very difficult to narrow down on possible options to achieve the objective. The objective describes the desired outcome and impact of the intervention (Fig. III.3). The *decision-making criteria* are the specific success criteria against which options will be assessed and compared. For example, they will normally include '*effectiveness in meeting the objectives*', '*feasibility*', *'value for money'* or '*efficiency*[28]'. The criteria could also be related to the objectives and the attitudes to uncertainty. For example, a criterion might be that the outcomes of the intervention are robust to long-term climate change – or in other words, that the chance of maladaptation is minimised (see Section IV).

Figure III.3: The 'results chain' of an intervention.

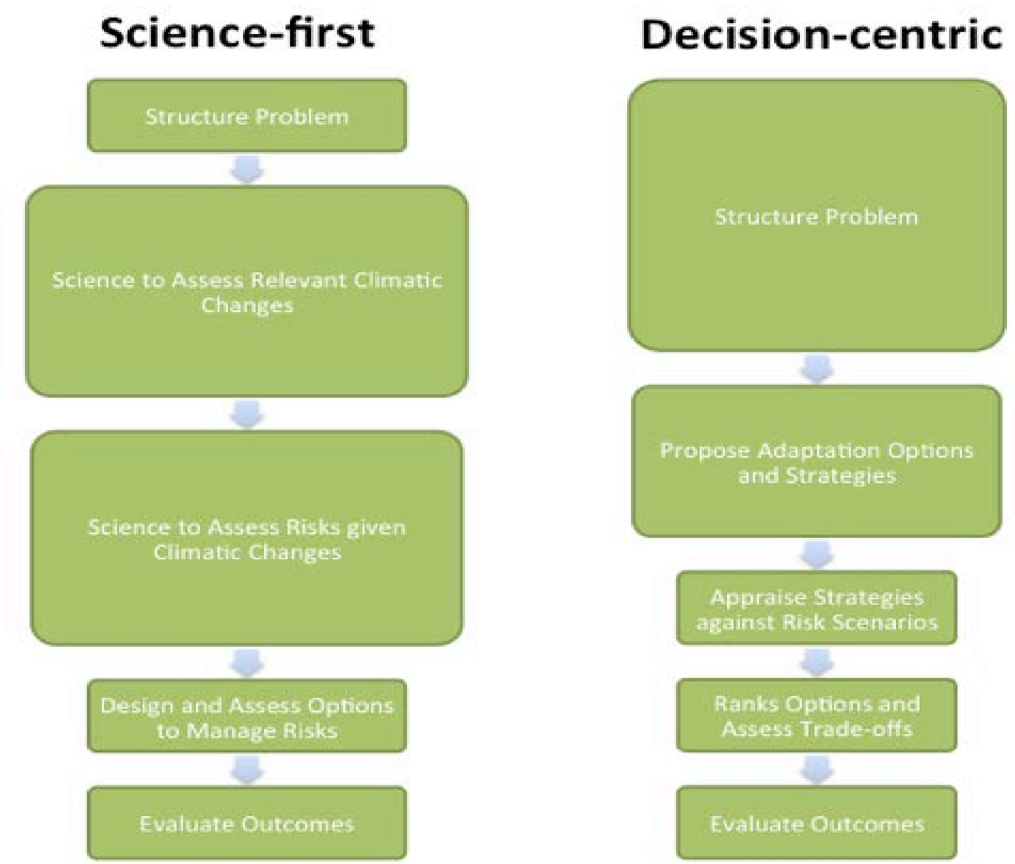
To better understand the complex and uncertain relationships between inputs and impacts, and map out decision criteria, one might employ conceptual tools like the Theory of Change and draw on consultative or participatory decision making techniques (Vogel, 2012).

27 For more in-depth examples of risk assessment tools; see UNFCCC's 'Compendium on Methods and Tools to Evaluate Impacts of, Vulnerability and Adaptation to Climate Change', available online.

28 In appraisal, efficiency is usually defined as the expected benefits of the intervention outweighing the costs.

Box III.1: Science-first versus policy-first decision making

The decision process outlined in this section is different to the 'science-first' approach that was initially adopted by experts working on climate change related problems. A science-first process begins with the climate projections. These are used to generate impact projections. With this information, the adviser would then try to identify and assess adaptation options.



The alternative 'policy-first' approach is in line with the standard project cycle. In this approach, the focus of the analysis is on the problem itself and identifying solutions. Climate and impact projections are only involved the appraisal and refinement of different options. **Effectively, climate change is *mainstreamed* within the decision process, rather than being the driver of it.** This makes the approach more suitable for including climate change as one factor in a larger decision-making process, as will often be necessary in designing development interventions. A policy-first process also has the advantage of greater resource efficiency, as the scale of the climate analyses can be better tailored to meet the needs of the project and is not 'overblown'. By focusing on the problem, it also becomes easier to identify options that are more robust.

Sources: Ranger et al. (2010) and Dessai and Hulme (2007)

Box III.2: The role of the public sector in adaptation

Most adaptation will be *autonomous*, undertaken by households, the private sector and civil society. One of the responsibilities of the public sector is to undertake *planned adaptation* that is not just reacting to climate stressors but proactively preparing for expected changes in events such as heat waves or flooding (for example). One of the roles of the public sector is to provide an enabling framework that encourages and supports autonomous adaptation (e.g. Cimato and Mullan, 2010). We categorise the role of the public sector into five types, which represent different state functions and grades of public intervention:

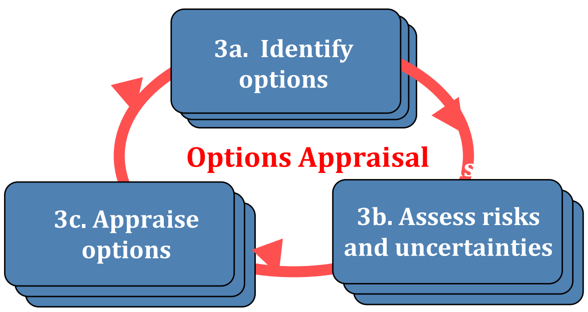
- Providing adaptation services directly, where the public sector commissions or delivers adaptation as a public good. This includes adapting public assets, services and operations;
- Enabling adaptation in areas where public policy needs to overcome private barriers to adaptation, including financial, moral hazard, legal, behavioural or coordination barriers, or provide incentives through price signals and regulation;
- Assisting with adaptation, for example with help to vulnerable people and other support to ensure a fair and equitable adaptation outcome;
- Informing about climate risks to overcome knowledge barriers, and providing public information (climate and other) as a way to support private adaptation; and
- Monitoring risks and progress in adaptation.

Source: Fankhauser et al. (2013)

Options Appraisal ***(>> the DFID appraisal case)***

The third stage is *options appraisal*. Options appraisal aims to identify the 'best' set of options or measures to achieve the objective, where 'best' implies the best performance against the decision-making criteria – for example, the option with the greatest *efficiency, equity*, *effectiveness and robustness* in achieving the objective.

Options appraisal can be a multi-stage and circular process (Fig. III.3), where an initially wide list of possible *options*[29] is pared down and refined to zero in on the best solution. The first pass in identifying options (3a, in Fig. III.3) may be a high-level brainstorm of the various options and their characteristics (including their benefits, risks, uncertainties and flexibility). In the first pass, these might then be appraised based on a simple qualitative risk screening and sensitivity analysis considering climate change and other long-term factors.



1. Qualitative risk screening and sensitivity analysis ('back-of-envelope')
2. Simple quantitative risk screening and sensitivity analysis
3. Simple decision analysis
4. Technical decision analysis

Figure III.4: Illustration of the multi-stage options appraisal, where the analysis is repeated in increasing detail until the best solution is identified.

In each cycle of the options appraisal, the analysis can become deeper, more specific and accurate, drawing in more information, until the best solution is identified. Each stage will result in a more refined list of options, which considers the timing of adaptation (Box III.3) and the opportunities to build in flexibility, low-regrets and progressive strategies as outlined

29 An option may include the specific inputs, processes and outputs required to achieve a desired outcome. Guidance is available on scoping options for adaptation; for example, see UKCIP (2009) and OECD (2009) section 9.3.2(ii).

in Section III.1. This process may involve stakeholder engagement (e.g. participatory decision making) to identify, appraise and refine the options. Potential risk screening tools are discussed in Box II.3. The more quantitative tools for options appraisal and their inputs are discussed in Section IV.

This circular process aims to ensure that the appraisal is not unnecessarily resource intense. There is no need to delve into detailed climate model projections at the start of the options appraisal – this effort would be wasted if climate change is revealed to be a small factor compared with other risks and uncertainties. Initially, some high-level climate projections (e.g. from the IPCC Assessment Reports) and a broad understanding of the sensitivity of the intervention or outcomes to climate will usually be enough to determine the importance of climate change relative to other risks and uncertainties (Ranger et al. 2010). Detailed model projections will only be needed if the design or choice between options is shown to be sensitive to climate change and uncertainty (Section IV).

The Green Book provides clear guidance on how risks and uncertainties should be considered in this process. Risks (Box II.2) should be quantified (and minimised where feasible) and their impact accounted for using the standard techniques within the economic appraisal of options (Section IV). However, as described in the previous section, climate uncertainty is deep uncertainty – it cannot be quantified meaningfully and so is not a '*risk'*. For *deep uncertainties,* like climate change (and many other long-term changes, like population growth and long-term exchange rates) the Green Book recognises that a different approach is needed. It recommends the following steps:

1. *Consider how exposed each option or strategy (a group of options) is to the future uncertainty*. For example, are the outcomes of some options more affected by uncertainty over climate change than others?
2. *Consider if and how uncertainties would affect the choice between options or strategies*. Under different climate scenarios, would option B be preferable to option A and vice versa? How much would the climate need to change to make A the preferable option? ('Switching value');
3. *Are there ways of designing or implementing options or strategies to reduce the impact of uncertainty?* If uncertainty is shown to be a key factor in the options appraisal, then it may be beneficial to design an option or strategy that is more robust to uncertainty, using one or a combination of the approaches given in Section III.1. Timing of adaptation will be an important consideration here (Box III.3). Such options should then be appraised.

Section IV discusses qualitative and quantitative methods and tools, like cost–benefit analysis, multi-criteria analysis, robustness analyses and real options analyses that can be used to appraise options as part of this process, including, for example, the costs of delay and value of flexibility.

Box III.3: The timing of adaptation

The options appraisal should consider the timing of adaptation – *should we act now, or delay until we have more information and the uncertainties are lower?* In some cases, there good, economically rational reasons to act now to implement adaptation, but in other cases, delay (specifically, waiting and learning) may be the best course of action.

Costs of delay
The economics (discounting and learning, Section IV) would tend to favour delaying action, unless there is a cost of delay. The following are examples of situations where there is a cost of delay, strengthening the justification for early action (OECD, 2009; Ranger et al. 2010):

- *Where there are sizeable benefits (or co-benefits) to action today*, for example, climate-resilient development or reducing the risks from current climate variability;
- *Where a lack of action today could lock in long-term risks*, which are costly, difficult or impossible to rectify later. This includes adaptations to long-lived infrastructure and long-term development planning;
- *Where early adaptation could lock in lasting benefits or avoid irreversible impacts,* for example, preventing damages to ecosystems and extinction of species; and
- *Where the lead times of action are long,* such as research and development.

Benefits of delay
Where dealing with uncertainty, delay could be a useful strategy where the costs of delay are low and where there is a good chance that uncertainties can be narrowed over time; for example, uncertainties concerning tipping points in vulnerability[30].

Uncertainty alone is not a justification for delay or inaction; indeed, it may drive earlier precautionary action in some cases. If the decision is taken to delay, this should be the result of a deliberate decision rather than a failure to act.

Narrowing uncertainties requires experimentation, research and monitoring (Hallegatte et al. 2012). It may also be possible to reduce risks in the interim through adopting low-regrets measures, like sustainable farming practices or early warning systems[31].

Following the options appraisal, the decision-making criteria and judgement are used to select the best option(s). This is not necessarily the end of the design process. It may be necessary to go back and reconsider the objectives and decision-making criteria in light of the findings, and then search for other options. It will also be necessary to consider appropriate processes for implementations, for example the role of the private sector or the best delivery channels. The outcome of this process should be to identify a *solution* – the specific inputs, processes and outputs of the intervention that will deliver the objective and a reflection of this *solution* in the project's logical framework and list of project deliverables.

Monitoring and evaluation ***(>>the DFID management case)***
The Green Book explains that monitoring and evaluation should aim to *"assess to what extent an intervention has been, and will continue to be, successful, in what circumstances and why"*. We argue that to cope with climate uncertainty, monitoring and evaluation must evolve from a backward-looking process to become an integral part of the management of

30 Interventions should not rely on the chance that long-term uncertainties in climate change projections and climate impacts will be significantly reduced over time.

31 This approach was adopted in the UK Thames Estuary 2100 project, where a major decision to upgrade the Thames Barrier was delayed whilst more research and monitoring took place and in the interim, low-regrets measures were implemented to reduce flood risk around the estuary, including upgrading smaller flood defences. The costs of delay were low in this case, because the existing barrier could provide adequate protection until at least 2030, even under worst-case sea level rise scenarios. This was possible partly because the original barrier was built with some safety margins (Reeder and Ranger, 2011).

the project. Monitoring and evaluation must become a continuous, learning process, which feeds information back into the project cycle, enabling interventions to be refined to suit changing conditions. OECD (2009) suggests that monitoring and evaluation become both a ‘learning by doing’ and ‘doing by learning’ process.

Monitoring and evaluation may also need to take place over much longer time periods than in the past, as it will take a long time to observe the full benefits (or negative effects) of a climate change related intervention, particularly where the aim is to reduce long-term risk specifically (OECD, 2009)[32]. The UK’s Adaptation Sub-Committee overcomes this problem by monitoring not only the effects of adaptation measures (the outcomes and impacts), but also the inputs, processes and outputs of adaptation (ASC, 2011). For example, they monitor the deployment of measures (such as levels of investment in flood defences), decision-making processes, and specific outputs (such as the fraction of new properties exposed to flooding), as well as the outcome (damages from flooding). A similar approach in monitoring performance indicators[33] was adopted by the Asian Development Bank for the Hunan Flood Management Sector Project in China (ADB, 2006)[34].

But as well as monitoring the progress and success of the interventions themselves, the project should also monitor the changing environment of the intervention, in order to inform future action (OECD, 2009). This may include, for example, monitoring current climate variability, vulnerability and developments in knowledge of future local climate change.

There are also a number of technical changes to monitoring and evaluating adaptation in developing countries. See, for example, Brooks et al. (2013).

III.3 Prioritising interventions in sectoral, regional and national policies

At the sectoral, regional and national level, the same general principles apply for making projects climate-resilient:

- Assess risk from climate change to achieving policy objectives;
- Assess the risk of development interventions to climate vulnerability (i.e. maladaptation);
- Identify possible cost-effective sectoral and cross-sectoral interventions; and
- Prioritise and consider timing.

Potential methods for initial screening of projects and portfolios are described in Box II.3.

In planning, prioritisation plays a critical role both in allocating resources across projects, but also in identifying what should be done now and what can be delayed until later. For governments, prioritisation will occur in national and sub-national budgets and medium-term expenditure planning, but also in regional, sector and local-level planning (OECD, 2009). For a development organisation, like DFID, it is a crucial component of operational planning and portfolio management. Here, we consider how to prioritise adaptation (including climate-resilient development) interventions specifically, using the approaches from Section III.1.

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32 This is particularly the case for measures that aim to reduce the impacts of extreme weather, which occurs rarely.

33 OECD (2009) also recommends using a range of performance indicators (sections 8.2.4, 9.3.4).

34 See OECD (2009) Table 9.2.

In practice, resource allocation at the local, sector, or country level will consider many priorities aside from climate change. Indeed, a challenge for development professionals is that climate change is often given a lower priority as a result of its perceived long-term (and uncertain) nature, versus more pressing, immediate and certain priorities, such as poverty alleviation and economic growth (OECD, 2009; see also Section I.3). This is understandable, but this Topic Guide has described three important facts that must be considered rationally in resource allocation:

1. *Reducing the risks from climate shocks will bring immediate economic and social benefits from reduced exposure/increased resilience to current weather variability*, both in terms of direct monetary and social benefits of avoiding losses, injury and fatalities, but also through safeguarding investments and hard-won advances in poverty reduction, economic growth and development in the near term (as well as the long term);
2. *Poverty reduction, development and economic growth themselves are an important ingredient in reducing the immediate and long-term risks from climate*, yet policies, projects and programmes in these areas must consider climate change, or risk inadvertently locking in greater risks in the future that would be costly to reverse in the future (Box III.3); and
3. *In some areas there are high costs to delaying adaptation*, for example, if climate change is not considered in infrastructure decisions from the start, this could lead to poorer performance, costly retrofits or earlier replacement in the medium term. Also, some vulnerable communities are already at much greater risk due to climate change.

Timing is important in adaptation – some adaptation measures come with a significant *cost of delay* (Box III.3), while for other measures, there might be an informed decision to delay to give time to gather more information. The prioritisation of a set of interventions should be determined by not only the scale (and timing) of the risk to be avoided, but also the characteristics of the interventions, in particular, the timing of the benefits and costs of delay[35]. Uncertainty will also play a role, for example, tending to prioritise low-regrets measures in the near-term, while avoiding locking in future risk or foreclosing options.

Based on these factors, several reports have tried to identify some generic categories of measures that will take higher priority (for example, Defra [2012][36] and Fankhauser et al. [2013]) and specific priority areas for national-level policies and planning in developing countries (for example, OECD [2009] and Ranger and Garbett-Shiels [2012]).

Fig. III.5 gives the simple framework of four priority measures identified by Fankhauser et al. (2013) (see also Table III.1).

35 Risk and cost of delay are not independent.

36 See, for example, Chapter 9 of Defra (2012); http://ccra.hrwallingford.com/

Figure III.5: Four priorities for investment in adaptation identified by Fankhauser et al. (2013), to deliver effective, robust and adaptive adaptation.

Three of these pillars all entail low-regrets measures, consistent with the third pillar of Fig. III.1. The remaining pillar, *'act to avoid locking in future* risk', relates to the first and second pillars of Fig. III.1 – avoiding lock-in through flexible and progressive adaptation. Table III.1 maps the priorities identified by Fankhauser et al. (2013) onto implications for development interventions, based on OECD (2009) and Ranger and Garbett-Shiels (2012).

Table III.1: Generic classes of priority adaptation measures (Fankhauser et al. 2013), with specific applications to development interventions (based on OECD [2009] and Ranger and Garbett-Shiels [2012])

Generic area of priority action Source: Fankhauser et al. (2013)	**Application to priorities for development interventions** Sources: OECD (2009)[37] and Ranger and Garbett-Shiels (2012)
• ***Adaptations with early, robust benefits.*** Fast tracking adaptation makes sense if the proposed measures have immediate, robust benefits that would be otherwise be forgone; for example, where there is an existing vulnerability or expected near-term impacts from climate change [low-regrets, see Section III.1].	• ***Invest in climate-resilient development.*** Well-designed development policies can be a no-regrets form of adaptation through reducing social and economic vulnerability. • ***Reduce vulnerability to current climate variability and extreme weather events.*** Disaster risk management (DRM) can be a low-regrets adaptation, bringing immediate benefits. • ***Improve the availability and quality of climate information.*** Including monitoring systems, future scenarios and vulnerability assessments. • ***Adopt measures to reduce the immediate impacts of climate change and other stresses on the most vulnerable people and systems.*** Some human and natural systems, including terrestrial, marine and freshwater ecosystems, can be vulnerable even to small changes in climate. Actions could include enhancing the implementation of relevant multilateral and regional environmental agreement. • ***Review and adjust regulations and standards to reflect climate change impacts.*** For example, to help to remove any barriers to adaptation or perverse incentives (overcome market failures) on firms or individuals (Box III.2)
• ***Areas where decisions today could lock in vulnerability profiles for a long time.*** Fast tracking adaptation is desirable if today's decisions could commit society to a particular, more vulnerable development path that would be costly to reverse later. Several strategic decisions fall into this category, including long-term infrastructure, land use planning and managing development trends such as growing water demand.	• ***Incorporate climate change and adaptation considerations within national development policies***, including long-term visions, poverty reduction, economic growth and sustainable development strategies. Avoid making decisions today in ways that could lock in impacts or increase future vulnerability. Instead seek low-cost ways to design strategies so that they enhance long-term resilience. • Where dealing with expensive, long-term projects, such as public infrastructure or urban planning, seek options and strategies that will build in flexibility to cope with the uncertainty over future climate. This is relevant to new projects, but also upgrades and maintenance cycles.
• **Building adaptive capacity.**	• ***Building the long-term capacity for climate-resilient development***, including developing appropriate institutional structures, skills and knowledge at multiple levels.
• ***Low-regrets adaptation measures with long lead times.*** It makes sense to fast track low-regrets adaptations that have long lead times, such as research and development, even if the benefits will not be accrued until later.	• Supporting the development and deployment of relevant agricultural technologies and other innovation that can reduce long-term social and economic vulnerabilities.

[37] See Table 7.3 in OECD (2009) for specific challenges and actions.

Table III.2: Immediate and short-term programmes and activities outlined in the Bangladesh Climate Change Strategy and Action Plan 2009; extract from the table presented in World Bank (2010b) (Bangladesh case study, Table ES.1). The text colour categorises the activities on the categories laid out in Table III.1: early, robust benefits (green), lock-in (brown), low-regret (red), and capacity building (grey)

Theme	Immediate	Short-Term
Food, security, Social protection and health		• Water and sanitation programme in vulnerable areas • Livelihood protection in ecologically fragile areas • Livelihood protection of vulnerable socioeconomic groups (including women)
Comprehensive disaster management	• Improvement of flood forecasting and early warning system • Improvement of cyclone and storm surge warning • Awareness raising and public education towards climate resilience	• Planning, design, and implementation of resuscitation of networks of rivers and 'khals' through dredging and de-siltation work
Infrastructure	• Repair and maintenance of existing flood embankments • Repair and maintenance of existing cyclone shelters	
Research and knowledge management	• Establishment of a centre for research, knowledge management, and training climate change • Climate change modelling at national and sub-national levels	• Preparatory studies for adaptation against sea level rise (SLR) and its impacts
Capacity building and institutional strengthening	• Revision of sectoral policies for climate resilience • Mainstreaming climate change in national, sectoral and spatial development programmes • Strengthening institutional capacity for climate change management • Mainstreaming climate change in media	• Strengthening human resource capacity • Strengthening gender consideration in climate change management

We are beginning to see this type of prioritisation in real adaptation plans. For example, the Bangladesh Climate Change Strategy and Action Plan 2009 identifies low-regrets measures, like comprehensive disaster management (particularly early warning systems and raising awareness), infrastructure (repair and maintenance of protective infrastructure, embankments and cyclone shelters), mainstreaming into national, sectoral and spatial development programmes, institutional capacity building and information as immediate priorities (Table 5, World Bank, 2010b). However, the IEG (2012) reports that there are few examples in the World Bank's portfolio of successful forward-looking, progressive and flexible interventions in areas of infrastructure and land use planning – that is, measures to avoid locking in long-term risks.

Prioritising interventions is important, firstly for allocating resources across specific projects and programmes, but also for identifying what should be done now, versus later. This is relevant in national and sub-national budgets, as well as in medium-term expenditure planning (OECD, 2009). In practice, resource allocation at the local, sector or country level will consider many priorities aside from climate change. Indeed, a challenge for development professionals is that climate change is often given a lower priority as a result of its perceived long-term (and uncertain) nature, versus more pressing, immediate and certain priorities, such as poverty alleviation and economic growth (OECD, 2009). This is understandable, but this Topic Guide has described three important facts that must be considered rationally in resource allocation:

1. *Reducing climate risks will bring immediate economic and social benefits*, both in terms of direct monetary and social benefits of avoiding losses, injury and fatalities, but also through safeguarding investments and hard-won advances in poverty reduction, economic growth and development in the near term (as well as the long term);
2. *Poverty reduction, development and economic growth themselves are an important ingredient in reducing the immediate and long-term risks from climate*, yet policies, projects and programmes in these areas must consider climate change, or risk inadvertently locking in greater risks in the future that would be costly to reverse in the future (Box III.3); and
3. *In some areas there are high costs to delaying adaptation*, for example, if climate change is not considered in infrastructure decisions from the start, this could lead to poorer performance, costly retrofits or earlier replacement in the medium-term. Also, some vulnerable communities are already at much greater risk due to climate change.

As shown in the previous section, timing is important in adaptation – some adaptation measures come with a significant *cost of delay* (Section III.2, options appraisal), while for other measures, it might be better to delay to give time to gather more information. The prioritisation of a set of climate-related interventions should be determined by not only the scale (and timing) of the risk to be avoided, but also the characteristics of the interventions, in particular, the timing of the benefits and costs of delay[38]. As described, uncertainty plays a role, for example, tending to prioritise 'low-regrets' measures in the near-term, while avoiding locking in future risk or foreclosing options.

III.4 Practical challenges in dealing with uncertainty

There are many practical challenges to planning and implementing adaptation, particularly in developing countries. A full discussion of these challenges is beyond the scope of this paper[39]. Yet, it is important to recognise here that the uncertainties inherent in long-term climate impacts can exacerbate these challenges for the following reasons:

- Firstly, designing interventions that can cope well with long-term changing risks and uncertainty will require additional resources, information and technical capacities, in an environment where there are already constraints in these areas (Lal et al. 2012);
- Secondly, officials tend to be less willing to prioritise investments where the uncertainties are high and the options more disputed (O'Brien et al. 2012). In addition, Hallegatte et al. (2012) suggest that there are particular difficulties in justifying the most robust option rather than a best option in practice; experience suggests that decision makers would prefer to delay action and invest in further research that will give them the best prediction of the future, in order to select the best option; and
- Lastly, as described above, uncertainty will require a more long-term, progressive and flexible approach to decision making in core areas like development planning

38 Risk and cost of delay are not independent.
39 See, for example, WRI (2011) for an overview.

and disaster risk management (DRM). Yet, there is little evidence or practical case studies on how this can be delivered in practice (Lal et al. 2012). Historically, planning and policymaking are often slow to react, learn from and foresee change (WRI, 2011). For example, a survey of Sub-Saharan African countries suggested that few currently review, update and improve their DRM plans over time (World Bank, 2008).

These challenges apply equally to country officials and donor organisations, like DFID. For example, there are open questions about how to deliver long-term, progressive interventions over 20 to 30 years or so, when the average length of an intervention is around three to five years, and operational plans are revised over each five-year Spending Review period.

The World Resources Report 2010–2011[40] (WRI, 2011) outlines five elements that are necessary to significantly strengthen the ability of all governments to make effective adaptation decisions:

- *Public communication and participation:* on-going public engagement and involvement in adaptation, including participatory decision making and community-based adaptation, are central in defining adaptation needs, selecting priorities, defining acceptable levels of risk and identifying what would constitute successful adaptation. This can include games to enhance understanding (Jones et al. 2013);
- *Decision-relevant information:* governments should step up efforts to collect and distribute information to inform climate-resilient development and adaptation, but this must be user driven, accessible, regularly reviewed, cost effective, appropriate (in terms of accuracy and scope), relevant and targeted;
- *Institutional design:* appropriate coordination between national government agencies, stakeholders and other institutions, from local to international scale, is a prerequisite for successful adaptation;
- *Tools for planning and policymaking:* methods and tools (including simple guidance, risk and vulnerability screening and more specialised decision support tools) can help public officials to make difficult adaptation decisions; and
- *Resources:* including human, social, financial and ecological resources.

These elements might form an important foundation of development interventions at the national, sectoral, local and project levels. Similar conclusions have been drawn by many other studies and this is being complemented by a growing body of detailed case studies[41].

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40 The WRR is a joint publication by the United Nations Development Programme, the United Nations Environment Programme, the World Bank and the World Resources Institute. These conclusions are based on extensive consultations and research with stakeholders and experts from more than 30 countries.

41 A good summary of the evidence was provided by the recent Special Report of the Intergovernmental Panel on Climate Change on ‘Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation’. For example, see Cutter et al. (2012) and http://cdkn.org/srex/, where the findings of the IPCC’s Special Report are summarised in a series of papers by the Climate Development Knowledge Network.

Key messages from this section

- **A resilient programme or project is not only one that is able to achieve its objectives today, but also one that is *robust*, meaning that it performs well under a wide variety of futures, and *adaptive* meaning that it can be adapted to changing (unforeseen) future conditions**. This principle is equally relevant at the national, sectoral, local and project scales.
- **There are three possible approaches to building robust and adaptable development interventions**:
  - **Progression:** In practice, the deep and multiple uncertainties involved mean that development programmes should be a continuous and forward-looking process of planning, implementation, learning and adjustment. Monitoring and evaluation is a crucial component.
  - **Flexibility:** For traditionally inflexible measures, like infrastructure and urban planning, the solution is to design these measures in a way that builds in flexibility from the start through, for example, safety margins, designing in adjustability and obsolescence.
  - **Low-regrets:** Many types of interventions have benefits for vulnerability and resilience yet are not sensitive to uncertainty over future climate.

  A resilient plan will require each of these pillars. Importantly, a low-regrets measure is rarely a substitute for flexible and progressive measures and should be subject to the same scrutiny as other measures based on a careful consideration of available evidence.
- **Implementing progressive and flexible interventions may raise institutional challenges for development organisations like DFID**, where project timescales are relatively short and value for money must be demonstrated quickly.

  In addition, monitoring and evaluation frameworks may need to evolve from a backward-looking process, to become an integral part of the management of the project. Monitoring and evaluation must become a continuous, learning process, which feeds information back into the project cycle, enabling interventions to be refined to suit changing conditions.
- **Climate change and uncertainty can and should be addressed using the tried-and-tested methods and tools for project appraisal and risk management,** employed routinely in government and elsewhere.
- **There are many places where it makes sense to invest early in adaptation, even though the benefits will not be accrued until later. Similarly, in some cases, the most rational cause of action will be to wait until more information is available.** The timing of adaptation interventions is an important consideration and will not only be determined by the risks to be avoided and the uncertainty, but also the costs of delay (linked to the lifetime, reversibility or absence of the intervention). The most urgent measures tend to be where not acting today can commit us to greater costs and risks in the future, such as long-lived infrastructure and urban development.
- **We can draw out four priority areas for adaptation today:**
  - **Measures with early and robust benefits:** Low-regrets measures, like climate-resilient development, early warning systems and insurance.
  - **Acting to avoid locking in long-term risks:** taking action to account for changing risks in long-term decisions such as critical infrastructure, urban development, land use change or sectoral development strategies.
  - **Capacity building:** building the capacity for implementing development programmes that are resilient to the changing environment.
  - **Low-regrets measures with long lead times:** for example, investing now in long-term agricultural research programmes to increase future options.
- **There are indications that many development interventions are failing to tackle**

the tough choices in managing long-term risks. A number of recent reviews of development portfolios suggest that the majority of so called 'adaptation' interventions today focus on low-regrets measures and capacity building, and are failing to address the need to avoid locking in risk.

- **There are several practical challenges to communicating and acting on uncertainty on the ground.** For example, officials tend to be less willing to prioritise investments where the uncertainties are high and the options more disputed. There are also particular difficulties in justifying the most robust option rather than a best option in practice, with decision makers preferring to delay action in anticipation of better information, despite the costs of delay. Also, historically, planning and policymaking are often slow to react, learn from and foresee change.

Where can I find more information?

- *The UK Green Book (HMT, 2003)* and its Supplementary Guidance on *"Accounting for the Effects of Climate Change" (HMT/Defra, 2009).* The Green Book is a surprisingly accessible source of guidance on the project cycle, options appraisal and dealing with risk and uncertainty. A downside is that it gives few case studies.
- *World Resources Report 2010-2011; "Decision Making in a Changing Climate".* An accessible account of the practical challenges of dealing with uncertainty and how these can be overcome, including case studies, participatory decision making exercises and commentaries from world experts. http://www.worldresourcesreport.org/wrr-2010-2011
- *Willows and Connell (2003).* This report was written by the UK Climate Impacts Programme, in collaboration with Defra and the Environment Agency. We recommend having a look other adaptation tools and reports developed by UKCIP, including "*Identifying Adaptation Options*" and the "*Adaptation Wizard*". These are focused on the UK, but include some simple tools that are relevant to all adaptation problems.

A vast range of other adaptation guidance and tools are available. See, for example, the collection provided by the Governance Social Development Humanitarian and Conflict PEAKS (GSRDC): http://www.gsdrc.org/go/topic-guides/climate-change-adaptation/adaptation-guidance-and-tools

SECTION IV Climate change uncertainty and economic appraisal of development interventions

“Uncertainty over the future impacts of climate change means that the ability to use and value flexibility is vital”, Supplementary Green Book Guidance, June 2009

Economic appraisal aims to help identify options that are *efficient* and provide the *best value for money* in achieving a certain goal. It is one stage of the options appraisal process (Section III.2) and is usually the step where quantitative analysis is introduced. It compares the costs of different options with their expected benefits (Fig. IV.1), usually in monetary terms. Climate change and adaptation raise a number of challenges for economic appraisal. Many of these will not be new to development professionals – for example, a lack of data and problems in valuing benefits.

In this section, we focus on the challenge of addressing climate uncertainty in economic appraisal. This section is more technical than the earlier parts of the Topic Guide. DFID is developing guidance on the economic appraisal of interventions related to climate change. This Topic Guide does not replace that guidance, but instead aims to explain the key issues and highlight, in accessible terms, some possible approaches to cope with uncertainty. The goal is not to provide a comprehensive review, but to help development professionals ask the right questions of themselves, advisers or consultants, and be able to identify the advantages and disadvantages of various methods in their own work. It covers the following issues:

1. *Why conventional tools for economic appraisal tend to break down when there is deep uncertainty about the future;*
2. *The implications of climate change for discounting costs and benefits;*
3. *The tools for economic appraisal under deep uncertainty; and*
4. *The climate information needed in options appraisal.*

As this is a relatively new area of applied economic appraisal, there is still disagreement about what tools to use in which circumstances, as well as a lack of good quantitative case studies that demonstrate what works in practice (Hallegatte et al*.* 2012). For this reason, it is a good idea to get expert advice from economists experienced with climate change from the start.

In the following sections we explain briefly what can be done to assess costs and benefits of adaptation projects (Section IV.1) and the extent to which development and adaptation options are sensitive to uncertain futures and what to do about this (Section IV.2). In Section IV.3, we list and briefly describe a number of tools that are useful in narrowing down the choice of feasible development and climate adaptation options in the context of an uncertain future.

IV.1. Conventional economic appraisal

Conventional economic appraisal focuses on identifying the best or optimal option(s) to achieve an objective. For example, it sets out to identify the option(s) with:

- The highest *expected net present value* (in cost–benefit analysis);
- The lowest *net present cost* to achieve a given outcome (in cost-effectiveness analysis); and
- The highest total *scoring* against criteria for the least cost (in multi-criteria analysis).

Each of these *decision-making criteria (or decision rules*) is about *optimising* the choice of option(s) to meet an objective. The challenge is that in some cases, this optimisation will be highly sensitive to uncertainty. If this uncertainty is ignored in the appraisal, it could lead an adviser to select an option that performs less well, or leads to adverse outcomes. The three main conventional tools are discussed below[42].

Cost–benefit analysis

The most common tool used in economic appraisal is cost-benefit analysis (CBA). CBA compares the monetised (*discounted*) costs and benefits (Fig. IV.1) of a proposal or range of options. An adviser may wish to select the 'optimal' option, with the greatest benefits compared to costs (the highest *net present value*), or may simply test whether a proposal meets a criterion.

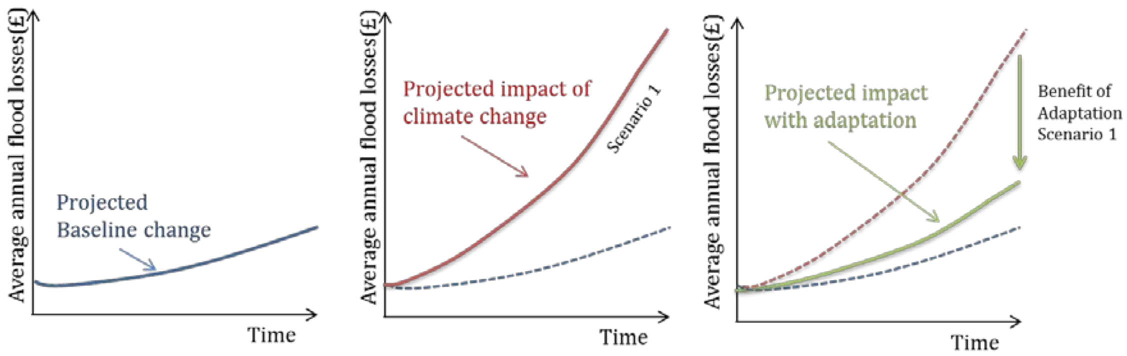

Figure IV.1: Schematic of the effect of climate change and the benefits of adaptation with no uncertainty[43]. Source: based on Boyd and Hunt (2006)

Uncertainty can have a significant impact on the outcome of CBA. For example, Hallegatte et al*.* (2012) showed that the net present value of an improvement in flood protection in New Orleans could be anything from US$0.6 billion to US$140 billion, due to uncertainties over climate change, the valuation of non-monetary benefits and appropriate discount rates. Within CBA, quantifiable uncertainties (or *risks*) are routinely incorporated within the process by calculating the '*expected' net present value*[44] of an option (HMT, 2003)[45]. For example, weather is a risk. To account for current weather variability, a decision maker could estimate the likelihood of different levels of seasonal rainfall based on historical data. However, CBA does not provide any way for accounting for deep (unquantifiable) uncertainties, like those inherent in projections of long-term climate because of the difficulties assigning probabilities to future states (Section II). This means that where the decision is sensitive to these uncertainties, conventional CBA breaks down[46]. This is true for long-term forecasts of population growth, economic growth or commodity prices.

Why can't we just fit a probability distribution to projections, or assume that all scenarios are equally likely? This might be a helpful first step, to better understand the implications of

42 See Pearce et al*.* (2006) for more specialised tools.

43 A key feature of appraising adaptation options that is implicit in this diagram is that, in most CBAs, we assume that the baseline for the 'without project' case or do-nothing option is just a continuation of the past. With adaptation projects we need to be clear that the baseline itself is a change from the past. This will be covered in more detail in the Climate Economic appraisal guidance.

44 Expected value is the sum of all the possible outcomes multiplied by their likelihood of occurring (HMT, 2003). This is sometimes called the 'risk-adjusted value'.

45 This approach is otherwise known as *expected value analysis.*

46 Note that this is also the case for CBA's relatives, such as *expected utility analysis*.

uncertainty, but it should not be the end game. As explained in Box II.2, the nature of the uncertainties in future climate and impacts mean that estimates of the likelihood of different future scenarios, even where based on the best expert advice or best models, are not reliable and do not lend themselves to reliable probability distributions[47]. Experts have demonstrated that where there is ambiguity over the likelihood of different scenarios (for example, where different experts or models would give different estimates of likelihood) it is not rational to ignore this ambiguity and rely on a single estimate[48]. Such an approach could itself lead to costly maladaptation.

Box IV.1: Discounting in adaptation

Discounting adjusts for the timing of costs and benefits. In standard discounting, costs and benefits that are accrued in the future are given a lower value (known as the present value) than those that are accrued earlier, to reflect the fact that people prefer to receive goods and services now than later and the fact that we expect to be richer in the future. The UK Treasury's Green Book requires that for overseas development programmes the discount rate used be appropriate to the benefiting country. A fixed discount rate of 10% a year has often been used for a range of countries. This means, for example, that the present value of a benefit accrued in 30 years' time would have only 6% of the value of the same benefit today. The result is that the benefits tomorrow would need to be larger to justify an investment today.

Valuing the costs of delaying action
Discounting can have a big effect on the economics of adaptation, where significant benefits may only be accrued in the distant future. All else being equal, this would tend to suggest delaying an investment in adaptation. But this will not always be the case. Earlier adaptation will be justified where there are costs associated with delay, for example, where delay closes down future options (Box III.2). For advisers, this means that care must be taken to include all the benefits (and co-benefits) of adaptation, including the full costs of delaying action and value of flexibility, in the economic appraisal (HMT, 2003).

Discounting for long-lived adaptation measures
Uncertainty should also have an impact on how we discount future outcomes. For projects in the UK with long-term impacts or benefits (beyond 30 years), the UK Green Book recommends a declining discount rate to reflect the inherent uncertainty over the long term (and thus how much richer people will be in future). The logic behind this is that where there is uncertainty over the future rate of economic growth, the discount rate should not be constant but rather decline. For example, for investment in the UK, it recommends that the discount rate should decline from 3.5% to 3% beyond 30 years, and to 2.5% beyond 75 years. DFID – in line with other development agencies and with developing country governments – still uses a fixed discount rate. However, this is under review and advice should be sought from economists on what level and pattern of discount rate to use.

Adaptation to reduce the chance of very large (non-marginal) and irreversible losses
Economic appraisal techniques such as cost-benefit analysis (CBA) assume that the intervention being appraised will have only a localised or relatively limited (marginal) effect on an economy. If, however, the adaptation in question could avert the chance of a very large (non-marginal) and irreversible loss which would affect the country's growth prospects then the intervention would change the discount rate and so, technically, conventional CBA is not applicable. An example could be a programme to protect a major coastal city or the main port. There is no clear guidance yet on applying such approaches, so expert advice should be sought in such circumstances.

Source: HMT (2003), HMT/Defra (2009) and Dietz and Hepburn (2010)

47 Generating probabilistic climate impact projections remains an active research topic in the academic community (indeed, the UK Climate Projections 2009 give likelihood estimates); if used, these estimates should be treated as subjective and complemented with expert judgement.

48 For example, see Gilboa et al. (2009); Lempert et al. (2003) and Morgan (2003). In addition, Ellsberg (1961) and Slovic and Tversky (1974) demonstrate that in cases where there is ambiguity, subjective utility theory (on which CBA is based) is not a good model of actual behaviour as decision makers tend to put more weight on options that have a lower degree of ambiguity (i.e. they are ambiguity averse).

Cost effectiveness and multi-criteria analysis
Cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA) are often used in the appraisal of development interventions, because they allow a decision maker to compare options where it is not possible to monetise all or some of the benefits. CEA compares the costs of alternative ways of producing similar outputs (Pearce et al. 2006). From here, the adviser can rank the options in terms of their cost effectiveness[49]. MCA is similar, but it involves multiple objectives[50]. Here, options are scored against different measures of effectiveness and then weighted based on expert's (or public's) preferences. These scores may also be based on expert judgement or quantitative methods. Uncertainty over future climate affects CEA and MCA in a similar way to CBA; it means that there is unquantifiable uncertainty over the effectiveness or scoring of different measures.

IV.2. A toolbox for decision making under uncertainty

The presence of uncertainty means that it is impossible to optimise the choice of option, so the *decision-making criteria* of economic appraisal will often evolve from *optimisation* towards *robustness*. For example, under uncertainty we tend to prefer options that:

- Minimise the *worst* outcome if the *worst-case scenario* prevailed (in maximin); and
- Minimise the *regret* across the widest range of scenarios (in robust decision making).

Put simply, where there is deep uncertainty, there will often be a preference for selecting options that are effective over the widest range of possible future climates. In Section III.1, we introduced the strategies that could be adopted to help ensure that interventions meet this criterion. In this section, we are concerned with the tools that can be used to appraise those strategies. Many of these tools stem from scenario planning and analyses (Walker et al. 2013).

Regret is defined as the difference between the performance of a given strategy and what would have been the best performing strategy for the same future scenario (Lempert et al. 2003)

As discussed in Section III.2, options appraisal should be a multi-stage process, where the analysis is repeated in increasing detail to refine the design and choice between options. We are assuming here that the identification and design of options has considered the pillars laid out in Section III.1, and so we focus on the analysis of the choice between options.

We group the toolbox into three potential levels of analysis, discussed below. Level 1 contains the simplest tools, whereas level 3 involves more resource- and computationally-intensive tools. The appraiser need only progress to the level that is necessary to identify the best solution. For example, if the best solution is clear after level 1, then there is no need to progress to level 2. Level 1 tools should be usable by all development professionals, whereas level 3 tools are likely to require expert guidance. Here, we focus only those tools that have been applied in practice in relevant areas[51].

49 Cost-effectiveness ratio = E/C, where E is an indicator of effectiveness and C is the cost (Pearce et al. 2006). For example, the appraisal might compare the cost of saving 1 hectare of land for a range of options.
50 CEA may also use multiple indicators of effectiveness (Pearce et al. 2006).
51 For a detailed discussion of a broader range of tools, see Ranger et al. (2010).

Level 1: Simple sensitivity testing and switching values
The Green Book recommends that it is essential to consider how uncertainty over the future affects the choice between options (HMT, 2003). The key questions being, *how does future climate affect whether Plan A or Plan B is the better choice in delivering my objective? Is uncertainty critical to whether or not the intervention will succeed in meeting the objective?*

As a first step, it recommends *sensitivity analyses* on the CBA (or similarly, CEA or MCA). For example, an adviser could repeat the analysis under two or more scenarios that represent the plausible range of what might occur in the future (including climate, but also other key changes)[52]. If the choice between options is shown to be sensitive to the uncertainties, then more detailed investigation will be required. It is also useful to consider *'switching values'* – this asks, *by how much would the climate need to change to justify a different choice?* If the switching value is within the range of plausible future scenarios then again, more detailed investigation will be needed.

Sensitivity analyses are an important step to take before embarking on a more detailed appraisal – they are simple but can be revealing and can avoid unnecessarily complex analyses. For example, in practice, there are many examples of where climate uncertainty does not materially affect the choice between options[53] (see, for example, Case Study 3).

Where uncertainty is shown to be important, the next step is to consider whether impact of uncertainty can be reduced. This will involve scoping a new suite of options that are more robust to uncertainties, considering timing, flexibility and low-regrets measures (Section III.2). The new extended suite of options should then be re-appraised.

Level 2: Tools with moderate complexity
Where uncertainty has been shown to be an important factor in a decision (from the level 1 analysis), further analyses may be required to inform choices. Here, we give two examples of tools of moderate complexity that build on a simple scenario-planning approach – the robustness matrix and qualitative real options analysis.

Case Study 7 gives an illustrative example of a robustness matrix applied to a programme that aims to reduce flood risk in a forested region, as well as provide irrigation for local farmers. The matrix helps the decision maker to identify which options are most robust to uncertainty. The robustness matrix ranks the performance of different possible options against a set of future scenarios (including climate change but also socioeconomic factors). These scenarios aim to represent the most important uncertainties, and cover the range of plausible futures. The ranking could be based on expert opinion or a quantitative sensitivity analysis (as in level 1).

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52 Giving an expected net present value for each future scenario (HMT, 2003).

53 World Bank (2010b), ECAWG (2009) and Hallegatte et al. (2012) all include case studies where climate change is found not to affect the choice between adaptation options.

Case Study 7: A robustness matrix approach to decision making under uncertainty

The example takes a heavily forested region, with farmland downstream. Timber harvesting increases soil erosion and downstream flood risk. The objective of the intervention is to reduce flood risk, as well as provide irrigation for local farmers. A group of experts defines three possible interventions: (i) build dams, supplying an irrigation system and moderating downstream flood risk, and (ii) implement a forest management plan to reduce soil erosion and reduce flood risk.

The major uncertainties in the effectiveness of these interventions are climate change, changing demand for timber and government forestry policy. Four possible future scenarios are developed, mapping out the extremes of how conditions could change. The options and scenarios are mapped out in the robustness matrix. Each combination is rated in terms of the performance of the intervention under the scenario, from zero, for the lowest performance, to four, for the highest performance. This rating could, for example, be based on expert opinion, participatory decision making (e.g. ranking options through workshops) or on sensitivity analyses on the CBA, CEA or MCA (or a combination).

Table IV.1: Illustrative robustness analysis, based on Hallegatte et al. (2012). The values indicate the performance of each option under each of the four future scenarios. In italics is the level of 'regret' across each scenario.

	1: a larger dam with an irrigation system, and no forest management	**2: two small dams with an irrigation system and a small forest management programme**	**3: one small dam, large-scale irrigation ponds, and a large forest management programme**
A: central scenario	**4**	3 *(1)*	2 *(2)*
B: heavier rainfall and increased timber demand	0 *(2)*	1 *(1)*	**2**
C: lower rainfall and no change in timber demand	2 *(1)*	**3**	2 *(1)*
D: lower rainfall and afforestation due to government Reducing Emissions from Deforestation and Forest Degradation (REDD) policy	1 *(2)*	2 *(1)*	**3**
Worst performance	**0**	**1**	**2**
Average regret	**5**	**3**	**3**
Maximum regret	**2**	**1**	**2**

Table IV.1 shows that all options perform more poorly if rainfall becomes heavier (scenario B). Option 1 performs most poorly because with the much heavier rainfall and no forest management coupled with higher timber demand, there is heavier soil erosion, leading to siltation of the dam and flooding. Option 2 performs best as the large forest management programme reduces soil erosion and flood risk. Option 1 also performs poorly under scenarios C and D as the larger dam is has too large a capacity for the smaller amount of rainfall.

If we adopted a 'maximin' approach, *minimising the worst outcome if the worst-case scenario prevailed* (in this case, scenario B) then we would exclude option 1.

We could also think about minimising *regret*. The regret of each option under each scenario is shown in italics[54]. In terms of the average regret across all of the scenarios, option 1 again performs most poorly. Options 2 and 3 perform equally well. Option 2 performs slightly better than option 3 in *minimising the maximum level of regret* across all scenarios[55].

[54] For example, for scenario B, the regret of option 1 is 2, because 2 is the difference between its performance (0) and that of the best performing option (option 3, 2).

[55] Option 2 has a maximum regret of only 1. This is because option 3 performs poorly in scenario A.

Given that the performance of options 2 and 3 is close, Hallegatte et al. suggest that new options might be developed that take the most robust elements and combine these to create a more flexible set of options. For example, there could be another option to build the small dam (with expansion capacity) and implement a small forestry programme first, while maintaining the flexibility to increase action later after more information is gathered. The new options should be fed back into the matrix and the appraisal repeated. In some cases, the analysis could also be refined by gathering more information on the relative likelihood of the scenarios – the resulting analysis would be less robust, but could be justified if, for example, there was reliable information suggesting that one scenario had a much greater or lower likelihood of occurring.

This example has considered only one generic performance criterion. However, it could be repeated for multiple criteria, making it compatible with MCA (Montibeller and Franco, 2011).

Source: based on Hallegatte et al. (2012)

The problem with these types of analysis, as outlined by Montibeller and Franco (2011), is that they adopt less rigorous decision rules than CBA and MCA. They are more *exploratory tools*, enabling a decision maker to tests the sensitivities in their plans and identify where robustness can be built in. They can also be useful tools to communicate with local stakeholders as well as inputs for participatory decision making – see, for example, the South East Queensland Climate Adaptation Research Initiative (Low Choy et al. 2012), which used scenario analyses to help local communities design their own adaptation strategies.

A similar exploratory tool is the *qualitative real options analysis* (HMT/Defra, 2009). This tool, also known as a *decision tree* or *adaptation pathways* approach (Reeder and Ranger, 2011), can help an adviser to map out how options can be implemented flexibly and progressively, to give the best performance over time, while maintaining the future option to adjust or scale up plans if need be.

Figure IV.2 gives an illustrative decision tree for three new options, or *pathways*, identified for Case Study 7[56]. These new pathways incorporate flexibility by scaling up action during a second phase after more information is gathered (for example, scaling up forest management in pathway 1, or staggering the building of dams in pathway 3). The performance ratings show that in all but one case, performance either remains the same or improves compared with the one-off measures in Table IV.1. An adviser could refine this decision tree by considering at what point in time, or threshold in observed climate change, the decision would need to be made to select between options in the second stage (see also Section III.2 and Case Study 4).

56 For simplicity only three scenarios and two distinct time periods are considered.

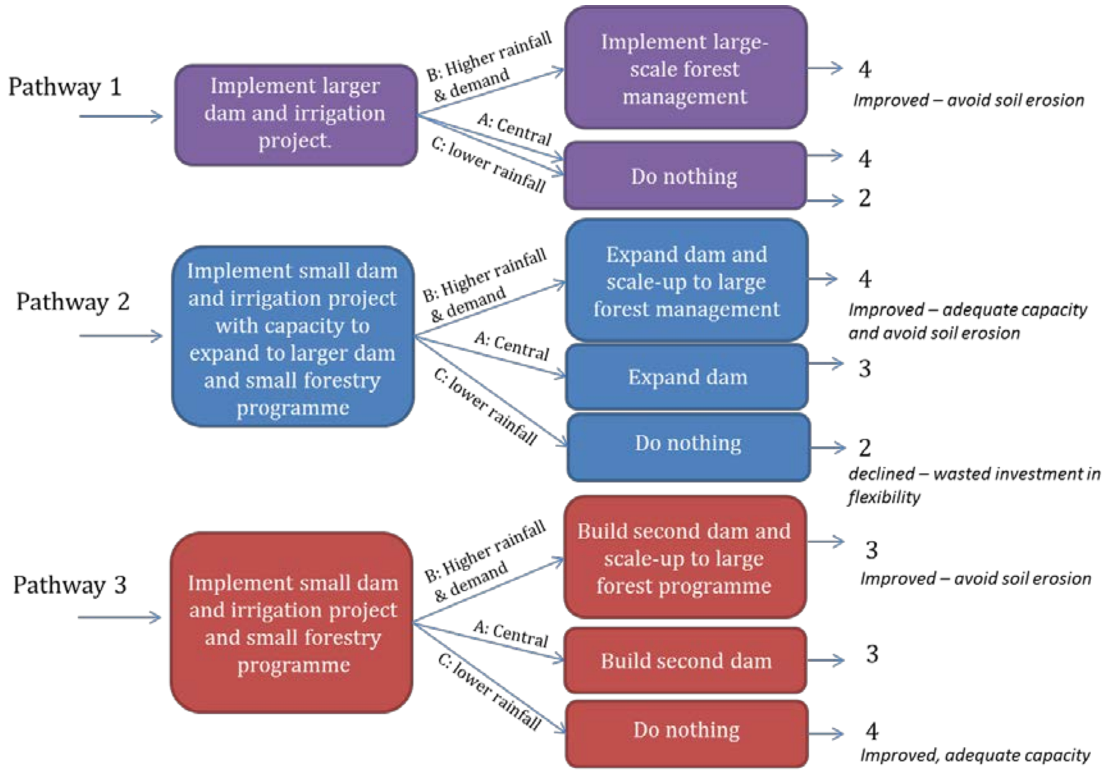

Figure IV.2: Illustrative extension to Table IV.1, using a decision tree to consider how flexibility could be built in through a multi-stage adaptation process. Source: author's estimates based on Hallegatte et al. (2012)

Level 3: The expert toolbox

In some cases, the simple tools may lead to a very clear answer and no further analysis will be needed. But where there is a more difficult choice between options, a more formal decision method can be helpful. Below we list and discuss some formal tools being increasingly used in adaptation planning, based on Ranger et al. (2010) and Hallegatte et al. (2012). Table IV.2 compares and summarises a selection of broader decision tools.

Many tools are available to inform decision making under uncertainty. A challenge is that many have resource needs (in terms of time, skills and data) that are unrealistic, except for major projects.

Firstly, ***robust decision making (RDM)*** works in a similar way to the robustness matrix above, but is far more exhaustive in its testing of the interdependencies of scenarios, priorities, options and objectives. This makes it quite resource-intensive to apply[57]. A major (and attractive) component of RDM is its focus on participatory decision making to identify vulnerabilities, priorities and suitable options. RDM is applied through a progressive process, where findings are presented to stakeholders and then refined based on their input to zero in on the most acceptable solution. RDM can incorporate probabilistic information, as well as missing and imprecise probabilities and differing expectations of the future, in an exploratory mode as part of the participatory process. For further information see, for example, Groves et al. (2008) and Feifel (2010).

57 Previous applications have been very resource intensive because they have involved complex simulation models, for example of water resources management in Southern California (Groves et al. 20087).

***Climate-informed decision analysis (CIDA)*:** this is similar in principle to the robustness matrix approach above, with the key difference being the use of estimates of the 'plausibility' of different climate scenarios (based on expert judgement and climate modelling) to identify the 'best' option. This approach tries to make the best use of available climate information, recognising the deficiencies. A downside is that it is reliant on subjective judgements about the plausibility of different climate scenarios. See two case studies; Brown (2010) and Brown et al*.* (2011).

There have been several critiques of robustness-based approaches, like RDM and CIDA. The first is their inherent pessimism and sensitivity to the worst-case scenario, which it is argued, will increase the cost of an intervention. Hallegatte et al. (2012) respond that this is unavoidable given the nature of the uncertainties involved – ignoring uncertainties will lead to poorer performance of the intervention. We add that a robustness-based approach need not lead to higher costs; if the options scoping is thorough it should reveal more flexible options with no higher costs provided the options are considered at the highest feasible level of the logframe (outcome) rather than just choice of delivery partner (inputs).

Secondly, a further critique, particularly of RDM, is that it is more resource- and data-intensive to apply than the conventional approaches. The World Bank and others are currently working on the design and testing of more 'resource light' versions of RDM.

Real options analysis (ROA) is very different to RDM and CIDA. ROA is similar to CBA[58], but provides a much richer framework to incorporate timing and uncertainty into a decision, and importantly, to value flexibility – specifically the value of a 'real' option being available in the future, as a result of an action taken today. For example, it provides a framework for appraising the value of waiting and learning before acting, or of building a flood defence with larger foundations now, so that it can be easily upgraded in the future. If this value of flexibility of an option is not included in the appraisal, then its total value will be underestimated. The Green Book recommends that ROA is suitable for projects, programmes or policies where there is uncertainty over the future, the potential for flexibility to adjust plans and the potential to learn – that is, to make a better decision in the future through learning more (HMT, 2003). This learning might occur, for example, as a result of growing knowledge about the climate over time, through investments in modelling or through monitoring the changes that occur. The classic example of a ROA applied to adaptation is the Thames Estuary 2100 project (see Reeder and Ranger, 2011).

Aside from its ability to rigorously value flexibility, ROA is attractive because it readily fits within the conventional framework of optimising decisions. A critique of ROA for adaptation planning is that it (strictly) requires estimates of the likelihood of each future scenario. But ROA can be used in a sensitivity testing mode (as in the TE2100 case). For example, it can be used to assess how large the probability of a worst-case outcome would need to be to justify switching to plan B. Expert judgement may then be able to help determine if this threshold is realistic. Even without probabilities, ROA can be a useful tool in helping to identify key decision points in an incremental strategy (see Case Study 6 and Reeder and Ranger, 2011).

[58] It is similar in that streams of costs and benefits over time are computed for each possible adaptation pathway, under different climate change scenarios, to calculate a net present value for each path and scenario.

Table IV.2: Brief summary of decision tools. Source: Extract and update from Ranger et al. (2010)

Decision tool	Decision-making criteria	Assumptions	Future scenarios
Methods when exact probabilities are known			
Cost-benefit analysis (expected value analysis)	Economic costs and benefits	Risk neutral. Time discounting. Does not account for equality of outcomes Only marginal costs and benefits	Requires known probabilities over all events No learning
Expected utility analysis	Consumption (including non-monetary factors)	Time discounting Can account for non-marginal change, risk aversion and equality of outcomes.	Requires known probabilities over all events No learning
Multi-criteria analysis	Multiple criteria	As for expected utility analysis	Requires probability distributions
Methods where exact probabilities are known, but will change over time			
Real options analysis	As for expected utility analysis	As for expected utility analysis and accounts for learning and flexibility	Requires known probabilities, as well as model of how probabilities respond to new information
Methods when exact probabilities are not known			
Maximin expected utility	As for expected utility analysis	As for expected utility, but pessimistic (acts as if the worst plausible probability distribution were correct)	Multiple plausible probability distributions
Maximin	Any criteria	Ranking of outcomes	No likelihood information
Minimax regret	Any criteria	Information on how much better one outcome is than another	No likelihood information
Robust decision making	Multiple criteria	Information on how much better one outcome is than another	Multiple plausible probability distributions for exploratory analysis
Climate-informed decision analysis	Multiple criteria	Information on how much better one outcome is than another	Subjective probability distribution
Info-gap decision theory	Multiple criteria	Does not rigorously account for preferences. Assumes satisficing thresholds[59]	A 'best guess' model of the decision environment, and a set of models that are 'close' to this best guess.

IV.3. Climate information for decision making

In this sub-section, we briefly explore the climate information needs for decision making. The type of climate and impact scenarios needed for options appraisal will vary based on the problem itself. A full discussion of the appropriate information is beyond the scope of this Topic Guide. Below we give a few general recommendations and provide links to where readers can obtain further information.

Firstly, we recommend taking a scenario-based approach, both to climate change but also for other major changes that are important to the case, such as population changes. In all cases, the **central principle must be that the scenarios cover the plausible range of possible futures across the dominant sources of uncertainty**. Indeed, Lempert et al. (2003) emphasise the value of representing the extremes of what might happen in the options

59 A satisficing threshold is the value of a decision criterion at which an adaptation option is considered good enough.

appraisal and HMT (2003) warns against incurring spurious accuracy by using too narrow a scenario set. See, for example, Low Choy et al. (2012) for a good example of where scenarios have been developed for adaptation planning in a community in Queensland, Australia, and used to engage communities in appraising adaptation options.

Importantly, the range of projections from climate models does not represent the full range of uncertainty. This is because models tend to share similar deficiencies and so the final projections can often be biased. Scientists can advise on where this might be a problem and ways to resolve it. This might include some scenarios based on expert judgement, as was used in the Thames Estuary 2100 project to explore the uncertainties due to missing ice sheet processes in the models (see, for example, Reeder and Ranger, 2011).

Table IV.3: A review of methods to generate regional climate scenarios (Wilby et al. 2009)

Method (application)	Advantages	Disadvantages
Sensitivity analysis *Resource management, Sectoral*	1. Easy to apply; 2. Requires no future climate change information;3. Shows most important variables/ system thresholds; 4 Allows comparison between studies.	1. Provides no insight into the likelihood of associated impacts unless benchmarked to other scenarios; 2. Impact model uncertainty seldom reported or unknown.
Change factors *Most adaptation activities*	1. Easy to apply; 2. Can handle probabilistic climate model output	1. Perturbs only baseline mean and variance; 2. Limited availability of scenarios for 2020s.
Climate analogues *Communication, Institutional, Sectoral*	1. Easy to apply; 2. Requires no future climate change information; 3. Reveals multi-sector impacts/vulnerability to past. climate conditions or extreme events, such as a flood or drought episode.	1. Assumes that the same socio-economic or environmental responses recur under similar climate conditions; 2. Requires data on confounding factors such as population growth, technological advance, conflict.
Trend extrapolation *New infrastructure (coastal)*	1. Easy to apply; 2.Reflects local conditions; 3. Uses recent patterns of climate variability and change; 4. Instrumented series can be extended through environmental reconstruction; 5. Tools freely available.	1. Typically assumes linear change; 2. Trends (sign and magnitude) are sensitive to the choice/length of record; 3. Assumes underlying climatology of a region is unchanged; 4. Needs high quality observational data for calibration; 5. Confounding factors can cause false trends.
Pattern-scaling *Institutional, Sectoral*	1. Modest computational demand; 2. Allows analysis of GCM and emissions uncertainty; 3. Shows regional and transient patterns of climate change; 4. Tools freely available.	1. Assumes climate change pattern for 2080s maps to earlier periods; 2. Assumes linear relationship with global mean temperatures; 3. Coarse spatial resolution.
Weather generators *Resource management, Retrofitting, Behavioural*	1. Modest computational demand; 2. Provides daily or sub-daily meteorological variables; 3. Preserves relationships between weather variables; 4. Already in widespread use for simulating present climate; 5. Tools freely available.	1. Needs high quality observational data for calibration and verification; 2. Assumes a constant relationship between large-scale circulation patterns and local weather; 3. Scenarios are sensitive to choice of predictors and quality of GCM output; 4. Scenarios are typically time-slice rather than transient.
Empirical downscaling *New infrastructure, Resource management, Behavioural*	1. Modest computational demand; 2. Provides transient daily variables; 3. Reflects local conditions; 4. Can provide scenarios for exotic variables (e.g., urban heat island, air quality); 5. Tools freely available.	1. Requires high quality observational data for calibration and verification; 2. Assumes a constant relationship between large-scale circulation patterns and local weather; 3. Scenarios are sensitive to choice of forcing factors and host GCM; 4. Choice of host GCM constrained by archived outputs.
Dynamical downscaling *New infrastructure, Resource management, Behavioural, Communication*	1. Maps regional climate scenarios at 20-50km resolution; 2. Reflects underlying land-surface controls and feedbacks; 3. Preserves relationships between weather variables; 4. Ensemble experiments are becoming available for uncertainty analysis.	1. Computational and technical demand high; 2. Scenarios are sensitive to choice of host GCM; 3. Requires high quality observational data for model verification; 4. Scenarios are typically time-slice rather than transient; 5. Limited availability of scenarios for 2020s.
Coupled AO/GCMs *Communication, Financial*	1. Forecasts of global mean and regional temperature changes for the 2020s; 2. Reflects dominant earth system processes and feedbacks affecting global climate; 3 Ensemble experiments are becoming available for uncertainty analysis.	1. Computational and technical demand high (supercomputing); 2. Scenarios are sensitive to initial conditions (sea surface temperatures) and external factors (such as volcanic eruptions); 3. Scenarios are sensitive to choice of host GCM; 4. Coarse spatial resolution.

Secondly, scenarios should start off simple, and then be refined as necessary. For example, at the initial stage of an appraisal process, simple 'what if' scenarios may be sufficient. These can be based on historical events, climate analogues (for example, testing the resilience to events that have occurred in neighbouring regions) or publically available sources, like the IPCC Assessment Reports. However, for major projects, where the initial appraisal has shown that the choices are very sensitive to uncertainty, detailed scenarios may be required. For example, construction of a new major dam will require detailed climate and hydrological modelling.

Thirdly, seek expert advice where more detailed projections are required. As explained above, some development interventions may require detailed, high-resolution information about future climate at the local scale. Yet, there are significant uncertainties in such information, requiring expert interpretation. We recommend Wilby et al. (2009), which provides a detailed review of the methods to generate scenarios – see Table IV.3 for a summary of the advantages and disadvantages of different techniques.

There are a number of issues to consider in using climate projections in detailed assessments, for example:

- *Do not confuse weather and climate, particularly in the medium term (next 20 years):* When generating scenarios, it is important not to inadvertently confuse uncertainty due to natural weather variations, with the uncertainty driven by human-made climate change. Over the next few decades, weather variations can actually be larger than the effect of climate change. This means that a climate model could produce a projection of a 30% decline in rainfall by 2020, but this could actually be just normal year-to-year weather variations. If this change is mistaken for climate change then it could lead to significant over-adaptation. Scientists can quantify and remove the effect of weather by running large *ensembles* of the same climate model, or (more simply, but less effectively) averaging over long time periods. Decision makers should seek input from experts to identify if natural weather uncertainty has been quantified adequately in scenarios; and
- *Downscaling a projection to the local scale increases its precision, but will also increase its uncertainty*. Global climate models are often downscaled to produce local projections. Downscaling enhances projections for a locale by better representing local factors that affect climate, like mountains. Downscaling is done using either a high-resolution *regional climate model* or an empirical (statistical) model, coupled to a global model. Because the downscaling still uses the global model, its uncertainty is still present in the projections. The downscaling model adds an additional layer of uncertainty. For this reason, for regional projections, it is important to capture both the uncertainty due to the global model, and that due to the downscaling model (e.g. by using multiple models).

Models should always be complemented by expert and local knowledge to ensure that their outputs are suitable and accurate for use in policy (Hallegatte et al. 2012).

Finally, in some cases it may be necessary to commission new analyses to generate appropriate scenarios. But importantly, the decision maker must consider whether the value of additional information is worth the cost. In all cases, the key is not to aim for perfect information, but sufficient information to enable a thoughtful consideration of options (OECD, 2009; Ranger et al. 2010). It could take years and significant financial resources to fully understand the vulnerability of one community, or develop a suite of regional climate model projections. Decision makers should not jump to commissioning new modelling or downscaling exercises. There are many existing studies available that are likely to provide sufficient information, particularly given the uncertainties inherent in all projections. There are particularly strong arguments over the value of expensive and time-consuming downscaling exercises using regional climate models. Hallegatte et al*.* (2012) comment that a skilled climatologist, with a few days' work, can usually provide a projection that is just as good as that which a downscaling exercise would produce in several months. Funding the skilled local climatologist has the additional advantage of building local capacity.

Broader information needs

While in this section we have focused on climate information, typically the most important input to an appraisal process will be an understanding of the **vulnerability of a system to climate shocks and losses** (Ranger et al. 2010) and the socioeconomic trends that may influence vulnerability over the long term. Historical losses from weather and vulnerability to past climate variability can be a crucial indicator of future vulnerability. However, one must also tease out the drivers of future vulnerability, including the capacity of the system to adapt autonomously (OECD, 2009).

OECD (2009) suggests the need for special attention to the sensitivity of more vulnerable groups, including women, children and marginalised groups. Tipping points in vulnerability are also important to map – for example, the level of climate change at which the impacts would become much worse, on the tolerance of a crop variety or the performance of a water system, for example. The analyses should ideally also consider international vulnerability, for example, to global food prices; however, in practice such additional analysis my not be feasible or practical.

Key messages from this section

- **The key to success in applying this section is ensuring that the options being appraised have been considered at the right level.** They should ideally be at the outcome level or, failing that, the output level.
- **The Green Book recommends that it is essential to consider how uncertainty over the future affects the choice between options,** for example *how does future climate affect whether Plan A or Plan B is the better choice? Is uncertainty critical to whether or not the intervention will succeed in meeting the objective?*
- **The conventional tools for economic appraisal, like cost–benefit analyses and cost-effectiveness analyses, break down when there is deep uncertainty.** Each of these tools *aims to optimise* the choice of option(s) to meet a certain objective. The challenge is that in some cases, this optimisation will be highly sensitive to uncertainty. These tools have no formal way of dealing with deep uncertainty. If this uncertainty is ignored, it could lead an adviser to select an option that performs less well, or leads to adverse outcomes.
- **To deal with uncertainty, a first step is to *sensitivity test* the cost-benefit analysis** (or equivalent) to uncertainty, and to consider *'switching values'*.

Where necessary, an expert toolbox of decision methods, such as robust decision making and real options analysis, is available to help in appraising options. A challenge is that these can be resource-intensive to apply in practice and they are relatively untested in development interventions.

Where can I find more information?

- DFID economic appraisal guidance for climate change (forthcoming)
- *The UK Green Book (HMT, 2003)* and its Supplementary Guidance on *“Accounting for the Effects of Climate Change” (HMT/Defra, 2009).* The Green Book provides guidance on options appraisal and dealing with risk and uncertainty.
- Hallegatte et al. (2012) *“Investment Decision Making under Deep Uncertainty — Application to Climate Change”.* A detailed and technical summary of the state-of-the-art in decision making under uncertainty applied to climate change adaptation. *http://elibrary.worldbank.org/content/workingpaper/10.1596/1813-9450-6193*
- Walker et al. (2012) An accessible review of the history of scenario planning and robust decision making, with examples.
- Wilby et al. (2012) A detailed review of climate information for adaptation planning.

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Glossary

Taken from the IPCC Fourth Assessment Report and IPCC (2012):

adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

adaptive capacity: The ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies.

anticipatory adaptation: Adaptation that takes place before impacts of climate change are observed.

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

climate change: Climate change refers to any change in climate over time, whether due to long-term natural variability or as a result of human activity.

disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency responses to satisfy critical human needs. External support for recovery may also be required.

disaster risk management: Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, resilience and sustainable development.

emissions scenario: A plausible representation of the future development of emissions based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships.

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

resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

risk: The product of potential impact and its probability.

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