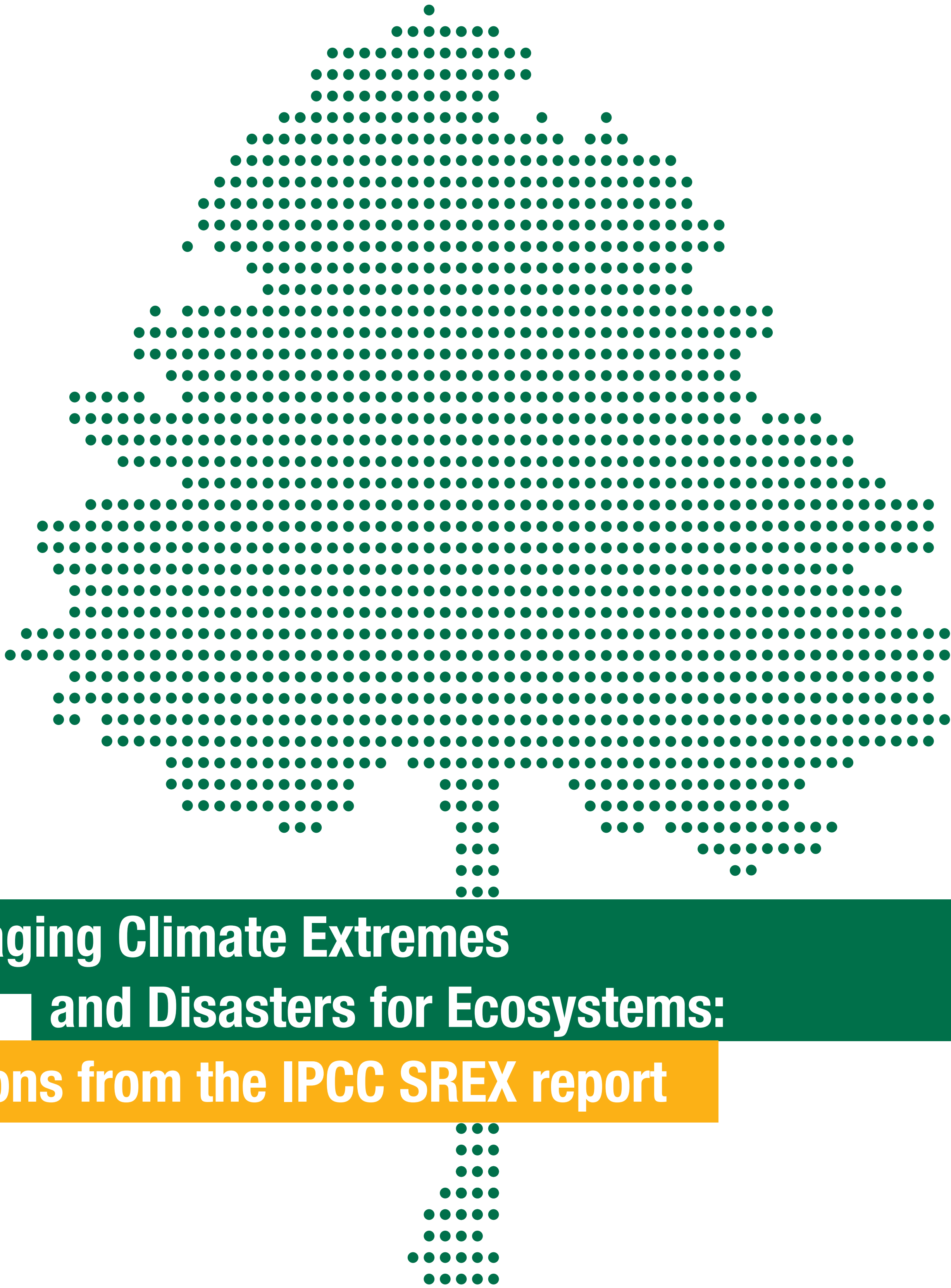
Climate & Development Knowledge Network



# Managing Climate Extremes and Disasters for Ecosystems: Lessons from the IPCC SREX report

# Contents


| | |
|---|---|
| 1. Introduction to SREX | 01 |
| 2. Changing disaster risks | 03 |
| 3. Future impacts | 07 |
| 4. Managing the risks of climate extremes and disasters | 09 |
| 5. Conclusions: what does this mean for decision-makers? | 13 |
| ANNEX I: Acronyms | 17 |
| ANNEX II: Changes in climate extremes | 19 |
| ANNEX III: Return period maps | 25 |
| ANNEX IV: IPCC uncertainty guidance | 29 |
| ANNEX V: IPCC SREX glossary of terms | 30 |



**This report was compiled by Catherine Cameron, Gemma Norrington-Davies and Emma Back of Agulhas: Applied Knowledge, with the guidance of Dr. Tom Mitchell, Overseas Development Institute.**



The authors would like to thank the following reviewers for their support and comments: Mairi Dupar, Padma Narsey Lal, Maarten van Aalst, Emily Wilkinson and Neville Ash.

This document should be referenced as follows:
Climate and Development Knowledge Network (2012).
Managing Climate Extremes and Disasters for Ecosystems:
Lessons from the IPCC SREX Report.
Available online at www.cdkn.org/srex.



**All correspondence should be addressed to:**

**Dr. Tom Mitchell**
**Overseas Development Institute**
**E: t.mitchell@odi.org.uk**

# 1. Introduction to SREX

## 1.1 About SREX

The Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) was commissioned by the Intergovernmental Panel on Climate Change (IPCC) in response to a recognised need to provide specific advice on climate change, extreme weather and climate events ('climate extremes'). SREX was written over two and a half years, compiled by 220 expert authors, 19 review editors, and took account of almost 19,000 comments. It went through three rigorous drafting processes with expert and government review. The findings were approved by the world's governments following a four-day meeting, where the Summary for Policy Makers was agreed. It thus provides the most complete scientific assessment available to date and describes the immediate and long-term action required to manage the risks we face. It comprises a policy summary released in November 2011 and the full report released in March 2012 (available online at http://ipcc-wg2.gov/srex).

This thematic brief summarises the key findings of the report relevant to ecosystems. It draws exclusively on material from SREX. It includes an assessment of the science and the implications for society and sustainable development. It is intended to be useful for policy makers, decision-takers and planners locally, nationally, and regionally. It recognises that these readers will have many competing calls on both their time and budgets. It thus seeks to highlight key thematic findings and learning from SREX. It makes suggestions for immediate action to avoid further damage and to build a more resilient future with benefits that go beyond ecosystems.

Although not an official publication of the IPCC, this summary has been written under the supervision of co-authors of SREX and it has been thoroughly reviewed by an expert panel. The summary includes material directly taken from SREX, where the underlying source is clearly referenced, but it also presents synthesis messages that are the views of the authors of this summary and not necessarily those of the IPCC. It is hoped that the result will illuminate SREX's vital findings for decision makers working on ecosystems, and so better equip them to make sound decisions about managing disaster risk in this context. This brief is one of four thematic briefs of SREX – on water, health, agriculture, and ecosystems – that can be read individually or as a suite. There are also three regional SREX summaries for Africa, Asia, and Latin America and the Caribbean[1], which provide further information as a rapid reference source.

SREX considered the effects of climate change on extreme events, disasters, disaster risk reduction (DRR), and disaster risk management (DRM). It examined how climate extremes, human factors, and the environment interact to influence disaster impacts and risk management, and adaptation options (Figure 1). The report considered the role of development in exposure and vulnerability, the implications for disaster risk and DRM, and the interactions between extreme events, extreme impacts, and development. It examined how human responses to extreme events and disasters could contribute to adaptation objectives, and how adaptation to climate change could become better integrated with DRM practice. The report represents a significant step forward for the integration and harmonisation of the (CCA), DRM, and climate science communities.

For policy-makers and planners working on ecosystems, or indeed anyone whose work contributes to the management of ecosystems, this brief should prompt discussion and understanding of several questions:

1. Why are extreme events critical for ecosystems?
2. How are ecosystems affected by the impact of extreme events?
3. What actions can be taken to manage these risks?

## 1.2 Ten key messages

Key overarching summary messages from SREX are[2]:

1. Even without taking climate change into account, disaster risk will continue to increase in many countries as more vulnerable people and assets are exposed to climate extremes. Healthy ecosystems have a critical role to play in reducing the impacts of climate extremes and disasters.
2. Based on data since 1950, evidence suggests that climate change has changed the severity and frequency of some extreme weather and climate events in some global regions already.
3. In the next two or three decades, the expected increase in climate extremes will probably be relatively small compared to the normal year-to-year variations in such extremes. However, as climate change becomes more dramatic, its effect on a range of climate extremes will become increasingly important and will play a more significant role in disaster impacts.
4. There is better information on what is expected in terms of changes in extremes in various regions and sub-regions, rather than just globally, although for some regions and some extremes uncertainty remains high (e.g. precipitation trends across Africa and drought trends across most of Asia).

1. http://cdkn.org/srex.
2. Highlights adapted from a note by Dr. Tom Mitchell, Overseas Development Institute and Dr. Maarten van Aalst, Red Cross/Red Crescent Climate Centre available at http://cdkn.org/srex.

5. High levels of vulnerability, combined with more severe and frequent weather and climate extremes, may result in some places – such as coastal areas and low lying islands – being increasingly difficult places in which to live and work.

6. A new balance needs to be struck between measures to reduce risk, transfer risk (e.g. through insurance), and effectively prepare for and manage disaster impact in a changing climate. This balance will require a stronger emphasis on anticipation and risk reduction.

7. Existing risk management measures need to be improved as many countries are poorly adapted to current extremes and risks, so are not prepared for the future. This should include a range of ecosystem management and restoration measures, to allow a greater range of ecosystem responses to hazards. People's exposure to negative climate impacts could also be reduced through better land use planning and enforcement, and more robust decision-making processes for water allocation and use.

8. Countries' capacity to meet the challenges of observed and projected trends in disaster risk is determined by the effectiveness of their national risk management system. Such systems include national and sub-national governments, the private sector, research bodies, and civil society including community-based organisations. Transboundary issues may also be important for ecosystems.

9. More fundamental adjustments are required to avoid the worst disaster losses and tipping points where vulnerability and exposure are high, capacity is low, and weather extremes are changing.

10. Any delay in greenhouse gas mitigation is likely to lead to more severe and frequent climate extremes in the future and will likely further contribute to disaster losses.

## 1.3 What does this mean for management of ecosystems?

Good ecosystems management is critical for managing climate extremes and disasters. It plays three positive roles:

- delivery of ecosystem-based adaptation;
- delivery of co-benefits for livelihoods and biodiversity conservation; and
- support for climate mitigation.

Healthy ecosystems, whether natural or modified, have a critical role to play through **adaptation** by reducing the risk of impacts from climate extremes and disasters on human society. Investment in sustainable ecosystem management has the potential to provide improved livelihoods and well-being. For example, conservation of water resources and wetlands that provide hydrological sustainability can further aid adaptation by reducing the pressures and impacts on human water supply. Forests have also been used in the Alps and elsewhere as effective risk reducing measures against avalanches, rock-falls and landslides since the 1900s, and mangrove replanting has been used as a buffer against cyclones and storm surges, with reports of 70 to 90% reduction in energy from wind-generated waves in coastal areas and reduction in the number of deaths from cyclones, depending on the health and extent of the mangroves.

The benefits of healthy ecosystems should place ecosystem services management at the heart of key policy decisions associated with climate change. Some countries have begun to explicitly consider ecosystem-based solutions for climate change mitigation, adaptation, and responses to weather and climatic extremes as an integral element of national and sectoral development planning. These include Brazil, the Caribbean Islands, Tajikistan and Vietnam. However, in choosing an ecosystem-based adaptation option, decision-makers may need to make tradeoffs between particular climatic risk reduction services and other ecosystem services also valued by humans.

Investment in sustainable ecosystems and environmental management has the potential to provide **improved livelihoods.** There is consensus on the important role of ecosystems in risk reduction and well-being, which should make the value of ecosystem services an integral part of key policy decisions associated with adaptation. Ecosystem-based adaptation integrates the sound management of biodiversity and ecosystem services into an overall adaptation strategy, and can provide cost effective risk reduction.

**Increasing and restoring the biological diversity of ecosystems** allows a greater range of ecosystem responses to hazards, thus increasing the resilience of the entire system. With a changing climate there is a likelihood of pest, diseases and non-native species expansion. This can adversely affect species distribution and dominance in a given ecosystem and therefore affect the system's overall resilience. Reducing non-climate stresses on ecosystems can also enhance their resilience to climate change and weather extremes.

For example, coral reef ecosystems are damaged by overfishing, damage, and extraction of corals and shells for sale.

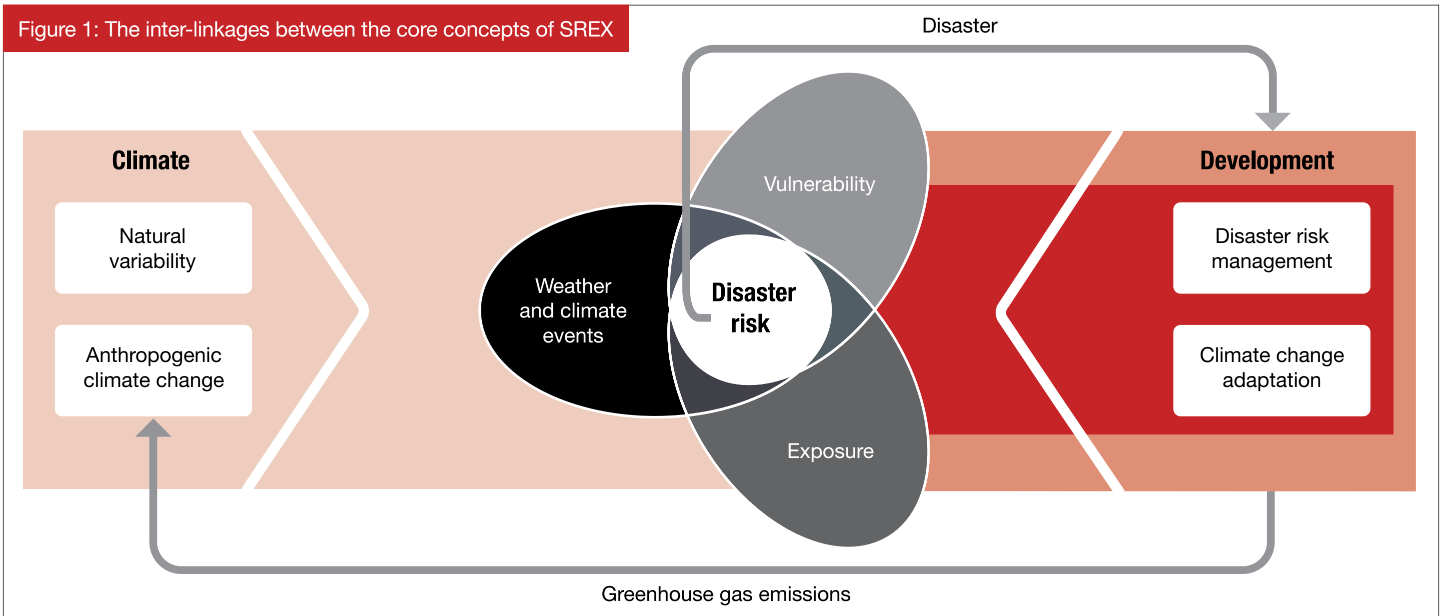
Ecosystem management can play an important part in the global endeavour to mitigate greenhouse gas emissions and therefore avoid the worst climate extremes and their associated impacts. For example, supporting forest ecosystems can deliver both adaptation and mitigation benefits, providing a 'win-win' response. Forest conservation can reduce carbon emissions and, where timber extraction is carefully managed at renewable rates to provide sustainable biomass for heat and power, can contribute to human development. Forest conservation can create or maintain large contiguous areas of wildlife habitat that increase species' resilience to weather and climate extremes.

Finally, there must be consideration that in some cases today's climate extremes will be tomorrow's 'normal' weather. Tomorrow's climate extremes may therefore stretch our imagination and challenge our capacity to manage change as never before.

# 2. Changing disaster risks

**This section looks at the components of changing disaster risk in more detail. The inter-linkages between the core concepts discussed in SREX are illustrated in Figure 1. This shows how both changes in vulnerability and exposure, and changes in weather and climate extremes, can contribute and combine to create disaster risk hence the need for both DRM and CCA within development processes.**

Figure 1: The inter-linkages between the core concepts of SREX




## 2.1 Changes in extreme events[3]

A changing climate leads to changes in the frequency, intensity, spatial extent and duration of weather and climate extremes, and can result in unprecedented extremes. 'An *extreme (weather or climate) event* is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper or lower ends ('tails') of the range of observed values of the variable'[4]. Temperature, for example, is associated with several types of extremes, e.g. heat waves and cold spells, and related impacts, e.g. on human health, the physical environment, ecosystems, and energy consumption.

High temperature extremes (i.e. heat waves), drought, and floods substantially affect ecosystems. Increasing gaps and overall contraction of the distribution range for species habitat could result from increases in the frequency of large-scale disturbances due to extreme weather and climate events. An assessment of 19 studies found that 20 to 30% of studied plant and animal species may be at an increased risk of extinction if warming exceeds 2 to 3°C above the pre-industrial level. Changes due to climate extremes, e.g. of critical temperature thresholds, could also result in shifts of ecosystems to less desired states with the potential loss of ecosystem services.

CDKN has extracted region-specific data from SREX to provide an easy-to-use guide to future climate extremes in Africa, Asia and Latin America and the Caribbean, respectively. These are at Annex II.

3. Draws on material from SREX Chapter 3, Nicholls. N. et al, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment' and Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
4. SREX Section 3.1.2 has a full explanation.

## 2.2 Ecosystems definitions and inter-linkages[5]

Extreme events can have positive as well as negative impacts on ecosystems and human activities. However, extreme impacts on humans and ecosystems are commonly conceptualised as 'disasters' or 'emergencies'.

Many contemporary definitions emphasise that a disaster results either when the impact is such that local capacity to cope is exceeded or when it severely disrupts normal activities. Many ecosystems are dependent on climate extremes for reproduction (e.g. through fire and floods), disease control, and in many cases for general ecosystem health (e.g. fires or windstorms allowing new growth to replace old). How such extreme events interact with other trends and circumstances can be critical to the outcome. For example, floods that would normally be essential to river gum reproduction may also carry disease and water weeds. Climate extremes can cause substantial mortality of individual species and contribute to determining which species exist in ecosystems. Drought, for example, plays an important role in forest dynamics, as a major influence on the mortality of trees. However, the impacts that climatic extremes have on humans and ecosystems (including those altered by humans) depend on several other non-climatic factors.

This summary report uses the Millennium Ecosystem Assessment (MEA) 2005 definition of an ecosystem and ecosystems services, together with well-being. This enables the reader to more clearly see the linkages between climate extremes and disasters and the impacts these have on ecosystems, including humans. These definitions are captured in Box 2, below.

A further breakdown of ecosystems services is provided in Figure 2, together with the linkages that these have with well-being; namely, security, the basic material for a good life, health, and good social relations. There are thus linkages with all four thematic summaries of agriculture, ecosystems, health and water.

### Box 1: What climate science tells decision-makers – climate smart DRM is a top priority

**Variability is always important. Climate trends are usually only one factor in the probability of hazards. In some regions and for some decisions, seasonal variability may be more important than long-term trends.**

**For decisions affecting just the next decade, it may be more important to think about what has changed already and what the near term range of variability is, rather than what will happen in the coming century.**

**We know that uncertainty is increasing. There are some hints of future trends or ranges of uncertainty – but there is seldom specific information on precise future probabilities of particular extremes.**

**The quality of available information will differ between global, regional and local scales.**

**There will be differences in what science can say about extremes. For example, the link between rising temperatures and heat waves is relatively robust; similarly the link between sea-level rise and high sea-level events is fairly straightforward. However, for some other extremes, such as tropical cyclones, trends are less directly related to well-predicted changes in average conditions.**

**These factors should be considered when reviewing climate science for decision and policy-making. However, uncertainty should not be used as a reason for inaction – investments must be made to reduce vulnerability and exposure. SREX provides enough information to show that more people and assets are in harm's way and much more can be done to reduce exposure, vulnerability, and risk.**

### Box 2: Ecosystems – key definitions[6]

***Ecosystem:*** **a dynamic complex of plant, animal, and micro-organism communities and the non-living environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems vary enormously in size; a temporary pond in a tree hollow and an ocean basin can both be ecosystems.**

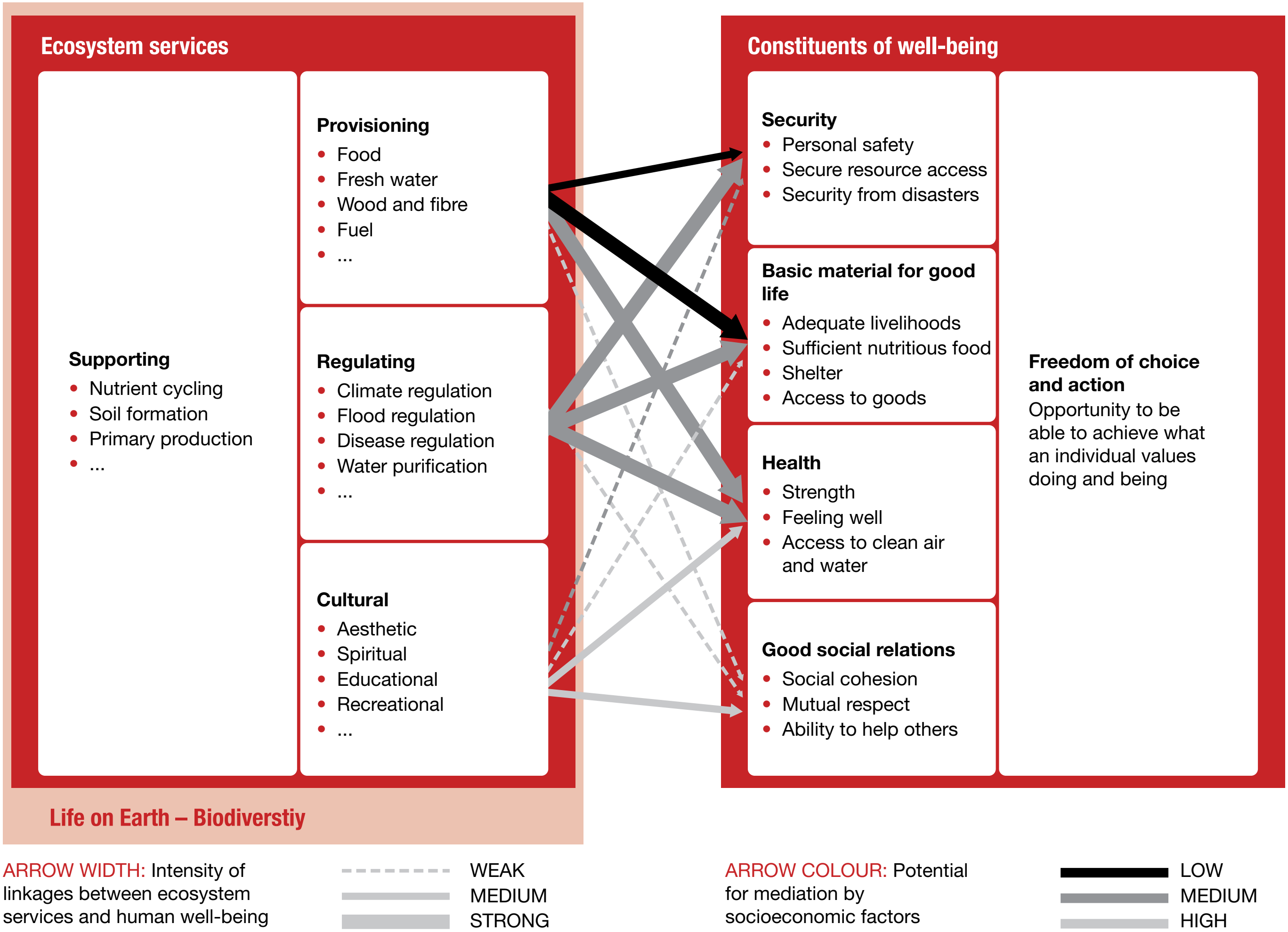
***Ecosystem services:*** **the benefits people obtain from ecosystems. These include:**

- ***provisioning*** **services such as food, water, and wood;**
- ***regulating*** **services such as regulation of climate, floods and disease, and water purification;**
- ***supporting*** **services such as soil formation, and nutrient cycling; and**
- ***cultural*** **services such as recreational, spiritual, aesthetic, and other non-material benefits.**

***Well-being:*** **human well-being has multiple constituents, including basic material for a good life, freedom of choice and action, health, good social relations, and security. Well-being is at the opposite end of a continuum from poverty, which has been defined as a 'pronounced deprivation in well-being.' The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances.**

5. Draws on material from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability' and Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
6. Source: MEA 2005.

Figure 2: Ecosystems services and their links to the constituents of well-being[7]




## 2.3 Disaster risk, vulnerability and exposure[8]

Impacts of extreme and non-extreme weather and climate events depend strongly on levels of vulnerability and exposure. Vulnerability and exposure are dynamic and depend on economic, social, demographic, cultural, institutional, and governance factors. Lack of resilience and capacity to anticipate, cope with and adapt to extremes are important elements of vulnerability. Originally, the concept of resilience was strongly linked to an environmental perspective: it related to ecosystems' ability to maintain major functions, even in times of crisis. The concept has undergone major shifts and has now been enhanced and applied in the field of socio-ecological systems and disaster risk.

Exposure is a necessary but not sufficient condition for impacts. For exposed areas to be subjected to significant impacts from a weather or climate event there must be vulnerability. Vulnerability is composed of:

- susceptibility of what is exposed to harm (loss or damage) from the event; and
- its capacity to recover.

High vulnerability and exposure are generally the outcome of skewed development processes, such as environmental mismanagement, rapid and unplanned urbanisation, failed governance, and a scarcity of livelihood options. The intensity or recurrence of hazard events can be partly determined by environmental degradation, and human intervention in natural ecosystems. Landslides or flooding regimes associated with human-induced environmental alteration and new climate change-related hazards are examples of such socio-natural hazards.

## 2.4 Consequences of climate extremes on ecosystems[9]

This section builds on the information presented in this report so far and highlights how extreme climate and weather-related events – such as droughts, floods, and temperature extremes – directly and indirectly impact on ecosystems.

**Droughts** affect forestry, and terrestrial and aquatic ecosystems. Predicted changes in future climate will only exacerbate the impact of other factors, for example

7. Millennium Ecosystem Assessment, 2005, Chapter 1 Conceptual Framework: Ecosystems and their services: http://www.maweb.org/documents/document.765.aspx.pdf
8. Draws on material from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability' and Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
9. Draws on material from Draws on material from SREX Chapter 3, Nicholls. N. et al, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment', SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

through increased likelihood of extreme fire danger days. A wildfire example is shown in Box 3. We are already seeing the impact of many factors on wildfires, and heat waves, for example, demographic and land use changes. A better understanding of the interplay of all the causal factors is required. In Syria prolonged drought (2008 to 2011) has affected 1.3 million people and the loss of the 2008 harvest has accelerated migration to urban areas and increased levels of extreme poverty. This has put pressure on water resources with the deficit exceeding 3.5 billion cubic metres in recent years.

**Heat waves** can directly impact ecosystems. For example they can constrain carbon and nitrogen cycling and reduce water availability, potentially decreasing production or even causing species mortality. Extreme temperature conditions can also shift forest ecosystems from being a net carbon sink to a net carbon source. For example, the net $CO_2$ exchange levels for tall-grass prairie ecosystems decreased in both an extreme warming year (2003) and the following year in central Oklahoma, United States. A 30% reduction in gross primary productivity together with decreased ecosystem respiration over Europe during the 2003 heat wave resulted in natural ecosystems becoming a strong net source of $CO_2$ to the atmosphere and reversed the effect of four years of net ecosystem carbon sequestration. Such a reduction in Europe's primary productivity is unprecedented during the last century.

**Dzud** is a compound hazard occurring in Mongolia's cold dry climate that encompasses a range of weather extremes that take place at different times throughout the year, including drought, heavy snowfall, extreme cold and windstorms. It puts heavy pressure on ecosystems services and infrastructure, and social services. It lasts all year round and causes dramatic socioeconomic impacts, including significant loss of livestock, unemployment, poverty, and mass migration from rural to urban areas.

**Floods** impact ecosystems, including species populations. An extreme flood event affected a desert rodent community that had been monitored for 30 years. It induced a high mortality rate, eliminated the advantage of previously dominant species, reset long-term population and community trends, and altered competitive and metapopulation dynamics.

**Hurricanes and storms** can impact forest ecosystems, particularly in pre-alpine and alpine areas. Saltmarshes, mangroves, and coral reefs can also be vulnerable to such climate extremes. Hurricanes and storms can cause widespread mortality of wild birds, and their aftermath may cause further declines due to the birds' loss of resources for foraging and breeding.

**Oceanic warming and acidification** are having a negative impact on marine ecosystems and this is particularly apparent for coral reef ecosystems. Coral reefs are diverse and fragile ecosystems that deliver ecosystems services to tourism, fisheries and shoreline protection. Healthy reef systems mitigate against erosion and inundation by providing a buffer zone for the shoreline during extreme surge and wave events. They are also a source of carbonate sand and gravel for atolls, which are delivered to shore by storms and swell. Anthropogenic oceanic changes may contribute indirectly to damage to coral atolls, by affecting the health of the surrounding reef system. Such changes include:

1. warming of the surface ocean, which slows or prevents growth in temperature-sensitive species and causes more frequent coral bleaching events;

2. oceanic acidification, caused by increases in the atmospheric $CO_2$ that is absorbed by the oceans, which lowers coral growth rates; and

3. reduction in oxygen concentration in the ocean due to a combination of changes in temperature-driven gas solubility, ocean ventilation due to circulation changes, and biological cycling of organic material.

**Coastal impacts** include widespread erosion, loss or degradation of coastal ecosystems, and sea level rise. These impacts can result in significant exposure to coastal flooding. Large parts of Great Britain's coast, for example, are already experiencing this. In Poland, lagoons, river deltas, and estuaries are assessed as being particularly vulnerable. In Estonia, there are reports of increased beach erosion, believed to be the result of increased storminess in the eastern Baltic Sea since 1954, combined with a decline in sea ice cover during winter. In Germany, residents rely heavily on hard coastal protection against extreme sea level hazards, which will increase ecological vulnerability over time.

**Permafrost** is widespread in the Arctic, in subarctic regions, in ice-free areas of Antarctica, and in high-mountain regions. Permafrost regions occupy approximately 23 million km$^2$ of land areas in the northern hemisphere. Melting of massive ground ice and thawing of ice-rich permafrost can lead to landslides, slope instabilities, subsidence of the ground surface, and to the formation of uneven topography known as thermokarst. Such changes have implications for ecosystems, landscape stability, and infrastructure performance.

Box 3: Heat waves and wildfires in Australia

**An episode of extreme heat waves began in South Australia on 25 January 2009. In Melbourne, the temperature was above 43°C for three consecutive days, reaching a peak of 45.1°C on 30 January 2009, the second highest temperature on record. The extremely high day and night temperatures also combined to produce a record high daily mean temperature of 35.4°C. During the early afternoon of 7 February a power line broke just outside the town of Kilmore, sparking a wildfire that become one of the largest, deadliest, and most intense firestorms ever experienced in Australia's history. As a result of the bushfires, 173 people died and 430,000 hectares of forests, crops and pasture, and 61 businesses were destroyed.**

**A key focus during the wildfire season is protecting the reservoirs. During the February 2009 fires, billions of litres of water were moved from affected reservoirs to other safe reservoirs to protect Melbourne's drinking water from contamination with ash and debris.**

# 3. Future impacts

**Extreme events will have a broad range of impacts on both human systems and ecosystems. These include economic losses, impacts on infrastructure, and transport. Collectively these impacts can have a significant adverse effect on people, communities, and systems. This section looks ahead to explore the range of possible future impacts.**

As shown in Section 2, extreme events will have a broad range of impacts in future on both human systems and ecosystems. These impacts will include economic losses, impacts on sectors including water and agriculture, and impacts on particularly exposed settlements such as coastal cities. Collectively these impacts could have significant adverse effects on the population. A sample of impacts can be found below.

## 3.1 Impacts of extremes on ecosystems and human systems[10]

The impact of climate extremes and disasters on economies, societies, and ecosystems can be measured as the costs of damage, and losses of economic assets or stocks, as well as consequential indirect effects on economic flows, such as on GDP or consumption. Many impacts, such as the loss of human lives, cultural heritage, and ecosystem services, are difficult to measure, so they are not normally given monetary values or bought and sold, and thus are poorly reflected in estimates of losses. These items are often referred to as intangibles in contrast to tangibles, such as tradable assets, structures, and infrastructure.

Risk accumulation can be driven by underlying factors such as a decline in the regulatory services provided by ecosystems, inadequate water management, land use changes, rural-urban migration, unplanned urban growth, the expansion of informal settlements in low-lying areas, and an under-investment in drainage infrastructure. Future trends in exposure, vulnerability and climate extremes may further alter disaster risk, and associated impacts. Underlying drivers of vulnerability include inequitable development, poverty, declining ecosystems, lack of access to power, basic services and land and weak governance.

Research suggests that increasing the biological diversity of ecosystems allows a greater range of ecosystem responses to hazards, and this increases the resilience of the entire system. Other research has shown that reducing nonclimate stresses on ecosystems can enhance their resilience to climate change. This is the case for coral reefs and rainforests for example. For these reasons, managing the resources at the appropriate scale, e.g. water catchment or coastal zone, instead of managing smaller individual tributaries or coastal sub-systems (such as mangroves), is becoming more urgent. It is therefore important that the governance system is able to map to the appropriate ecological scale so that decisions can be based on an assessment of broader flows of ecosystem goods and services. At the same time it is essential that links are maintained between larger-scale governance, and local actions on the ground.

The response to extreme climate and weather impacts needs to be holistic in order to avoid a mitigation-led response, which can undermine broader resilience. For example, the planting of a monoculture forest can be effective as a carbon sink, but is highly susceptible to disease and/or reduces biodiversity. Planting trees to store carbon is another mitigation-led strategy, however, if trees are water-hungry it can reduce water availability for other uses in the area.

10. Draws on material from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability', SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems' and SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.

## 3.2 Increasing economic losses[11]

There is high confidence that economic losses from weather and climate related disasters are increasing, albeit with large inter-annual variability. Costs arise due to the economic, social, and environmental impacts of a climate extreme or disaster. Annual accumulated estimates have ranged from a few billion to about 200 billion US$ (in 2010 dollars), with the highest value for 2005 (the year of Hurricane Katrina). While measured economic losses from disasters are largest in developed countries, there is high confidence that fatality rates and economic losses as a proportion of GDP are higher in developing countries. The largest absolute adaptation costs are expected in East Asia and the Pacific.

## 3.3 Ecosystems and local communities – virtuous or vicious circle

The degradation of ecosystems is undermining the capacity of local communities to provide ecosystem goods and services upon which human livelihoods and societies depend, and to withstand disturbances, including climate change. There is evidence that the likelihood of collapse and subsequent regime shifts in ecological and coupled socio-ecological systems may be increasing in response to the magnitude, frequency, and duration of climate change and other disturbance events. This limits options for future risk management and adaptation actions locally. However, reducing human pressures on ecosystems and managing natural resources more sustainably can facilitate efforts to mitigate climate change and to reduce vulnerabilities to extreme climate and weather events.

Large, persistent shifts in ecosystem services not only affect the total level of welfare that people in a community can enjoy, they also impact the welfare distribution between people within and between generations and hence may give rise to new conflicts over resource use and questions on inter-generational equity. This could result in domino effects of increased pressure on successive resource systems, as has been suggested in the case of depletion of successive fish stocks.

11. Draws on material from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.

# 4. Managing the risks from climate extremes and disasters

**This section considers the ranges of responses required in order to try to better manage the risks of climate extremes and disasters.**

Increases in the occurrence of climate extremes and disasters will highlight and magnify the uneven distribution of risk between wealthier and poorer countries. Climate change is altering the geographical distribution, intensity and frequency of these hazards, threatening to exceed the capacities of poorer countries to absorb losses and recover from disaster impacts. So risk management becomes critical. This section considers the risk management options available to stakeholders and policy-makers.

## 4.1 Managing the risk[12]

**Ecosystem management and restoration activities that focus on addressing deteriorating environmental conditions are essential to protecting and sustaining people's livelihoods in the face of climate extremes.** Such activities include, among others, watershed rehabilitation, agro-ecology, and forest landscape restoration. Moreover, provision of better access to and control of resources will improve people's livelihoods, and build long-term adaptive capacity. Such approaches have been recommended in the past, but have not been incorporated into capacity building to date.

DRM efforts should seek to develop partnerships to tackle vulnerability drivers by focusing on approaches that:

- promote more socially-just economic systems;
- forge partnerships to ensure the rights and entitlements of people to access basic services, productive assets, and common property resources;
- empower communities and local authorities to influence the decisions of national governments, NGOs, international and private sector organisations, and to promote accountability and transparency; and
- promote environmentally sensitive development.

**Ecosystem-based adaptation strategies,** often considered 'soft' options, are widely applicable to CCA because they can be applied at regional, national and local levels, at both project and programmatic levels, and benefits can be realised over short and long time scales. They can be a more cost-effective adaptation strategy than hard infrastructures and engineering solutions, and produce multiple benefits. They are also considerably more accessible to the rural poor than measures based on hard infrastructure and engineering solutions, providing communities the opportunity to integrate, and maintain traditional and local knowledge, and cultural values in their risk reduction efforts.

12. Draws on materials from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters', SREX Chapter 7, Burton, I. et al, 'Managing the Risks: International Level and Integration Across Scales' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

Box 4: Challenges to be overcome in order to increase investment in ecosystem based solutions[13]

- ***Insufficient recognition*** **of the economic and social benefits of ecosystem services under current risk situations, let alone under potential changes in climate extremes and disaster risks.**
- ***Lack of interdisciplinary science and implementation capacity*** **for making informed decisions associated with complex and dynamic systems.**
- ***Inability to estimate economic values*** **of different ecosystem services.**
- ***Lack of capacity to undertake careful cost and benefit assessments of alternative strategies*** **to inform choices at the local level. Such assessments could provide total economic value of the full range of disaster related ecosystem services, compared with alternative uses of forested land, such as in agriculture.**
- ***Data and monitoring*** **on ecosystem status and risk are often dispersed across agencies at various scales and are not always accessible at the sub-national or municipal level, where land use planning decisions are made.**
- ***Geographic scales and mandates are mismatched*** **between the administration and responsibilities.**

Rigid plans and policies that are irreversible and based on a specific climate scenario that does not materialise can result in future maladaptation, and imply wasted investments or unnecessary harm to people and ecosystems. Adaptation and DRM approaches for many development sectors can benefit jointly from ecosystem-based adaptation and integrated land, water, and coastal zone management actions. For example, conservation and sustainable management of ecosystems, forests, land, and biodiversity have the potential to create 'win-win' disaster risk protection services for agriculture, infrastructure, cities, water resource management, and food security. Such approaches can also create synergies between CCA and mitigation measures, as well as produce many co-benefits that address other development goals, including improvements in livelihoods, and human well-being, particularly for the poor and vulnerable.

When considering an ecosystem-based adaptation option, decision-makers may need to make trade-offs among particular climatic risk reduction services, and other ecosystem services that are valued by society. Their choices would need to be subject to risk assessment, scenario planning, and adaptive management approaches that recognise and incorporate these potential trade-offs.

For example, deciding whether to manage wetlands in a way that stabilises them and accumulates silt for coastal protection would be a complex decision requiring long-term thinking: because such actions could affect wildlife and recreational values. Decision-makers need to overcome a number of challenges to be successful in increasing investment in ecosystem-based solutions, as outlined in Box 4.

13. Draws on materials from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.

**Enhanced scientific modelling and interdisciplinary approaches to early warning systems** can address some of these uncertainties, provided good baseline and time series information is available. However, even where such information is available, there remain other unresolved questions that influence the outcome of hazards. These relate to the capacity of ecosystems to provide buffering services, and the ability of systems to recover. Management approaches that take these issues into account include adaptive management, and resilience.

**Adaptive management** can be defined as a structured process for improving management policies and practices by systemic learning from programmatic outcomes. Adaptive management takes into account changes in external factors in a proactive manner. It is often associated with organisations that are not locked into rigid agendas and practices, such that they can consider new information, new challenges, and new ways of operating. Where this approach has worked best, outcomes have gone beyond specific management goals to include trust-building among stakeholders, a resource fundamental to any policy environment facing an uncertain future, and which also has benefits for quality of life, and market competitiveness.

Adaptive management requires revisiting the roles of and relationship between the state and local actors concerning support for innovation, particularly when experiments go wrong. Investing in experimentation and innovation necessarily requires some tolerance for projects that may not be productive or cost effective, or at least not in the short-term or under existing risk conditions. However, it is exactly the existence of this diversity that makes societies fit to adapt once risk conditions change, particularly in unexpected and nonlinear directions. Box 5 highlights some examples.

Box 5: Range of interventions to reduce the effect of disasters and enhance resilience[14]

**Observed trends in reducing the effects of disasters:**

- **Effective Early Warning Systems and emergency preparedness *(very high confidence).***
- **Integrated water resource management *(high confidence).***
- **Rehabilitation of degraded coastal and terrestrial ecosystems *(high confidence).***
- **Robust building codes and standards reflecting knowledge of current disaster risks *(high confidence).***
- **Ecosystem-based/nature-based investments, including ecosystem conservation measures *(high confidence).***
- **Micro-insurance, including weather-indexed insurance *(medium confidence).***
- **Vulnerability reducing measures such as pro-poor economic and human development, through, for example, improved social services and protection, employment, and wealth creation *(very high confidence).***

**Practices that enhance resilience to projected changes in disaster risk:**

- **Crop improvement for drought tolerance, adaptive agricultural practices, including responses to enhanced weather and climate prediction services *(high confidence).***
- **Integrated coastal zone management integrating projections of sea level risk and weather/climate extremes *(medium confidence).***
- **National water policy frameworks, and water supply infrastructures that incorporate future climate extremes and demand projects *(medium-high confidence).***
- **Strengthened and enforced building codes, standards for changed climate extremes *(medium confidence).***
- **Advances in human development and poverty reduction measures, through, for example, social protection, employment, wealth creation measures, taking future exposure to weather and climate extremes into account *(very high confidence).***

14. Draws on materials from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.

## 4.2 The importance of ecosystems is recognised at the international level[15]

The UNFCCC is a multilateral treaty aimed at addressing climate change. Its ultimate objective as stated in Article 2 is 'to achieve… stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner'. In the later United Nations Global Assessment Report on Disaster Risk Reduction (GAR), this calls for 'an urgent paradigm shift' in DRR to address the underlying risk drivers such as vulnerable rural livelihoods, poor urban governance, and declining ecosystems. To date one of the most important mechanisms devised for addressing a key ecosystems challenge has been the Reducing Emissions from Deforestation and Degradation, (REDD+), maintaining/enhancing carbon stocks and promoting sustainable forest management mechanism. This is highlighted in Box 6.

Box 6: The example of REDD+ at the international level

**International attention and support for efforts focused on REDD+ is increasing. This is an example of where incentives for the protection and sustainable management of natural resources driven by mitigation concerns also has the potential to generate co-benefits for adaptation. Ecosystem services supplied by forests can increase resilience to some climatic changes by mediating run-off and reducing flood risk, protecting soil from water and wind erosion, providing climate regulation, and providing migration corridors for species. Under the Amazon Protected Areas Program, Brazil has created a mosaic of more than 30 million hectares of biodiversity-rich forests, comprising state, provincial, private, and indigenous land. This forest reserve has the potential to reduce emissions estimated at 1.8 billion tonnes of carbon through avoided deforestation. Primary forests tend to be more resilient to disturbance and environmental changes, such as climate change, than secondary forests and plantations. However, forests are also vulnerable to climatic extremes, and the effects of global warming. Hence, the role of forest ecosystems in climate change mitigation and adaptation will itself depend on the rate and magnitude of climate change and whether the crossing of ecological tipping points can be avoided.**

15. Draws on materials from Chapter 7, Burton, I. et al, 'Managing the Risks: International Level and Integration Across Scales'.

# 5. Conclusions: what does this mean for decision-makers?

**This final section considers the implications for ecosystems in more detail. As manifestations of climate change such as climate extremes become more severe, disaster impacts are likely to increase. The capacity to meet this challenge will be determined by the effectiveness of risk management systems, including both adaptation and mitigation measures. Support to ecosystems can contribute to both of these.**

**Some countries are poorly prepared and need to reassess their vulnerability, exposure, and investments in order to better manage disaster risks. A new balance needs to be struck between measures to reduce and transfer risk, and to effectively prepare for and manage disaster impacts in a changing climate.**

## 5.1 Integrating DRM, CCA and sustainable development[16]

Sustainable development involves finding pathways that achieve a variety of socioeconomic and environmental goals, preferably without sacrificing any one for the sake of the others. As a result the relationships among adaptation, DRM, and sustainability are highly political. Successful reconciliation of multiple goals 'lies in answers to questions such as who is in control, who sets agendas, who allocates resources, who mediates disputes, and who sets the rules of the game'.[17]

There are many potential synergies between DRM and CCA strategies and tools that can contribute to social, economic, and environmental sustainability – and to a resilient future.

Box 7 provides specific examples of the value of ecosystem services in DRM and adaption.

**Box 7: Value of ecosystem services in DRM: some examples[18]**

- **In Vietnam, the Red Cross began planting mangroves in 1994 with the result that, by 2002, some 12,000 hectares of mangroves had cost US$ 1.1 million for planting but saved annual levee maintenance costs of US$ 7.3 million, shielded inland areas from a significant typhoon in 2000, and restored livelihoods in planting and harvesting shellfish.**
- **In the Maldives, degradation of protective coral reefs necessitated the construction of artificial breakwaters at a cost of US$ 10 million per kilometre.**
- **In the United States, wetlands are estimated to reduce flooding associated with hurricanes at a value of US$ 8,250 per hectare per year, and US$ 23.2 billion a year in storm protection services.**
- **In Orissa, India, a comparison of the impact of the 1999 super cyclone on 409 villages in two tahsils (administrative sub division of a district) with and without mangroves, show that villages that had healthy strands of mangroves suffered significantly less loss of life than those without (or with limited areas of) healthy mangroves, even though all villages had the benefit of early warning. The study controlled for other social and economic variables.**

16. Draws on material from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
17. Wilbanks, 1994.
18. Draws on material from SREX Chapter 1, Diop, C. et al, 'Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability and Resistance' and SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.

Some countries have begun to explicitly consider ecosystem-based solutions for climate change mitigation and/or adaptation to the risks associated with weather and climate extremes as an integral element of national and sectoral development decisions. Some examples are provided in Box 8.

How well a community responds to and survives disaster depends upon the resources that can be used to cope. Adaptation in anticipation of extreme events can help to limit the 'coping' that may be required to survive the next disaster, whilst adaptive capacity focuses on longer-term and more sustained adjustments. As possible climate futures are uncertain, 'low regrets' adaptation strategies are often recommended. They have net benefits over the range of anticipated future climate and associated impacts. Learning is also essential to risk management and adaptation.

Box 8: Some examples of ecosystem-based mitigation and adaptation strategies and DRM interventions[19]

- **Vietnam has applied Strategic Environmental Assessments to land use planning projects and hydropower development for the Vu Gia-Thu Bon river basin, including climatic disaster risks.**
- **European countries affected by severe flooding, notably the UK, the Netherlands, and Germany, have made policy shifts to make space for water by applying more holistic River Basin Management Plans and Integrated Coastal Zone Management.[20]**
- **At the regional level, the Caribbean Development Bank has integrated weather and climatic disaster risks into its Environmental Impact Assessments for new development projects.**
- **Under the Amazon Protected Areas Program, Brazil has created a mosaic of over 30 million hectares of biodiversity-rich forests reserve of state, provincial, private, and indigenous land, resulting in potential reduction in emissions estimated at 1.8 billion tons of carbon, through avoided deforestation.**
- **In Muminabad, Tajikistan a Swiss Development Cooperation project adopted an integrated approach to risk through reforestation and integrated watershed management.**

One way of increasing the effectiveness of climate disaster preparedness would be to exploit the potential synergies between DRM and adaptation to climate change. There are many potential synergies between DRM and CCA that can contribute to a sustainable and resilient future. Although there is no single approach, framework or pathway to achieve this, some important contributing factors have been identified. These include reducing exposure, reducing vulnerability, transferring and sharing risks and adequate preparation, response and recovery. These are captured in Figure 3.

Figure 3: Integrating adaptation and DRM approaches for a changing climate

**Risks acceptance threshold**

**Reduce risks**

**Reduce vulnerability**

- Poverty reduction.
- Health improvements.
- Access to services and productive assets enhanced.
- Livelihood diversification.
- Access to decision-making increased.
- Community security improved.

**Reduce hazards and exposure**

- Mainstream risk management into development processes.
- Building codes and retrofitting.
- Defensive infrastructure and environmental buffers.
- Land use planning.
- Catchment and other ecosystem management.
- Incentive mechanisms for individual actions to reduce exposure.

**Pool, transfer and share risks**

- Mutual and reserve funds.
- Financial insurance.
- Social networks and social capital.
- Alternative forms of risk transfer.

**Manage residual risks and uncertainties**

**Prepare and respond effectively**

- Early warning and communication.
- Evacuation plan.
- Humanitarian: relief supplies.
- Post-disaster livelihood support and recovery.

**Increase capacity to cope with 'surprises'**

- Flexibility in decision-making.
- Adaptive learning and management.
- Improved knowledge and skills.
- Systems transformation over time.

19. Draws on material from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.
20. This is a requirement under the EU Water Framework Directive 2000/60/EC. This has a timetable for implementation from 2000 to 2027.

## 5.2 Developing adaptation strategies: the importance of national systems[21]

The challenge for countries is to manage short-term climate variability while also ensuring that different sectors and systems become more resilient and adaptable to changing extremes and risks over the long-term. The requirement is to balance the short-term and the longer-term actions needed to resolve the underlying causes of vulnerability, and to understand the nature of changing climate hazards. Achieving adaptation and DRM objectives while attaining human development goals requires a number of cross-cutting, inter-linked sectoral and development processes, as well as effective strategies within sectors, and coordination between sectors.

It will be important to manage trade-offs in an open, efficient and transparent way with supportive institutional and legal arrangements for this. Climate change is far too big a challenge for any single ministry of a national government to undertake. Effective adaptation and risk reduction coordination among all sectors may only be realised if all areas of government are coordinated from the highest political and organisational level. Therefore, national systems need to be at the core of countries' capacity to meet climate challenges. Greater efforts are required to address the underlying drivers of risk and generate political will to invest in DRM. Changes in weather and climate extremes pose new challenges for national DRM systems, which are often poorly adapted to the risks. A range of possible ecosystem-based measures at national level, from 'low regrets' to 'win-win', is identified in Table 1.

Table 1: Range of adaptation strategies at national level

| 'Low regrets' actions for current and future risks | ('Low regrets' options plus…) Preparing for climate change risks by reducing uncertainties (building capacity) | ('Preparing for climate change' risks plus...) Reduce risks from future climate change | Risk transfer | Accept and deal with increased and unavoidable (residual) risks | 'Win-win' synergies for greenhouse gas reduction, adaptation, risk reduction, and development benefits |
|---|---|---|---|---|---|
| • Use of Ecosystem based Adaptation (EbA) or 'soft engineering'; integrate DRR and climate adaptation into integrated coastal zone and water resources management, forest management, and land use management, conserve, enhance resilience of ecosystems, and restore protective ecosystems services.<br>• Adaptive forest management, forest fire management, controlled burns; agroforestry; biodiversity conservation.<br>• Reduce forest degradations, unsustainable harvest, and provide incentives for alternative livelihoods, eco-tourism. | • Synergies between UNFCCC and Rio conventions; avoid actions that interfere with goals of other UN conventions.<br>• Research on climate change-ecosystem-forest links, climate and ecosystem prediction systems, climate change projections; monitor ecosystems and climate trends.<br>• Incorporate ecosystem management into National Adaptation Programmes of Action and DRR plans. | • Adaptation to modify climate change interventions to maintain ecosystem resilience; corridors, assisted migrations; planned EbA for climate change.<br>• Seed, genetic banks, new genetics, tree species improvement to maintain ecosystem services in future, adaptive agroforestry.<br>• Changed timber harvest management, new technologies for adaptation to climate change, new uses to conserve forest ecosystem services. | • Micro-finance and insurance to compensate for lost livelihoods.<br>• Investments in additional insurance, government reserve funds for increased risks due to loss of protective ecosystem services. | • Replace lost ecosystem services through additional hard engineering, health measures.<br>• Restore loss of damaged ecosystems. | • Sustainable afforestation (for robust forests), reforestation, conservation of forest wetlands and peatlands, sustainable and increased biomass, sustainable land use, land use change, and forestry; reducing emissions from deforestation.<br>• Incentives for sustainable sequestration of carbon; sustainable bio energy; energy self sufficiency. |

21. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

## 5.3 Building long-term resilience: from incremental to transformational approaches[22]

If extreme climate and weather events increase significantly in coming decades, CCA and DRM are likely to require not only *incremental (small, within existing technology and governance systems)* changes, but also *transformational (large, new system)* changes in processes and institutions. As the GAR highlighted above, there is a need for a paradigm shift. This will involve moving away from a focus on issues and events towards a change in culture and overall approach.

## 5.4 Planning for an uncertain future

**Partnerships:** Among the most successful DRM and adaptation efforts are those that have facilitated the development of partnerships between local leaders and other stakeholders, including extra-local governments. This allows local strength and priorities to surface, while acknowledging that communities and local governments have limited resources and strategic scope to address the underlying drivers of risk on their own.

**Leadership** can be critical for DRM and CCA, particularly in initiating processes and sustaining them over time. Change processes are shaped by the action of individual champions (including those resisting change and their interactions with organisations, institutional structures, and systems). Determined local leadership, such as in the Ethekwini Municipality for Durban, South Africa, has resulted in skillful planning, with a Municipal Climate Protection Programme, without national level policy or legal frameworks to guide adaptation planning at the local level. Leadership can be a driver of change, providing direction, and motivating others to follow. A number of private sector organisations have demonstrated this at Chair and CEO level enabling transformational change within their organisations.

### Some practical suggestions towards a more sustainable and resilient future

**Investment** in increasing knowledge and warning systems, developing adaptation techniques and tools, and implementing preventive measures will cost money now – but it will save money, species and lives in the future.

**Research** improves our knowledge, especially when it includes integration of natural, social, health, and engineering sciences and their applications. Ecosystems research can reveal the full benefits of ecosystem conservation and restoration across a range of social and economic criteria, including climate change resilience, which thus informs more robust decision-making on the trade-offs among different uses of ecosystem products and services. Research can also explore which climate mitigation options actively undermine the resilience of ecosystems, and the societies dependent upon them, in order to inform the design of effective and sustainable mitigation interventions.

**Empower all stakeholders:** Identifying the drivers of hazard and vulnerability in ways that empower all stakeholders to take action is key. This is done best where local and scientific knowledge is combined in the generation of risk maps or risk management plans, e.g. in the UK where citizens are voluntarily mobilised to gather species data for signs of change including for birds, butterflies and flora, providing data for scientific analysis on the changing climate and its implications. There is also need for better coordination and accountability within governance hierarchies and across sectors, and between international actors where they are engaged.

**International actors** can help by providing an institutional framework to support experimentation, innovation and flexibility, financing risk transfer, and supporting funding for ecosystem-based adaptation.

**Technology** is an essential part of responses to climate extremes, at least partly because technology choices and uses are so often a part of the problem. Appropriately deployed technology can transform ecosystem management, for example through the development of terracing techniques to reduce soil erosion, the development of innovative fire break techniques to limit fires, and the innovation of sluice and drainage technologies to manage scarce water resources more prudently. Although technology is an essential part of adaptation, climate change responses can also be improved by addressing social vulnerability, rather than focusing exclusively on technological approaches.

**Transformation** can imply loss of the familiar, creating a sense of disequilibrium and uncertainty. Desirable or not, transformations are occurring at an unprecedented rate and scale, influenced by globalisation, social and technological development, and environmental change. Climate change itself represents a system-scale transformation that will have widespread consequences on ecology and society, including through changes in climate extremes. Responses to climate change and changes in disaster risk can be both incremental and transformational. Sound ecosystem management and restoration of ecosystem services has been proven to have many co-benefits for livelihoods and quality of life, as well as for current and future climate adaptation and resilience. A great many restorative actions can therefore be considered very low regrets. A transformation is required in the respect and value accorded to valuable ecological assets if these assets and the services they deliver are to be maintained. Transformation calls for leadership, both from authority figures who hold positions and power, and from individuals and groups who connect present-day actions with building a sustainable and resilient future.

### For further information

**The Summary for Policy Makers, full report, fact sheet and video is available at: www.ipcc-wg2.gov/srex.**

**Other useful links including videos and recommended reading are on the CDKN website here: www.cdkn.org/srex.**

22. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

# ANNEXES

# Annex I: Acronyms

| | |
|---|---|
| **CBO** | Community Based Organisations |
| **CCA** | Climate Change Adaptation |
| **CDKN** | Climate and Development Knowledge Network |
| **CSO** | Civil Society Organisations |
| **DRM** | Disaster Risk Management |
| **DRR** | Disaster Risk Reduction |
| **EbA** | Ecosystem based Adaptation |
| **EM-DAT** | Emergency Disasters Database |
| **GCM** | Global Climate Model |
| **GDP** | Gross Domestic Product |
| **IFIs** | International Financial Institutions |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **LDC** | Least Developed Countries |
| **MEA** | Millennium Ecosystem Assessment |
| **SREX** | The Special Report on Managing the Risks of Extreme events and Disasters to Advance Climate Change Adaption |
| **REDD+** | Reducing Emissions from Deforestation and Degradation |

# Annex II: Changes in climate extremes

Key

**Symbols**

- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

**Level of confidence in findings**

- Low confidence
- Medium confidence
- High confidence

## Africa

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Africa. A summary of this information is captured in Table 2 and 3.

Table 2: Observed changes in temperature and precipitation extremes since the 1950s[24]

**Table 2 shows observed changes in temperature and precipitation extremes, including dryness in regions of Africa since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).**

| Region and Sub-region | Trends in maximum temperature (warm and cold days)[25] | Trends in minimum temperature (warm and cold nights)[26] | Trends in heat waves/ warm spells[27] | Trends in heavy precipitation (rain, snow)[28] | Trends in dryness and drought[29] |
|---|---|---|---|---|---|
| **West Africa** | Significant increase in temperature of warmest day and coolest day in large parts<br>Insufficient evidence in others | Increasing frequency of warm nights (decrease in cold nights in large parts)<br>Insufficient evidence in others | Insufficient evidence for most of the region | Precipitation from heavy rainfall events decreased in many areas (low spatial coherence), rainfall intensity increased | Increased dry spell duration, greater inter-annual variation in recent years |
| **East Africa** | Lack of evidence due to lack of literature and spatially non-uniform trends | Spatially varying trends in most areas<br>Increase in warm nights in southern tip (decrease in cold nights) | Insufficient evidence for most of the region | Insufficient evidence | Spatially varying trends in dryness |
| **Southern Africa** | Increase in warm days (decrease in cold days) | Increase in warm nights (decrease in cold nights) | Increase in warm spell duration | No spatially coherent patterns of trends in precipitation extremes | General increase in dryness |
| **Sahara** | Lack of literature | Increase in warm nights<br>Lack of literature on trends in cold nights | Insufficient evidence | Insufficient evidence | Limited data, spatial variation of the trends |

24. Period 1961 to 1990 used as a baseline.
25. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
26. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
27. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
28. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
29. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Table 3: Projected changes in temperature and precipitation extremes, including dryness, in Africa

**Table 3 shows projected changes in temperature and precipitation extremes, including dryness, in Africa. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[30] outputs run under the A2/A1B emissions scenario.**

| Region and Sub-region | Trends in maximum temperature (the frequency of warm and cold days)[31] | Trends in minimum temperature (the frequency of warm and cold nights)[32] | Trends in heat waves/ warm spells[33] | Trends in heavy precipitation (rain, snow)[34] | Trends in dryness and drought[35] |
|---|---|---|---|---|---|
| **West Africa** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Slight or no change in heavy precipitation indicators in most areas<br>Low model agreement in northern areas | Inconsistent signal |
| **East Africa** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Likely increase in heavy precipitation indicators | Decreasing dryness in large areas |
| **Southern Africa** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Lack of agreement in signal for region as a whole<br>Some evidence of increase in heavy precipitation in southeast regions | Increase in dryness, except eastern part<br>Consistent increase in area of drought |
| **Sahara** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Low agreement or no signal | Inconsistent signal of change |

30. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
31. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
32. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
33. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
34. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
35. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

## Asia

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Asia. A summary of this information is captured in Table 4 and 5.

**Key**

**Symbols**

- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

**Level of confidence in findings**

- Low confidence
- Medium confidence
- High confidence

Table 4: Observed changes in temperature and precipitation extremes since the 1950s[36]

**Table 4 shows observed changes in temperature and precipitation extremes, including dryness in regions of Asia since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).**

| Region and Sub-region | Trends in maximum temperature (warm and cold days)[37] | Trends in minimum temperature (warm and cold nights)[38] | Trends in heat waves/ warm spells[39] | Trends in heavy precipitation (rain, snow)[40] | Trends in dryness and drought[41] |
|---|---|---|---|---|---|
| **North Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Spatially varying trends | Increase in some regions, but spatial variation | Spatially varying trends |
| **Central Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Increase in warm spells in a few areas<br>Insufficient evidence in others | Spatially varying trends | Spatially varying trends |
| **East Asia** | Likely increase in warm days (decrease in cold days) | Increase in warm nights (decrease in cold nights) | Increase in heat waves in China<br>Increase in warm spells in northern China, decrease in southern China | Spatially varying trends | Tendency for increased dryness |
| **Southeast Asia** | Increase in warm days (decrease in cold days) for northern areas<br>Insufficient evidence for Malay Archipelago | Increase in warm nights (decrease in cold nights) for northern areas<br>Insufficient evidence for Malay Archipelago | Insufficient evidence | Spatially varying trends, partial lack of evidence | Spatially varying trends |
| **South Asia** | Increase in warm days (decrease in cold days) | Increase in warm nights (decrease in cold nights) | Insufficient evidence | Mixed signal in India | Inconsistent signal for different studies and indices |
| **Western Asia** | Very likely increase in warm days (decrease in cold days more likely than not) | Likely increase in warm nights (decrease in cold nights) | Increase in warm spells | Decrease in heavy precipitation events | Lack of studies, mixed results |
| **Tibetan Plateau** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Spatially varying trends | Insufficient evidence | Insufficient evidence. Tendency to decreased dryness |

Table 5: Projected changes in temperature and precipitation extremes, including dryness, in Asia

**Table 5 shows projected changes in temperature and precipitation extremes, including dryness, in Asia. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[42] outputs run under the A2/A1B emissions scenario.**

| Region and Sub-region | Trends in maximum temperature (the frequency of warm and cold days)[43] | Trends in minimum temperature (the frequency of warm and cold nights)[44] | Trends in heat waves/ warm spells[45] | Trends in heavy precipitation (rain, snow)[46] | Trends in dryness and drought[47] |
|---|---|---|---|---|---|
| **North Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Likely increase in heavy precipitation for most regions | Inconsistent signal of change |
| **Central Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Inconsistent signal in models | Inconsistent signal of change |
| **East Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Increase in heavy precipitation across the region | Inconsistent signal of change |
| **Southeast Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells over continental areas<br>Low confidence in changes for some areas | Inconsistent signal of change across most models (more frequent and intense heavy precipitation suggested over most regions) | Inconsistent signal of change |
| **South Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Slight or no increase in %DP10 index<br>More frequent and intense heavy precipitation days over parts of S. Asia | Inconsistent signal of change |
| **West Asia** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Inconsistent signal of change | Inconsistent signal of change |
| **Tibetan Plateau** | Likely increase in warm days (decrease in cold days) | Likely increase in warm nights (decrease in cold nights) | Likely more frequent and/or longer heat waves and warm spells | Increase in heavy precipitation | Inconsistent signal of change |

36. Period 1961 to 1990 used as a baseline.
37. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
38. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
39. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
40. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
41. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.
42. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
43. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
44. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
45. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
46. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
47. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

## Latin America and the Caribbean

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Latin America and the Caribbean. A summary of this information is captured in Table 6 and 7.

**Key**

**Symbols**

- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

**Level of confidence in findings**

- Low confidence
- Medium confidence
- High confidence

Table 6: Observed changes in temperature and precipitation extremes since the 1950s[48]

**Table 6 shows observed changes in temperature and precipitation extremes, including dryness in regions of Latin America since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).**

| Region and Sub-region | Trends in maximum temperature (warm and cold days)[49] | Trends in minimum temperature (warm and cold nights)[50] | Trends in the heat waves/warm spells[51] | Trends in heavy precipitation (rain, snow)[52] | Trends in dryness and drought[53] |
|---|---|---|---|---|---|
| **Amazon** | Insufficient evidence to identify a significant trend | Insufficient evidence to identify a significant trend | Insufficient evidence | Increase in many areas, decrease in a few areas | Decrease in dryness for much of the region. Some opposite trends and inconsistencies |
| **Northeastern Brazil** | Increase in warm days | Increase in warm nights | Insufficient evidence | Increase in many areas, decrease in a few areas | Varying and inconsistent trends |
| **Southeastern South America** | Spatially varying trends (increase in some areas decrease in others) | Increase in warm nights (decrease in cold nights) | Spatially varying trends (increase in some areas, decrease in others) | Increase in northern areas<br>Insufficient evidence in southern areas | Varying and inconsistent trends |
| **West Coast South America** | Spatially varying trends (increase in some areas decrease in others) | Increase in warm nights (decrease in cold nights) | Insufficient evidence | Increase in some areas, decrease in others | Varying and inconsistent trends |
| **Central America and Mexico** | Increase in warm days (decrease in cold days) | Increase in warm nights (decrease in cold nights) | Spatially varying trends (increase in some areas, decrease in others) | Increase in many areas, decrease in few areas | Varying and inconsistent trends |

48. Period 1961 to 1990 used as a baseline.
49. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
50. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
51. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
52. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
53. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Table 7: Projected changes in temperature and precipitation extremes at the end of 21st century[54]

**Table 7 shows projected changes in temperature and precipitation extremes, including dryness in Latin America. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[55] outputs run under the A2/A1B emissions scenario.**

| Region and Sub-region | Trends in maximum temperature (the frequency of warm and cold days)[56] | Trends in minimum temperature (the frequency of warm and cold nights)[57] | Trends in the heat waves/warm spells[58] | Trends in heavy precipitation (rain, snow)[59] | Trends in dryness and drought[60] |
|---|---|---|---|---|---|
| **Amazon** | Likely increase in warm days (likely decrease in cold days) | Very likely increase in warm nights (likely decrease in cold nights) | Likely more frequent and longer heat waves and warm spells | Tendency for increases in heavy precipitation events | Inconsistent trends |
| **Northeastern Brazil** | Likely increase in warm days (likely decrease in cold days) | Likely increase in warm nights (likely decrease in cold nights) | Likely more frequent and longer heat waves and warm spells in some studies. Non-significant signal in others | Slight or no change | Increase in dryness |
| **Southeastern South America** | Likely increase in warm days (likely decrease in cold days) | Very likely increase in warm nights (likely decrease in cold nights) | Tendency for more frequent and longer heat waves and warm spells | Increases in northern areas<br>Insufficient evidence in southern areas | Inconsistent trends |
| **West Coast South America** | Likely increase in warm days (likely decrease in cold days) | Likely increase in warm nights (likely decrease in cold nights) | Likely more frequent and longer heat waves and warm spells | Increases in tropics<br>Insufficient evidence in extratropics | Varying and inconsistent trends |
| **Central America and Mexico** | Likely increase in warm days (likely decrease in cold days) | Likely increase in warm nights (likely decrease in cold nights) | Likely more frequent, longer and/or more intense heat waves/warm spells in most of the region | Inconsistent trends | Increase in dryness in Central America and Mexico, with less confidence in trend in extreme South of region |

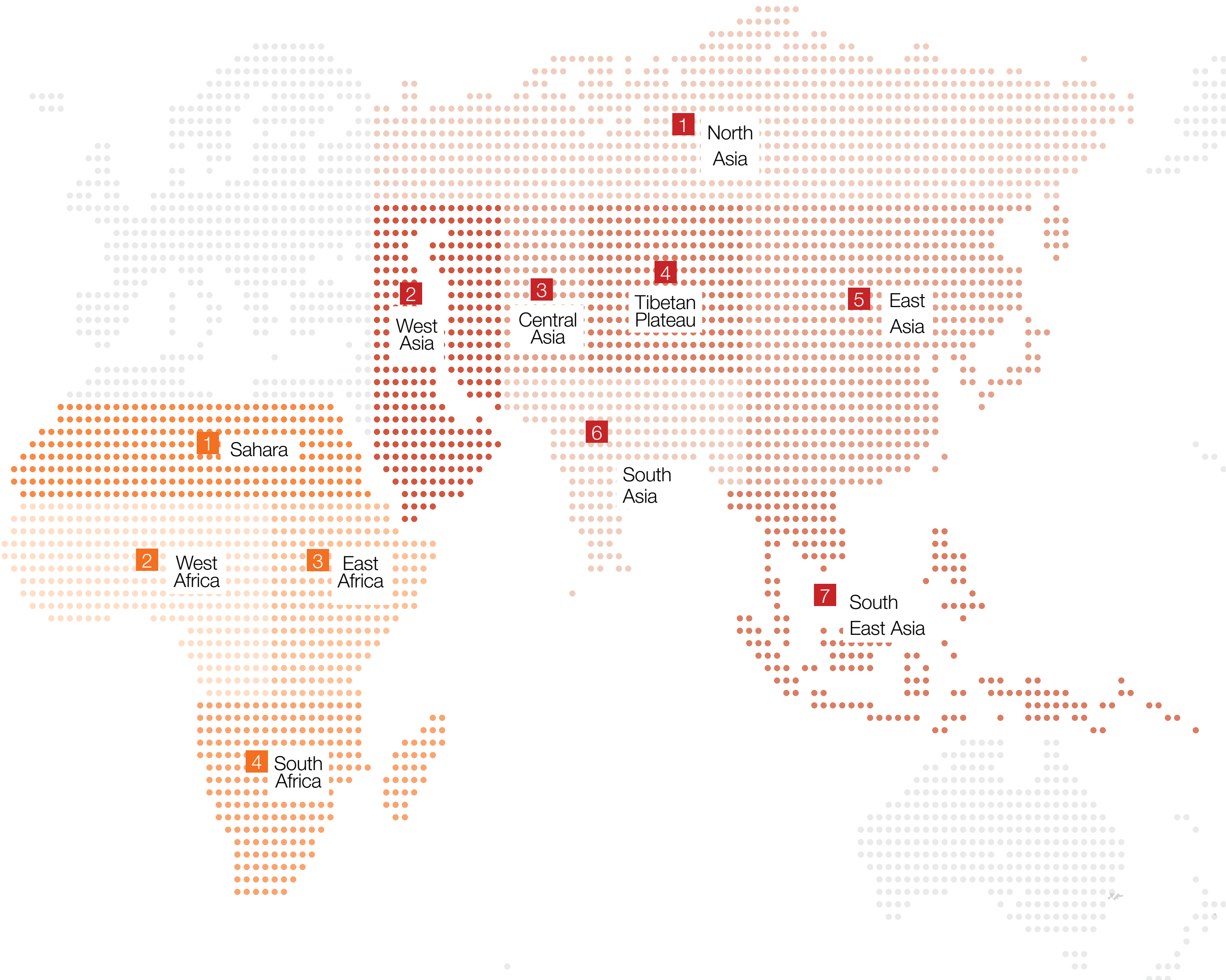
54. Projections are for the end of the 21st century vs end of the 20th century (e.g. 1961 to 1990 or 1980 to 2000 vs 2071 to 2100 or 2080 to 2100) and for the A2/A1B emissions scenario.
55. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
56. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
57. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
58. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
59. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
60. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

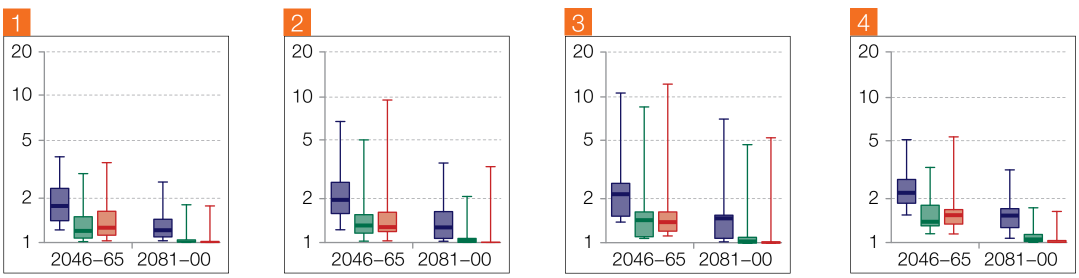
# Annex III: Return period maps

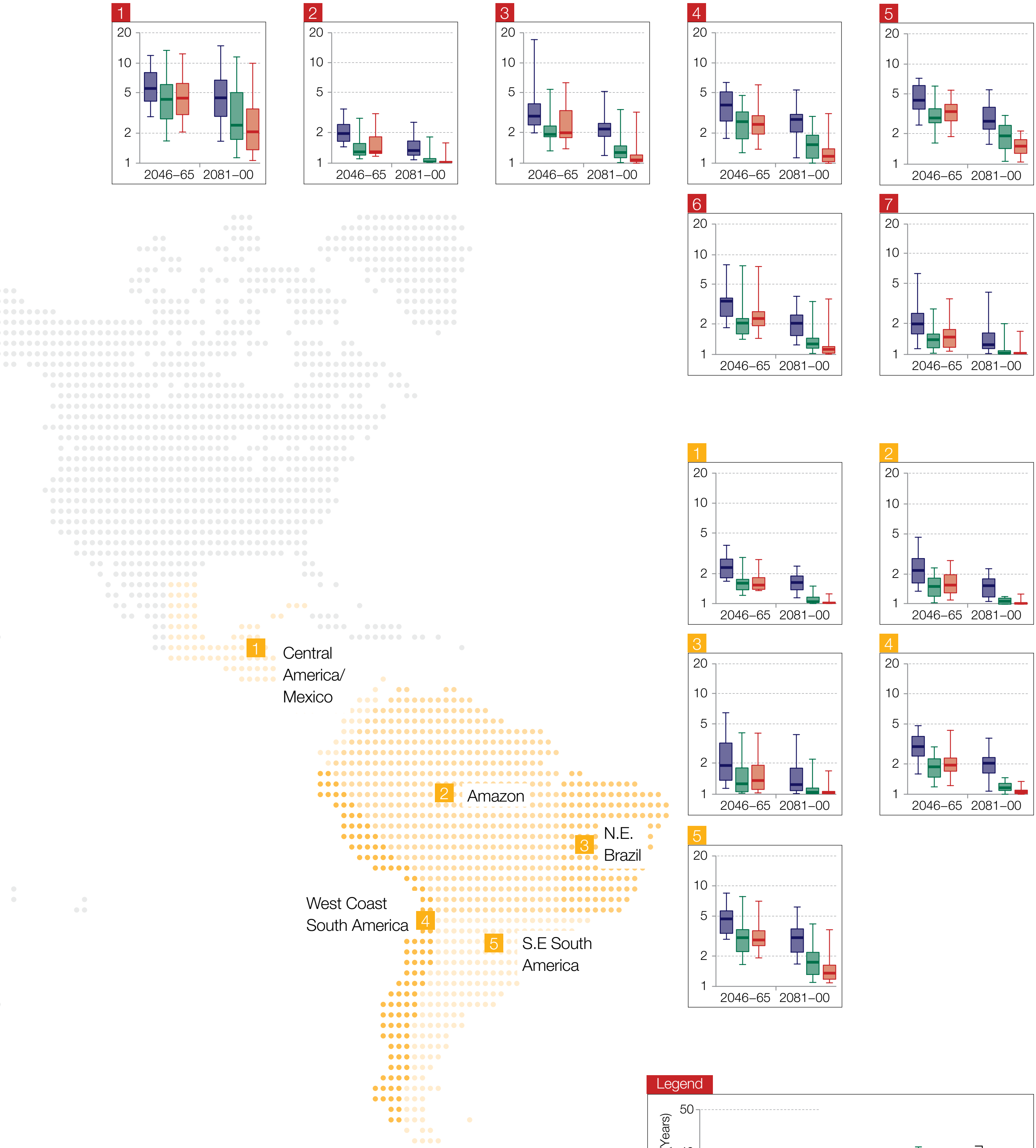
## (a) Temperature

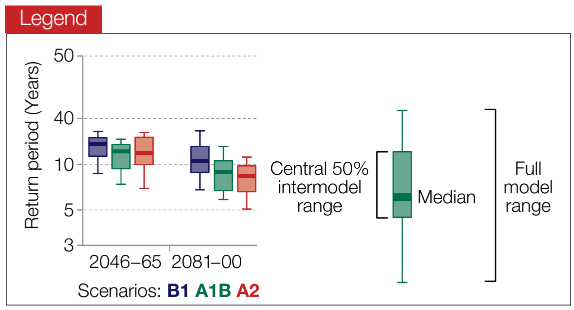
The temperature graph shows how often the hottest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[61]

For example the hottest day experienced in the last 20 years at the end of the 20th century will occur at least biannually by 2046-65 across the continent and under both the A1B and A2 scenarios by 2100, every year, everywhere. What is now an extreme will become normal.



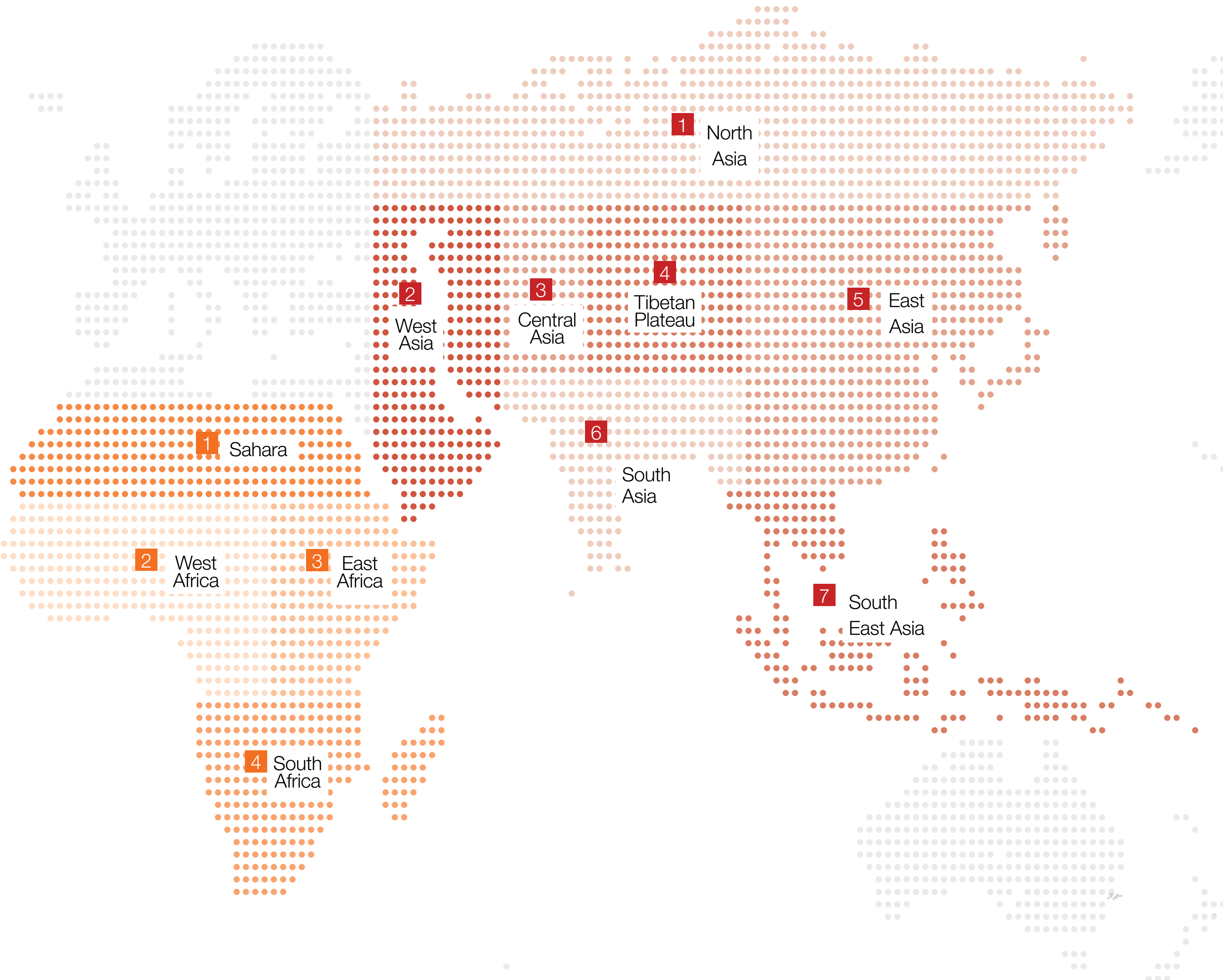


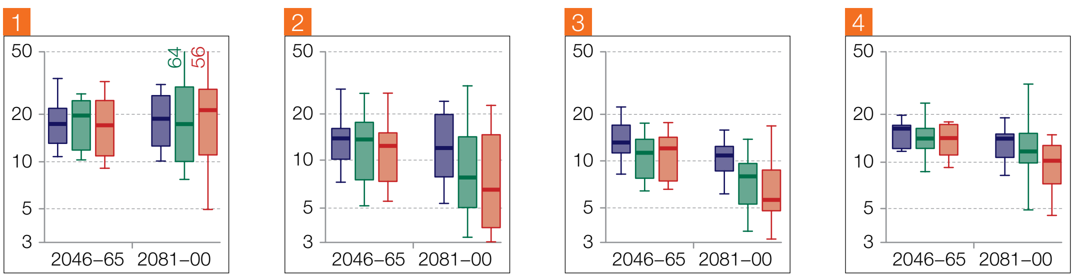



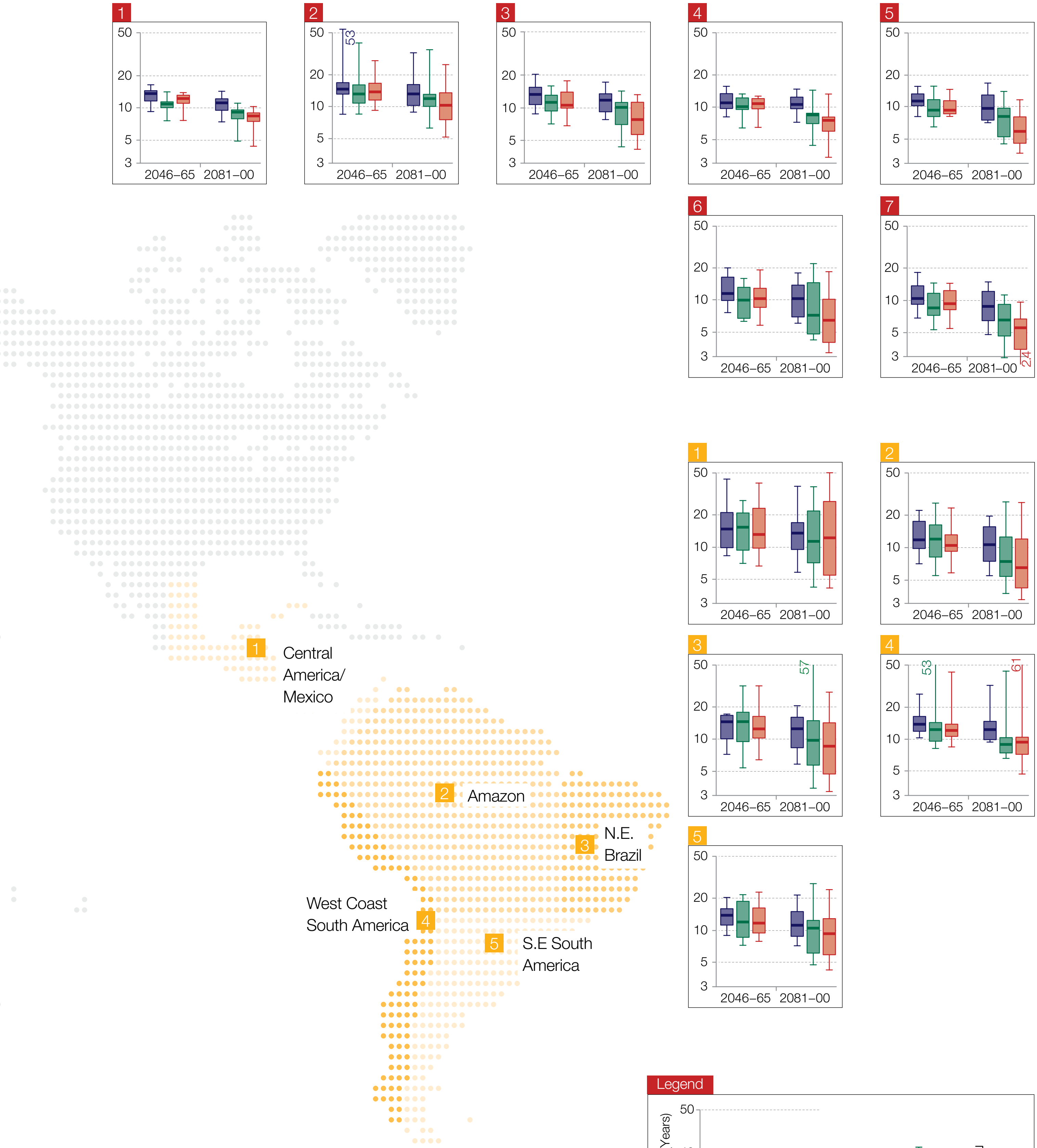

61. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development and growth, with balanced technological development across all sources, i.e. neither fossil intensive nor all non-fossil sources.
A2 is a heterogeneous world with self reliance and local identity, regional economic development, fragmented and slower growth.
See www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf Figure 1 for more information.

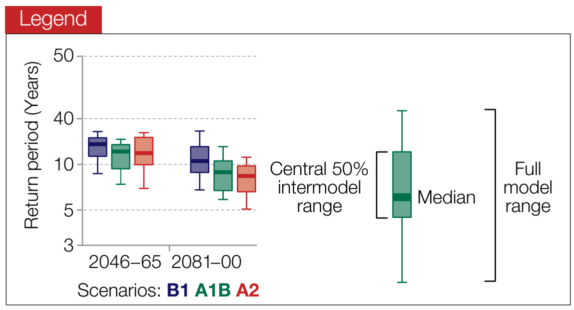
## (b) Precipitation

These graphs show how often the wettest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[62] For example, in East Asia and the Tibetan Plateau, the wettest day experienced in the last 20 years at the end of the 20th century will happen more like every 10 years by the end of the 21st Century depending on which emissions scenario is followed.



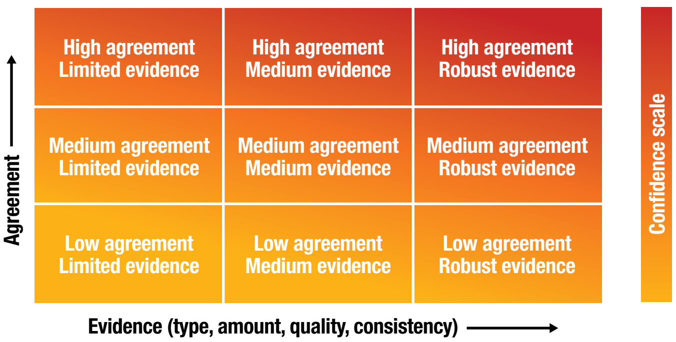



62. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development and growth, with balanced technological development across all sources. i.e. neither fossil intensive nor all non-fossil sources.
A2 is a heterogeneous world with self reliance and local identity, regional economic development, fragmented and slower growth.
See www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf Figure 1 for more information.

# Annex IV: IPCC uncertainty guidance

The standard terms used to define levels of confidence in this report are as given in the IPCC SREX uncertainty guidance note, namely:




The standard terms used in this report to define the likelihood of an outcome or result where this can be estimated probabilistically are:

| Term[63] | Likelihood of the outcome |
|---|---|
| Virtually certain | 99 to 100% probability |
| Very likely | 90 to 100% probability |
| Likely | 66 to 100% probability |
| About as likely as not | 33 to 66% probability |
| Unlikely | 0 to 33% probability |
| Very unlikely | 0 to 10% probability |
| Exceptionally unlikely | 0 to 1% probability |

63. Additional terms that were used in limited circumstances in the Fourth Assessment Report (extremely likely: 95 to 100% probability, more likely than not: >50 to 100% probability, and extremely unlikely: 0 to 5% probability) may also be used when appropriate.

# Annex V: IPCC SREX glossary of terms

## Core concepts defined in SREX and used throughout the summary include:

**Climate change:** A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

**Climate extreme (extreme weather or climate event):** The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes.' The full definition is provided in Section 3.1.2 of SREX.

**Exposure:** The presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.

**Vulnerability:** The propensity or predisposition to be adversely affected.

**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 response to satisfy critical human needs and that may require external support for recovery.

**Disaster risk:** The likelihood over a specified time period of 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 response to satisfy critical human needs, and that may require external support for recovery.

**Disaster risk management:** Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster DRR, 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.

**Adaptation:** In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

**Resilience:** The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

**Transformation:** The altering of fundamental attributes of a system (including value systems, regulatory, legislative, or bureaucratic regimes, financial institutions, and technological or biological systems).

This document is an output from a project funded by the UK Department for International Development (DFID) and the Netherlands Directorate-General for International Cooperation (DGIS) for the benefit of developing countries. However, the views expressed and information contained in it are not necessarily those of or endorsed by DFID or DGIS, who can accept no responsibility for such views or information or for any reliance placed on them.This publication has been prepared for general guidance on matters of interest only, and does not constitute professional advice. You should not act upon the information contained in this publication without obtaining specific professional advice. No representation or warranty (express or implied) is given as to the accuracy or completeness of the information contained in this publication, and, to the extent permitted by law, the entities managing the delivery of the Climate and Development Knowledge Network do not accept or assume any liability, responsibility or duty of care for any consequences of you or anyone else acting, or refraining to act, in reliance on the information contained in this publication or for any decision based on it. CDKN is led and administered by PricewaterhouseCoopers LLP. Management of the delivery of CDKN is undertaken by PricewaterhouseCoopers LLP, and an alliance of organisations including Fundación Futuro Latinoamericano, INTRAC, LEAD International, the Overseas Development Institute, and SouthSouthNorth.



ISBN: 978-1-907288-92-0