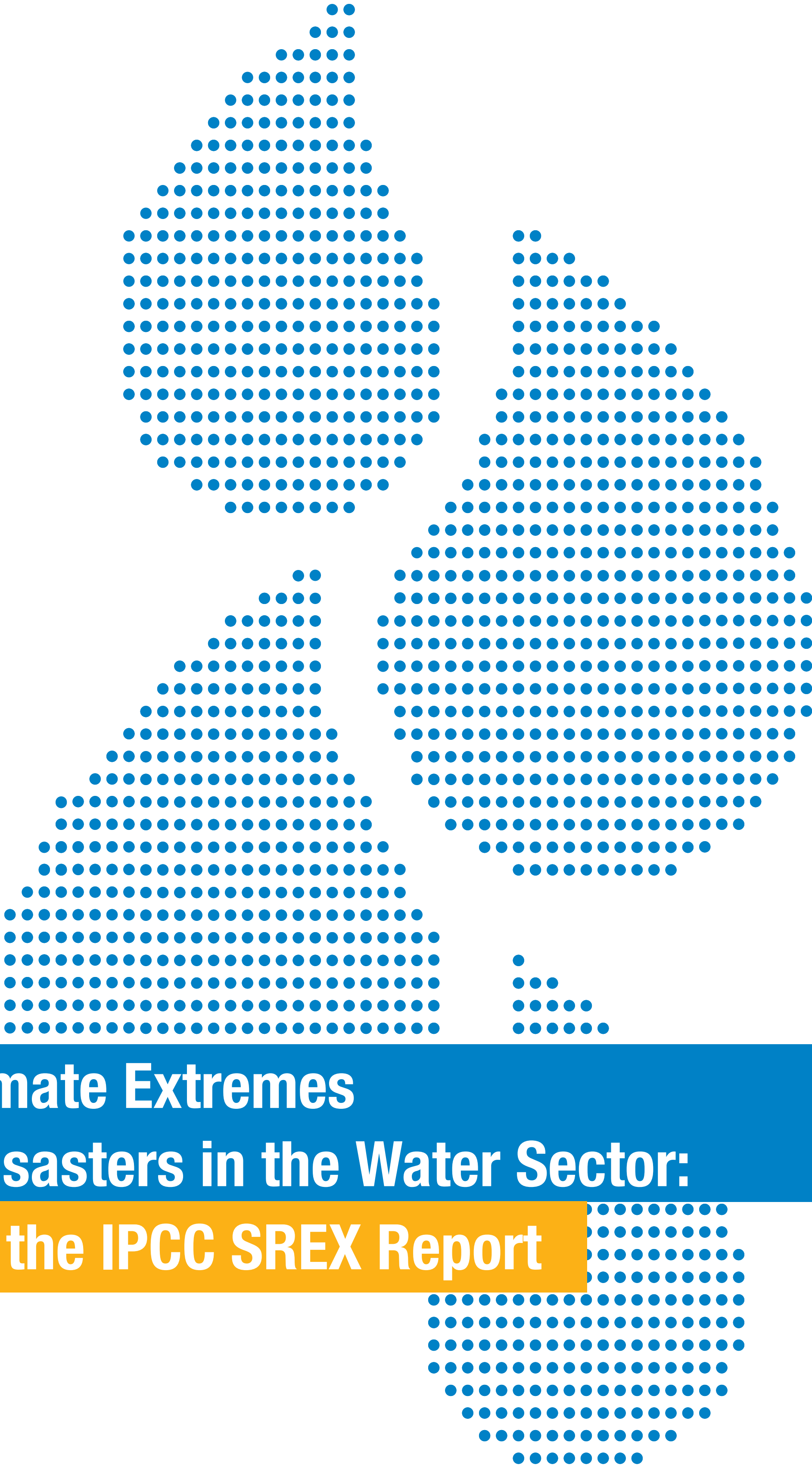
Climate & Development Knowledge Network



Managing Climate Extremes and Disasters in the Water Sector: Lessons from the IPCC SREX Report

Contents

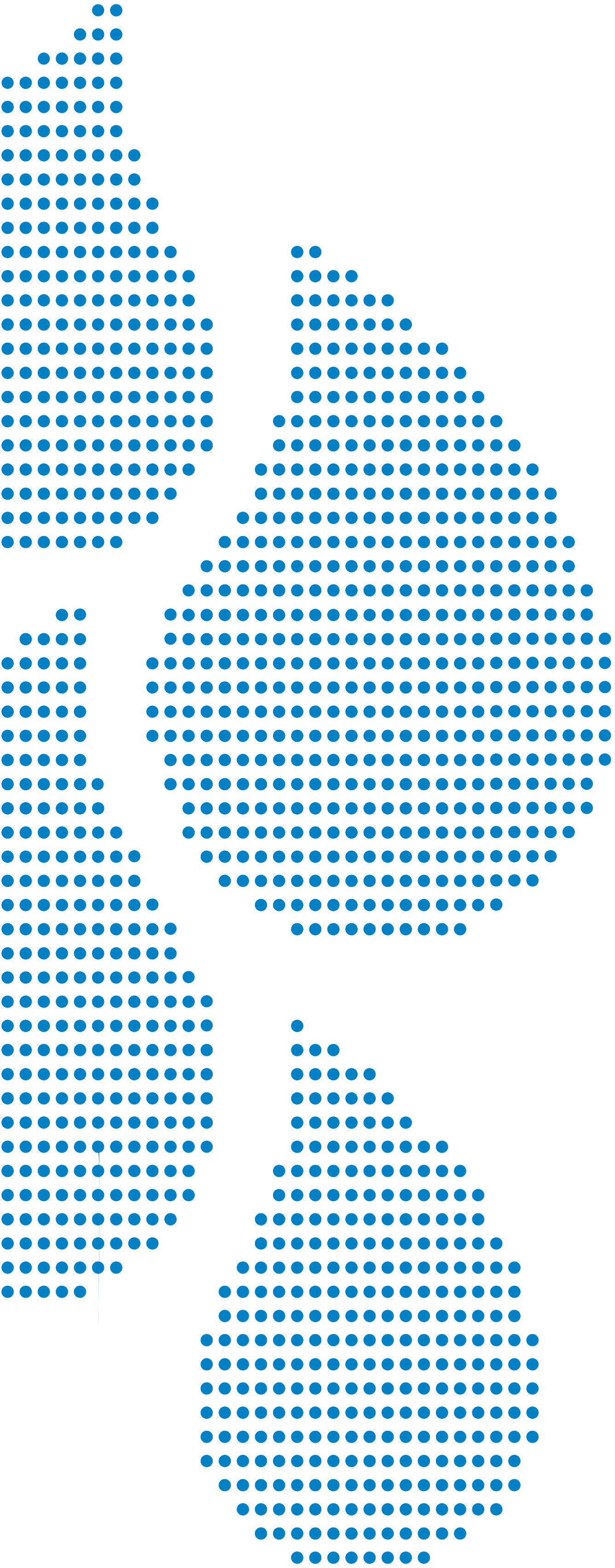
This report was compiled by Emma Back, Catherine Cameron and Gemma Norrington-Davies of Agulhas: Applied Knowledge, with the guidance of Dr. Tom Mitchell, Overseas Development Institute.

The authors would like to thank the following reviewers for their support and comments: Mairi Dupar, Maarten van Aalst, Michelle Kooy and Merylyn Hedger.

This document should be referenced as follows:
Climate and Development Knowledge Network (2012).
Managing Climate Extremes and Disasters in the Water Sector:
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

SREX 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 water resources, and water management. 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. In recognition that these readers will have many competing calls on both their time and budgets, this brief seeks to highlight key thematic findings and learning from SREX. It makes suggestions for immediate action to avoid further damage from climate extremes and to build a more resilient future with benefits that go beyond water management.

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 water issues, 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 climate change adaptation (CCA), DRM, and climate science communities.

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

1. Why are extreme events a critical issue for water management?
2. How is the water sector affected by the risk and 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.
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. While it remains difficult to attribute individual events to climate change, in July 2009, flooding in Brazil set record highs in 106 years of data records.
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.

1. http://cdkn.org/srex.
2. Highlights 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.

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, though for some regions and some extremes uncertainty remains high (e.g. precipitation trends across most of Africa).

5. High levels of vulnerability, combined with more severe and frequent weather and climate extremes, may result in some areas – such as coastal cities – 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 would include a wide range of measures such as improvements in health surveillance and early warning systems.

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.

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 water resources and water management?

A changing climate leads to changes in the frequency, intensity, spatial extent and duration of weather and climate events, and can result in unprecedented extremes, both through slow onset disasters (e.g. consecutive years of drought) and extreme events (e.g. heavy flooding). Many such events will have a direct impact on water resources now and in the future, including through increased frequency of heavy precipitation in many regions, intensified droughts across some areas, upward trends in extreme coastal high water levels, and changes in flood patterns.

Populations exposed to water-related hazards are already significant and are likely to increase. Water-related extreme events such as flooding, droughts and coastal inundation will have a broad range of impacts on humans and on ecosystems. These include economic losses, and pressures on particularly exposed human settlements such as coastal cities and small island developing states (SIDS).

There is high confidence that changes in the climate could seriously affect water management systems[3] – such as water storage and treatment plants, and supply systems. A surplus of water can affect system operation, but more typically there is a shortage of water relative to demand – a drought. Water supply shortages may be triggered by a shortage of river flows and groundwater, deterioration in water quality, or an increase in demand.

There are several approaches that planners and policy-makers can take, working with other stakeholders, to help manage the risks presented by climate extremes and disasters and their impact on water resources and water management. These include:

- assessing risks and maintaining information systems;
- developing strategies to support coping and adaptation;
- learning from experience in managing risk; and
- linking local, national, and international approaches.

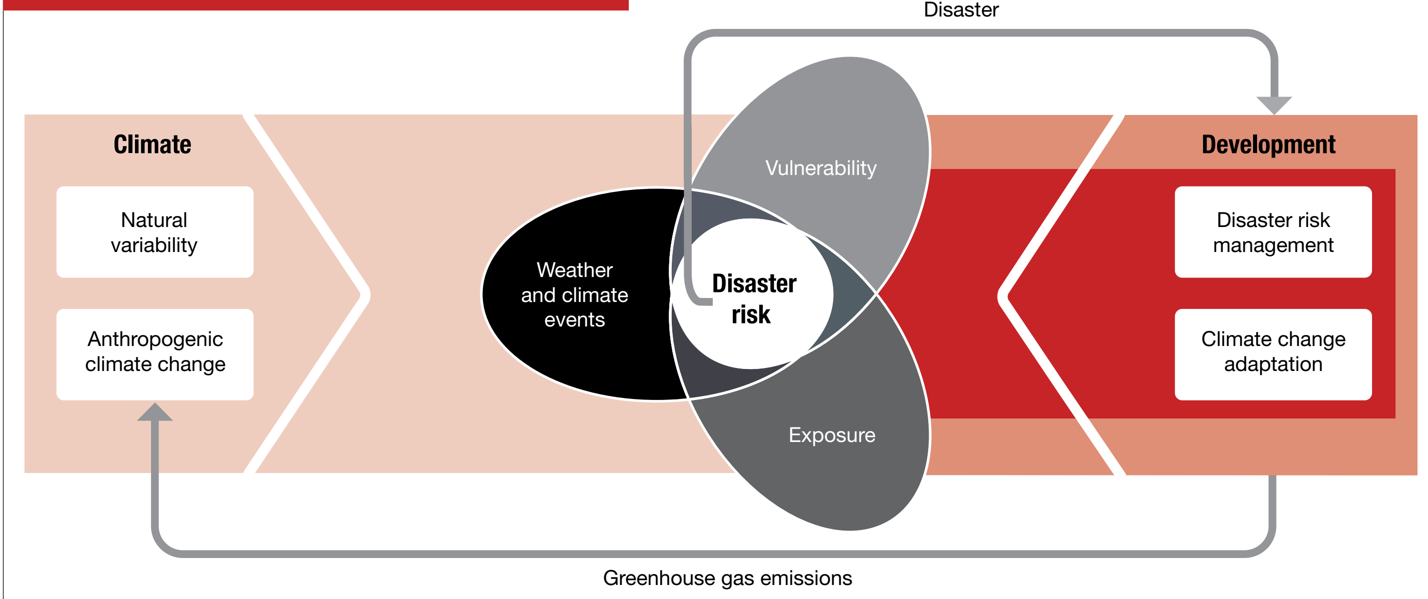
As extreme climate and water-related hazard events increase in coming decades, CCA and DRM are likely to require not only incremental but transformational changes in processes and institutions. This will involve moving away from a focus on issues and events towards a more holistic approach – for example, integrating water management with urban planning and design, and into policies on land use.

3. SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems' pp 235, 242.

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 extreme climate events, 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



Many of the projected increases in extreme weather and climate events will have a direct impact on water resources, for example[4]:

- It is likely that the frequency of heavy precipitation will increase in the 21st century over many regions.
- Projected precipitation and temperature changes imply changes in floods.
- There is evidence (medium confidence) that droughts will intensify over the coming century in southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa[5].
- It is very likely that average sea level rise will contribute to upward trends in extreme coastal high water levels.

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 can be found in Annex II.

4. See Annex IV: IPCC uncertainty guidance, which shows the probabilities attached to particular terms such as ‘likely’ or ‘very likely’.
5. Confidence is limited because of definitional issues regarding how to classify and measure a drought, a lack of observational data, and the inability of models to include all the factors that influence droughts.

2.1 Changes in extreme events[6]

A changing climate leads to changes in the frequency, intensity, spatial extent and duration of weather and climate events, and can result in unprecedented extremes. In some parts of the world, increases in some extreme weather and climate events have already been observed. Further increases are projected over the 21st century. '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 of the range of observed values of the variable' (see glossary[7]). The specification of weather and climate extremes relevant to the concerns of individuals, communities, and governments depends on the affected stakeholder, whether in agriculture, disease control, urban design, or water management for example.

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.

Recent modelling gives us much more information about what to expect in terms of both more and less water globally. Annex II has more detail.

6. 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'.
7. SREX Section 3.1.2 has a full explanation.

2.2 Disaster risk, vulnerability, and exposure[8]

Impacts of extreme and non-extreme weather and climate events depend strongly on levels of exposure and vulnerability. Exposure and vulnerability are dynamic and depend on economic, social, demographic, cultural, institutional, and governance factors. Individuals and communities are differentially exposed based on factors such as wealth, education, gender, age, class/caste, and health.

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.

So vulnerability is the propensity or predisposition of an exposed population to be adversely affected by weather or climate events. Therefore lack of resilience and capacity to anticipate, cope with and adapt to extremes are important factors of vulnerability. Different development pathways can make future populations more or less vulnerable to water-related hazards. High vulnerability and exposure are generally the outcome of skewed development, for example, environmental mismanagement, rapid and unplanned urbanisation, failed governance, and limited livelihood options.

Past and future changes in exposure and vulnerability to water-related climate extremes are driven by both changes in the volume, timing, and quality of available water, and changes in the property, lives, and systems that use the water resource, or that are exposed to water-related hazards. With a constant resource or physical hazard, there are two opposing drivers of change in exposure and vulnerability. Short-term risk management can have long-term adverse effects. For example, flood or water management measures may reduce vulnerability in the short term, but the resulting increased security may generate more development, and ultimately lead to increased exposure and vulnerability.

2.3 Consequences of climate extremes[9]

This section builds on the information presented so far, and highlights how extreme climate and weather-related events both affect and manifest in the water sector. It provides examples of the consequences and impacts that arise from water-related hazards – floods, droughts, sea-level rise, and tropical cyclones.

Floods can have direct and indirect impacts, compounding and exacerbating existing risks. Pakistan's 2010 floods left an estimated 6 million people in need of shelter. However, the compound effect of smaller, more frequent flood events can also result in mortality and destroy many houses, contributing to considerable displacement. Low-income urban poor populations often experience increased rates of infectious disease after flood events – for example, after the July 2005 floods in Mumbai, the prevalence of leptospirosis rose eight-fold. In Dhaka, Bangladesh, severe flooding in 1998 was associated with an increase in diarrhoea; with the risk of non-cholera diarrhoea being higher among those from a lower socio-economic group unable to use tap water. Flooding can be beneficial to water availability – for example in African dry lands (Sahara and Namib deserts), where floodwaters infiltrate and recharge alluvial aquifers along river pathways, extending water availability into dry seasons and drought years. However, flooding can result in rapid runoff, soil erosion, landslides, destruction of crops, and damage to other economic sectors, as well as contamination of water supply.

Drought: Impacts of drought can be both direct (e.g. famine, death of cattle, soil salinisation), and indirect (e.g. illnesses such as cholera). One of the main possible consequences of multi-year drought periods is severe famine (although there are other social, political and economic factors affecting the occurrence of famine). Prolonged drought in Syria (2008 to 2011) has affected 1.3 million people. 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 due to growing water demands and drought. In Africa, droughts have also affected the Sahel, the Horn of Africa, and Southern Africa. The Sahel drought in the 1980s caused many casualties and important socio-economic losses.

Sea-level rise: This can exacerbate inundation, erosion, and other coastal hazards, threaten vital infrastructure, settlements and facilities, and thus compromise the socio-economic well-being of coastal communities and island states. At Mar del Plata, in Argentina, sea-level rise has been linked to an increase in the number and duration of storm surges in the decade 1996 to 2005, as compared to records from previous decades.

Tropical cyclones: Damages from tropical cyclones are perhaps most commonly associated with extreme wind, but storm-surge and fresh-water flooding from extreme rainfall generally cause the great majority of damage and loss of life. Extreme strong winds damage buildings, infrastructure and other assets, torrential rains cause floods and landslides, and high waves and storm-surge lead to coastal flooding and erosion, all of which have major impacts on people. For example, Cyclone Nargis, which hit Myanmar in May 2008, caused over 138,000 fatalities. (Note that there is uncertainty about the attribution of current cyclone trends to climate change).

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 materials from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems', Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

3. Future impacts

Extreme events will have a broad range of impacts on and via water, such as flooding, droughts, and coastal inundation. This section looks ahead to explore the range of possible future impacts including economic losses, impacts on services including those for water management, supply and sanitation, and impacts on particularly exposed settlements such as coastal cities and SIDS. Collectively these impacts can have a significant adverse effect on people, communities, and systems.

3.1 Increasing economic losses[10]

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 US$ 200 billion (in 2010 dollars) globally, with the highest value for 2005 (the year of Hurricane Katrina). Whilst the dollar value of economic losses from disasters is largest in developed countries, there is high confidence that fatality rates and economic losses as a proportion of GDP are higher in developing countries. Developing countries are recognised as facing the greater impacts and having the most vulnerable populations, in the greatest number, who are least able to easily adapt to changes in *inter alia* temperature, water resources, agricultural production, human health, and biodiversity. The UNFCCC estimated that an additional amount of about US$ 41 billion would be needed to protect agriculture, water, health, and coastal zones, most of which would be used in developing countries.

Flooding can have a particularly devastating impact on people and economies. In July 2005, Mumbai, India, was struck by the largest storm in its recorded history. A week of heavy rain disrupted water, sewerage and drainage systems – as well as transport, power, and telecommunications. The damage and disruption had knock-on effects across India's economy: Mumbai-based ATM banking systems ceased working across much of the country, and the Bombay and National Stock Exchanges were temporarily forced to close.

3.2 Impacts on water management[11]

Extreme events have greater impacts on sectors that are closely linked with or dependent on the climate, for example water, agriculture and food security, forestry, health, and tourism. There is high confidence that changes in the climate could seriously affect water management systems, whether at the technical level, social level, or governance level. Extreme events can threaten the viability of the water supply 'system', from highly managed systems with multiple sources to a single rural well. A surplus of water can affect system operation, but more typically systems fail due to a shortage of water relative to demands – a drought.

Increasing risk of water shortages may be triggered by a shortage of river flows and groundwater, deterioration in water quality, or an increase in demand. A deterioration in water quality may be driven by a range of factors including local human influences, changes in land cover, or climate change. An increase in demand may be driven by demographic, economic, technological, or cultural drivers as well as by climate change. An increase in vulnerability to water shortage may be caused, for example, by increasing reliance on specific sources or volumes of supply, or changes in the availability of alternatives.

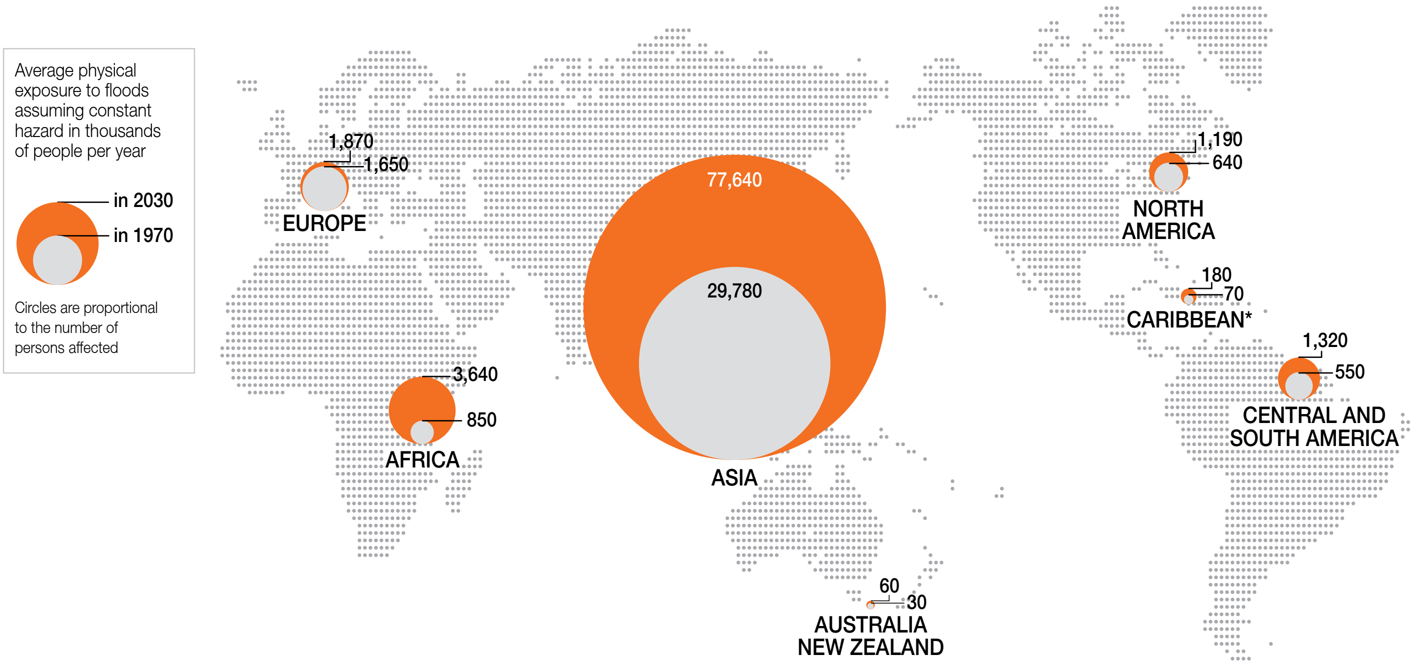
There is medium confidence that, since the 1950s, some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa[12].

3.3 Impacts on exposed settlements[13]

Populations exposed to water-related hazards are already significant and likely to increase. For example, in terms of exposure to flooding, about 800 million people are currently living in flood-prone areas, and about 70 million of these people are, on average, exposed to floods each year. It is difficult to estimate future flood hazards. However, using population increase in the flood-prone area, it is possible to look at trends in the number of people exposed per year on average at constant hazard. Figure 2 provides an estimate.

10. Draws on material from 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'.
11. Draws on material from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
12. Some studies show large potential reductions in supply reliability in future due to climate change, which will challenge existing water management systems; some show relatively small reductions that can be managed – albeit at increased cost – by existing systems, and some show that under certain scenarios the reliability of supply increases.
13. Draws on material from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems', SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters', and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

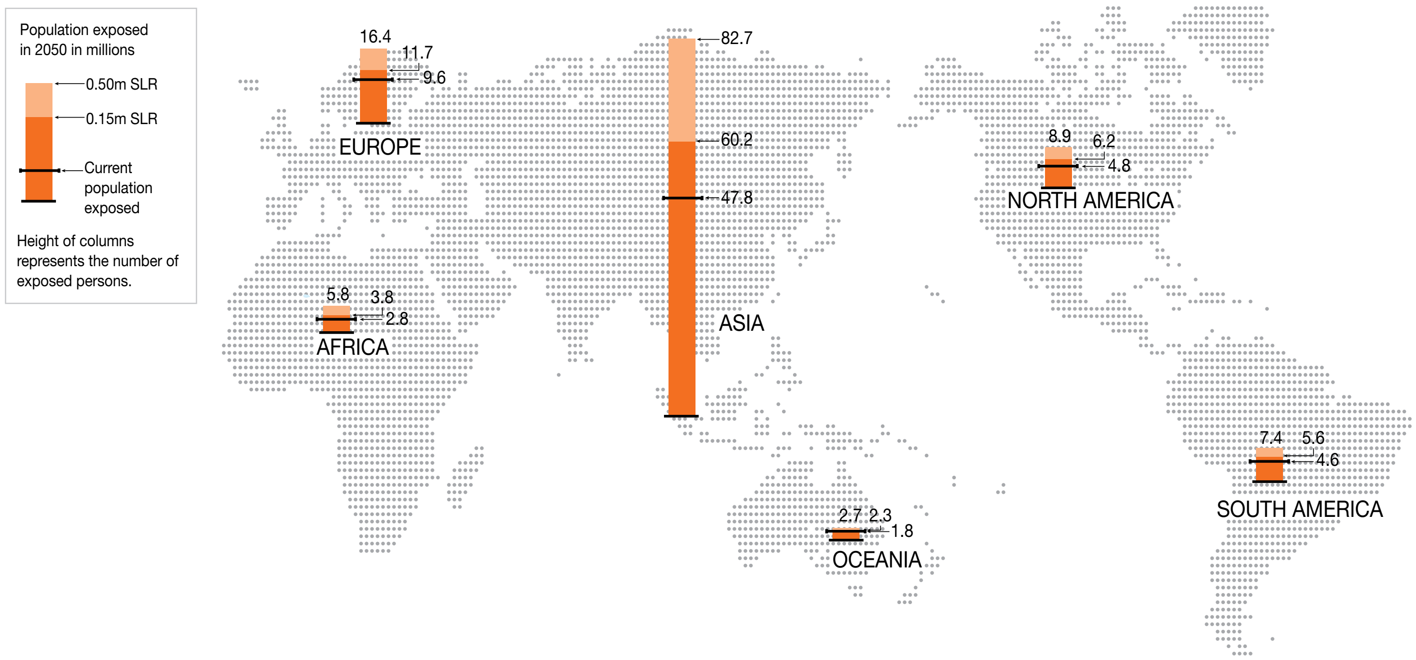
Figure 2: Average physical exposure to floods assuming constant hazard in thousands of people per year



*Only catchments bigger than 1,000 km^2 were included in this analysis. Therefore, only the largest islands in the Caribbean are covered.

The largest impacts from coastal inundation due to sea-level rise (and/or relative sea-level rise) in low-elevation coastal zones (i.e. coastal areas with an elevation less than 10m above present mean sea level) are thought to be associated with extreme sea levels due to tropical and extratropical cyclones. These will be superimposed upon the long-term sea-level rise. The impacts are considered to be more severe for large urban centres built on deltas and SIDS, particularly for those at the low end of the international income distribution. A substantial increase in the exposure of coastal populations to inundation has been estimated, as set out in Figure 3.

Figure 3: For low-elevation coastal areas, current and future (2050) population exposure to inundation[14]



Many coastal cities are already characterised by significant population and asset exposure to flooding. The amount of vulnerability concentrated within these cities will define their risks, and in the absence of adaptation there is high confidence that locations currently experiencing adverse effects, such as coastal erosion and inundation, will continue to do so in the future. For example, many of Africa's largest cities are on the coast and have large sections of their population at risk from flooding. Flooding regularly disrupts urban food production and distribution, which can undermine food security, particularly in poorer communities.

Mumbai, Kolkata, Dhaka, Guangzhou, Ho Chi Minh City, Shanghai, Bangkok, Rangoon, Hai Phòng, and Miami will have the greatest population exposure to coastal flooding in 2070. However, there is a certain limit to adaptation given that these cities are fixed in place and some degree of exposure to hazards is 'locked in' due to the unlikelihood of relocation. Increased urbanisation will lead to increased exposure to extreme events such as flooding, and place greater pressure on water resources. In central Dhaka, Bangladesh, infilling in areas occupied by natural water bodies and drains is increasing the risks of flooding. Building in the drained wetlands also generates new risks of liquefaction following earthquake. In Nairobi, Kenya, increasing exposure and vulnerability has resulted from a rapid expansion of poor people living in informal settlements, with poorly built houses constructed adjacent to rivers, and blocking natural drainage areas.

The particular impacts on SIDS are explored further in Box 2.

Box 2: Impacts on SIDS[15]

The small land area and often low elevation of SIDS make them particularly vulnerable to rising sea levels and impacts, such as inundation and saltwater intrusion into underground aquifers. Short record lengths and the inadequate resolution of current climate models to represent small islands limits the assessment of changes in extremes. However, there is medium confidence of observed increases in warm days and nights and decreases in cold days and nights over the Caribbean, and there is medium confidence in the projected temperature increases across the Caribbean. The very likely contribution of mean sea-level rise to increased extreme sea levels, coupled with the likely increase in tropical cyclone maximum wind speed, is a specific issue for small islands states in the Caribbean, where more than 50% of the population lives within 1.5 km of the shore. Sea-level rise could lead to a reduction in island size and could negatively impact on infrastructure, including international airports, roads, and capital cities.

14. In the case of the 1-in-100-year extreme storm for sea level rise of 0.15 m and for sea level rise of 0.50 m due to the partial melting of the Greenland and West Antarctic Ice Sheets. Data from Lenton et al, 2009.
15. Draws on material from SREX Chapter 3, Nicholls. N. et al, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment'.

4. Managing the risks of climate extremes and disasters[16]

This section considers the range of responses required in order to try to better manage the risks that climate extremes and disasters present for water resources and water management.

Exploiting potential synergies between DRM and adaptation to climate change will improve management of both current and future risks, and strengthen adaptation processes. DRM and adaptation to climate change literatures both now recognise the importance of bottom up, grass roots approaches, as well as the value of more holistic, integrated approaches. These include reducing exposure, reducing vulnerability, transferring and sharing risks, and adequate preparation, response, and recovery.

Managing climate-related disaster risks is a concern of multiple actors, working – often in partnership – across a range of scales from international, national, and sub-national and community levels, to help individuals, households, communities, and societies to reduce their risks. The actors comprise national and sub-national governments, the private sector, research bodies, civil society, and community-based organisations and communities. Effective national systems would ideally have each actor performing to their accepted functions and capacities. National and sub-national governments and statutory agencies have a range of planning and policy options available to them, which can help create the enabling environments for these agencies and individuals to act.

There are several approaches that planners and policy-makers can take, working with other stakeholders, to help manage the risks presented by climate extremes and disasters, and their impact on water resources and water management. These include:

- assessing risks and maintaining information systems;
- developing strategies to support coping and adaptation;
- learning from experience in managing risk; and
- linking local, national and international approaches.

4.1 Assessing risks and maintaining information systems[17]

The first step in managing risk is to assess and characterise it. Responding to risks is dependent on the way risk-based information is framed in the context of public perception and risk management needs. Given the 'public good' nature of much disaster-related information, governments have a fundamental role in providing good-quality and context-specific risk information about, for example, the geographical distribution of people, assets, hazards, risks, and disaster impacts, and vulnerability to support DRM. An example combining community engagement with global data and technology is provided in Box 3.

Alongside cross-cutting information (such as that derived from climate change modelling, human development indicators, and seasonal outlooks for preparedness planning), there is a range of information that can help to manage the risks presented by floods and droughts specifically. These information needs are set out in Table 1.

4.2 Developing strategies to support coping and adaptation[18]

How well a community responds to and survives disaster depends upon the skills and resources that can be used to cope in the face of adverse conditions. Adaptation, a process of adjustment 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 as these have net benefits over the range of anticipated future climate and associated impacts.

'Low regrets' adaptation options typically include improvements to coping strategies or reductions in exposure to known threats, such as better forecasting and warning systems, flood-proofing of homesteads, or interventions to ensure up-to-date climatic design information for engineering projects. Adaptation and DRM approaches for many development sectors 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 use, and biodiversity have the potential to create win-win disaster risk protection services for agriculture, infrastructure, cities, water resource management, and food security. A community approach to drought management is provided in Box 4.

16. 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' and SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.
17. SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.
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' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

Box 3: From local to global DRM: combining community engagement and technology

RANET (http://www.oar.noaa.gov/spotlite/archive/spot_ranet.html), a satellite broadcast service that combines radio and internet, was originally developed in Africa for drought and has since spread to Asia Pacific, Central America and the Caribbean. It has a strong community engagement component and disseminates comprehensive information from global climate data banks combined with regional and local data, and forecasts resulting in spin-offs to food security, agriculture, and health in rural areas.

RANET has already been found to reduce vulnerability to climate extremes in different areas in Africa. In parts of West Africa, communication of rainfall forecasts assists farmers with decisions on which crop variety to plant and field to use, where choice of field or different soil types existed, and also where to search for pasture and water for livestock during drought periods. However, to maximise its potential regionally and globally, RANET will need to overcome challenges of unavailability of technical support, follow-up training, power supply, and coordination.

Table 1: Information requirements for selected DRM and adaptation to climate change activities. Adapted from Wilby (2009)

Flood risk management	Early warning systems for fluvial, glacial, and tidal hazards	• Real-time meteorology, and water-level telemetry; rainfall, streamflow, and storm surge; remotely sensed snow, ice, and lake areas; rainfall-runoff model, and time series; probabilistic information on extreme wind velocities and storm surges.
	Flooding hot spots, and structural and non-structural flood controls	• Rainfall data, rainfall-runoff, stream flow, floods, and flood inundation maps. • Inventories of pumps, stream gauges, drainage and defence works; land use maps for hazard zoning; post-disaster plan; climate change allowances for structures; floodplain elevations.
	Artificial draining of proglacial lakes	• Satellite surveys of lake areas and glacier velocities; inventories of lake properties and infrastructure, and infrastructure at risk; local hydro-meteorology.
Drought management	Traditional rain and groundwater harvesting, and storage systems	• Inventories of system properties including condition, reliable yield, economics, and ownership; soil and geological maps of areas suitable for enhanced groundwater recharge; water quality monitoring; evidence of deep-well impacts.
	Long-range reservoir inflow forecasts	• Seasonal climate forecast model; sea surface temperatures; remotely sensed snow cover; *in situ* snow depths; multi-decadal rainfall-run-off series.
	Water demand management and efficiency measures	• Integrated climate and river basin water monitoring; data on existing systems' water use efficiency; data on current and future demand metering, and survey effectiveness of demand management.

Box 4: Rooibos farmer community approach to drought management in South Africa

In Northern Cape Province, South Africa there is a harsh landscape, with frequent and severe droughts and extreme conditions for the people, animals, and plants living there. This has a negative impact on small-scale rooibos farmers living in some of the more marginal production areas. Rooibos is an indigenous crop that is well adapted to the prevailing hot, dry summer conditions, but it is sensitive to prolonged drought. Rooibos tea has become well accepted on world markets, but success has brought little improvement to marginalised, small-scale producers. In 2001, a small group of farmers took collaborative action to improve their livelihoods and founded the Heiveld Co-operative Ltd. Initially established as a trading co-operative to help the farmers produce and market their tea jointly, it subsequently became apparent that the local organisation was also an important vehicle for social change in the wider community.

The Heiveld Co-operative became a repository and source of local and scientific knowledge related to sustainable rooibos production. Following severe drought in 2003 to 2005, and a perceived increase in weather variability, the Heiveld Co-operative farmers decided to monitor the local climate and to discuss seasonal forecasts and possible strategies in quarterly climate change preparedness workshops facilitated in collaboration with two local NGOs. They were supported by scientists to address farmers' questions in a participatory action research approach – to ensure that local knowledge and scientific input can be combined to increase the resilience of local livelihoods.

The Heiveld Co-operative has been an important organisational vehicle for this learning process, strongly supported by their long-term partners, with the focus on supporting the development of possible adaptation strategies through a joint learning approach to respond to and prepare for climate variability and change.

Adaptation in anticipation of extreme events can help to limit the 'coping' that may be required to survive the next disaster. Adaptive capacity focuses on longer-term and more sustained adjustments. As possible climate futures are uncertain, 'low regrets' adaptation strategies are often recommended as these have net benefits over the range of anticipated future climate and associated impacts.

4.3 Learning from experience in managing risk[19]

Learning is essential to risk management and adaptation. Research on learning emphasises the importance of action-oriented problem solving, learning-by-doing, and concrete learning cycles as key components for living with uncertainty and extreme events. It is nurtured by building the right kind of social/institutional space for learning and experimentation that allows for competing world views, knowledge systems, and values, and facilitates innovative and creative adaptation. The Global Assessment Report (GAR) identified the 2000 floods in Mozambique as one of four examples of large disasters that have highlighted DRM capacity gaps and have led to institutional learning, and resulting policy and legislative changes. These are outlined in Box 5.

4.4 Linking local, national, and international approaches[21]

Integration of local knowledge with additional scientific and technical knowledge can improve DRR and adaptation. This self-generated knowledge can uncover existing capacity, as well as identify important shortcomings. In India, for example, a combination of traditional and innovative technological approaches is used to manage drought risk. Technological management of drought (e.g. development and use of drought tolerant cultivars, shifting cropping seasons in agriculture, and flood and drought control techniques in water management) is combined with model-based seasonal and annual to decadal forecasts. Model results are translated into early warnings so that communities can take appropriate drought protection measures.

It is important to overcome the disconnect between local DRM and national, institutional, and legal policy and planning. Local level DRM for example can, and should, be supported by environmental planning, urban land use planning, livelihood strengthening, and improvements in health surveillance, water supply, sanitation and irrigation, and drainage systems. Such integrated approaches are visible in Bogota, São Paulo, and Santiago, where urban adaptation efforts are working to support existing DRM strategies.

Box 5: Institutional and legislative changes following flooding in Mozambique[20]

In February 2000, catastrophic floods in Mozambique caused the loss of more than 700 lives with over half a million people losing their homes, and more than 4.5 million affected. The flooding started with above-average rainfall in southern Mozambique and adjacent countries from October to December 1999. Record flooding ensued downstream on the Limpopo and Zambezi rivers, and in parts of the Sabie catchment the return period was in excess of 200 years. A series of cyclones exacerbated the situation.

Many small towns and villages remained under water for approximately two months. Access roads were rendered impassable, with railways, bridges, water management systems (including water intake and treatment plants), and more than 600 primary schools damaged or destroyed. The UN World Food Programme reported that Mozambique lost 167,000 hectares of agricultural land. Dams were overwhelmed. The incidence of malaria was reported as increasing by a factor of 1.5 to 2.0, and diarrhoea by a factor of 2.0 to 4.0. The government declared an emergency, mobilised its disaster response mechanisms, and made appeals for international assistance.

After these catastrophic floods, the Government of Mozambique took a range of measures to improve the effectiveness of DRM. In 2001, an Action Plan for the Reduction of Absolute Poverty (PARPA I) was adopted and later revised for the period 2006 to 2009 (PARPA II). In 2006, the government also adopted a Master Plan, which provides a comprehensive strategy for dealing with Mozambique's vulnerability to natural disasters. A large resettlement program for communities affected by the floods and tropical cyclones was initiated, with about 59,000 families resettled.

In 2007, similar flooding occurred in Mozambique, due to heavy rains and the approach of tropical cyclone Favio, but the country was prepared to a greater extent than before. From November 2006 to November 2007, the Severe Weather Forecasting Demonstration Project, conducted by the World Meteorological Organisation in southeastern Africa, tested a new concept for capacity building, which contributed to the forecasting and warnings about Cyclone Favio. The demonstration phase was found to be valuable, and the implementation phase continues, with training supported by efficient and effective forecasting and warning of tropical cyclones in developing countries.

19. 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' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
20. Draws on material from SREX Chapter 9, Murray, V. et al, 'Case Studies'.
21. Draws on material from SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level', SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

Changes in weather and climate extremes pose new challenges for national DRM systems, which are often poorly adapted to the risks. However, there are a few examples where mainstreaming adaptation to climate change and DRM issues have been priorities for many years and have made significant progress. For example, a coastal reforestation programme, including the planting in Sundarban, was initiated in Bangladesh in 1960, covering 159,000 hectares of the riverine coastal belt and abandoned embankments.

National systems are at the core of countries' capacity to meet climate challenges, although greater efforts are required to address the underlying drivers of risk, and generate political will to invest in DRR and DRM. A set of features has been identified that make efforts to systematically manage disaster risk more successful. These are captured in Box 6.

Box 6: Features of successful national DRM systems[22]

- **Risks are recognised as dynamic, and are mainstreamed and integrated into policy and strategy.**
- **Legislation for managing disaster risk is supported by clear regulations that are enforced.**
- **DRM functions are coordinated across sectors and scales and led by organisations at the highest political level.**
- **Risk is quantified and factored into national budgetary processes.**
- **Decisions are informed by robust information, using a range of tools and guidelines.**
- **Early warning systems are developed, and linked to planning and policy-making.**
- **Responses cover hard infrastructure based options as well as soft longer-term options building capacity and conservation measures.**

Transboundary management of water. There is a particularly important transboundary element to managing disaster risk in the case of water management, because so many freshwater resources (e.g. lakes and rivers) cut across boundaries. These boundaries may be national borders or may be trans-jurisdictional within the same country. This poses special governance challenges, particularly where water resources are affected by climate and weather-related extremes. Many river basins already have their own transboundary governance institutions. Where these exist, there are opportunities to integrate climate-related risk management into their technical operations and political decision-making.

International actors can also play a useful enabling role in risk management. International funding mechanisms such as the Adaptation Fund, the LDC (Least Developed Countries) Fund, the Special Climate Change Fund, the Multi-donor Trust Fund (MDTF) on Climate Change, and the Pilot Programme for Climate Resilience (PPCR) under the Climate Investment Fund (CIF) are making funding and resources available to developing countries to pilot and mainstream climate risk management and resilience building into development. This provides incentive for scaled-up action, and transformational change, although funding is inadequate.

Risk sharing (e.g. formal insurance and microinsurance) can also be a tool for risk reduction, and for recovering livelihoods after a disaster. Insurance is an instrument for distributing disaster losses among a pool of at-risk households, businesses, and/or governments, and is the most recognised form of international risk transfer. Insurance can provide the necessary financial security to take on productive but risky investments. Many of the ongoing microinsurance initiatives are index-based: a relatively new approach whereby the insurance contract is not against the loss itself, but against an event that causes loss, such as insufficient rainfall during critical stages of plant growth. Weather index insurance is largely at a pilot stage, with several projects operating around the globe, including in Mongolia, Kenya, Malawi, Rwanda, and Tanzania. An example from India is provided in Box 7.

Box 7: Risk transfer: the example of index-based micro insurance for drought risks in India

An innovative insurance program set up in India in 2003 covers non-irrigated crops in the state of Andhra Pradesh against the risk of insufficient rainfall during key times of the cropping season. The index-based policies are offered by a commercial insurer, and marketed to growers through microfinance banks. In contrast to conventional insurance, which is written against actual losses, this index-based (parametric) insurance is written against a physical or economic trigger, in this case rainfall measured by a local rain gauge. The scheme owes its existence to technical assistance provided by the World Bank. Schemes replicating this approach are currently targeting more than a million exposed farmers in India. One advantage of index-based insurance is the substantial decrease in transaction costs due to eliminating the need for expensive post-event claims handling, which has impeded the development of insurance mechanisms in developing countries. A disadvantage is basis risk, which is the lack of correlation of the trigger with the loss incurred.

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

5. Conclusions: what does this mean for decision-makers in the Water sector?

This final section considers the implications for water management. As climate change impacts become more severe, the effects on a range of climate extremes will become more important and will play a more significant role in disaster impacts and DRM. The capacity to meet this challenge will be determined by the effectiveness of national risk management systems, including adaptation and mitigation measures.

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[23]

Sustainable development involves finding pathways that achieve a variety of socio-economic and environmental goals, preferably without sacrificing any one for the sake of the others. Socio-economic and environmental dimensions are highly political, as are the relationships between adaptation, DRM, and sustainability. 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'.[24]

Climate change is typically viewed as a slow-onset, multigenerational problem. Consequently, individuals, governments, and businesses have been slow to invest in adaptation measures. Research in South Asia, for example, shows that in those regions where past development had prioritised short-term gains over long-term resilience, agricultural productivity in some areas is in decline because of drought and groundwater depletion, rural indebtedness is increasing, and households are sliding into poverty – with particularly insidious consequences for women, who face the brunt of nutritional deprivation as a result. Connecting short and long-term perspectives is thus seen as critical to realising the synergies between DRM and CCA that can contribute to a sustainable and resilient future.

There is a clear need to mainstream adaptation and DRM into existing national policies and plans, and to capitalise on opportunities for synergy with other national objectives. To date, studies have found that many strategies and institutions focus to a large extent on lower-risk actions dealing with science and outreach (knowledge acquisition) and capacity-building rather than specific adaptation, and DRM actions that might be more costly and difficult to implement.

Although there is no single approach, framework or pathway to achieve a truly integrated approach, 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 the graphic in Figure 4.

23. Draws on materials from SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
24. Wilbanks, 1994.

Figure 4: Integrating adaptation and DRM approaches for a changing climate

Risks acceptance threshold

Reduce risks		Manage residual risks and uncertainties		
Reduce vulnerability	**Reduce hazards and exposure**	**Pool, transfer and share risks**	**Prepare and respond effectively**	**Increase capacity to cope with 'surprises'**
• Poverty reduction. • Health improvements. • Access to services and productive assets enhanced. • Livelihood diversification. • Access to decision-making increased. • Community security improved.	• 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.	• Mutual and reserve funds. • Financial insurance. • Social networks and social capital. • Alternative forms of risk transfer.	• Early warning and communication. • Evacuation plan . • Humanitarian: relief supplies. • Post-disaster livelihood support and recovery.	• Flexibility in decision-making. • Adaptive learning and management. • Improved knowledge and skills. • Systems transformation over time.

The effectiveness of actions to reduce, transfer, and respond to current levels of disaster risk could be vastly increased. Exploiting potential synergies between DRM and adaptation to climate change will improve management of both current and future risks, and strengthen adaptation processes. DRM and adaptation to climate change literatures both now recognise the importance of bottom up, grass roots approaches, as well as emphasising the value of more holistic, integrated, trans-disciplinary approaches.

5.2 Developing adaptation strategies: the importance of national systems[25]

The challenge for countries is to manage short-term climate variability, while also ensuring that – over the long-term – different sectors and systems remain resilient, and adaptable to changing extremes and risks. The requirement is to balance short- and 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.

Climate change is thus far too big a challenge for any single national government ministry to address. Effective coordination of adaptation and risk reduction across sectors may only be realised if all areas of government are coordinated from the highest political and organisational level. National systems therefore 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 DRR and DRM, and in CCA. However, many strategies that countries can pursue would have significant societal benefits, even if climate change and disaster risks did not materialise. SREX refers to these as 'low regrets' strategies.

For the water sector, a range of adaptation strategies are set out in Table 2, ranging from 'low regrets' to 'win-win' strategies that address greenhouse gas reductions as well as adaptation and risk reduction, and which have broader developmental benefits.

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

Table 2: 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
• Implement Integrated Water Resource Management (IWRM), national water efficiency, and storage plans. • Effective surveillance, prediction, warning and emergency response systems; better disease and vector control, detection and prediction systems; better sanitation; awareness-raising, and training for public health. • Adequate funding, capacity for resilient water infrastructure and water resource management. • Improved institutional arrangements, negotiations for water allocations, and joint river basin management.	• Develop prediction, climate projection, and early warning systems for flood events and low water flow conditions; research and downscaling for hydrological basins. • Multi-sectoral planning for water; selective decentralisation of water resource management (e.g. catchments and river basins); joint river basin management (e.g. bi-national).	• National water policy frameworks, robust integrated and adaptive water resource management for adaptation to climate change. • Investments in hard and soft infrastructure considering changed climate; river restoration. • Improved weather, climate, hydrology-hydraulics, and water quality forecasts for new conditions.	• Public-private partnerships. • Economics for water allocations beyond basic needs. • Mobilise financial resources and capacity for technology, and Ecosystem based Adaptation (EbA). • Insurance for infrastructure.	• Enhance national preparedness and evacuation plans to cope with greater risks. • Enhance health infrastructure. • Alter transport, and engineering; increase temporary consumable water taking permits. • Enhance food and water distribution for emergencies, and plan for alternate livelihoods.	• Integrated and sustainable water efficiency and renewable hydropower for adaptation to climate change.

5.3 Building long-term resilience: from incremental to transformational[26]

If climate extremes 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. This will involve moving away from a focus on issues and events towards a change in culture, and overall approach. Box 8 outlines one example of initial steps towards transformation.

5.4 Planning for an uncertain future[28]

In order to manage short-term climate variability whilst ensuring resilience and adaptation to changing extremes over the long-term, planners and policy-makers need to be aware of the misaligned priorities and competition that may exist between different stakeholders and sectors. Individual actors, for example, will have different needs and priorities to be met over varying time scales.

Among the most successful DRM and adaptation efforts are those that have facilitated the development of **partnerships** between local leaders and other stakeholders, including national and local governments, and the private sector. This allows local strengths 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 is 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. Strong leadership can be an important 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.

Box 8: Holistic approach to water management in New York[27]

Conservation of water resources and wetlands that provide hydrological sustainability can further aid adaptation by reducing the pressures and impacts on human water supply. In New York, for example, untreated storm water and sewage regularly flood the streets because the ageing sewage system is no longer adequate. After heavy rains, overflowing water flows directly into rivers and streams instead of reaching water treatment plants. The US Environmental Protection Agency has estimated that around US$ 300 billion over 20 years would be needed to upgrade sewage infrastructure across the country. In response, New York City will invest US$ 5.3 billion in green infrastructure on roofs, streets, and sidewalks. This promises multiple benefits: the new green spaces may absorb more rainwater and reduce the burden on the city's sewage system, improve air quality, and reduce water and energy costs.

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

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 both money and lives in the future. In Bangladesh, for example, despite persistent poverty, improved disaster preparedness and response, and relative higher levels of household adaptive capacity have dramatically decreased the number of deaths as a result of flooding.

Research improves our knowledge, especially when it includes integration of natural, social, health, and engineering sciences, and their applications.

Empowering all stakeholders: It is important to identify national and local drivers of hazard and vulnerability in ways that empower all stakeholders to take action. This is done best where local and scientific knowledge and capacity are brought together to generate risk maps or risk management plans. Where decisions must be taken about resources as essential as water, robust and transparent governance processes are needed to debate the trade-offs, and ensure that people's basic needs are met. This is particularly important where water management projects are large-scale and could have wide-ranging impacts on people, communities, health, livelihoods and the environment – as is the case with major dams and reservoirs, for example (see Box 9). There is also need for better coordination and accountability within governance hierarchies and across sectors, and across geographical boundaries such as national borders.

Box 9: Trade-offs in large-scale climate adaptation and water management projects[29]

While there are many environmental benefits of hydroelectric power and large-scale water management, the uncertainty of climate change could alter such benefits at local to global scales, and influence the social and environmental ramifications of these projects. For example, the flooding caused by the construction of reservoirs could result in migration of affected communities, thereby increasing community fragmentation, poverty, and ill-health of humans and biota. Such local and regional impacts of dam construction may increase vulnerability to climate change in many localities. Degradation of flora and fauna also results in additional greenhouse gas emissions.

International actors can help by providing an institutional framework to support experimentation, innovation and flexibility, financing risk transfer, and supporting funding for adaptation. In the water sector, they can also play an important role in convening and/or mediating discussions about the management of transboundary water resources.

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. Enhancing early warning systems is one example where technology can play an important role in DRM. Although technology is an essential part of our response to climate change, great improvements can be made 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. It may be very difficult to adapt to climate and weather extremes associated with rapid and severe climate change, such as a warming beyond 4°C within this century, without transformational policy and social change: if not chosen through proactive policies, forced transformations and crises are likely to result. An example of the beginning of a transformational approach is given in Box 10.

Transformation calls for leadership, from authority figures who hold positions of 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.

Box 10: Innovation and transformation in water management in The Netherlands[30]

Given that the impacts of climate change in many regions are predominantly linked to the water system, in particular through increased exposure to floods and droughts, it is helpful to consider water as a key structuring element or guiding principle for landscape management and land use planning. This then requires not only technology but integrated systems thinking, and the art of thinking in terms of attractiveness and mutual influence, or even mutual consent, between different authorities, experts, interest groups, and the public.

One of the most pronounced changes can be observed in The Netherlands, where the government has requested a radical rethinking of water management in general and flood management in particular. The resulting 'Room for the River' (Ruimte voor de Rivier) policy and its successors have strongly influenced other areas of government policy. Greater emphasis is now given to the integration of water management and spatial planning, with high value accorded to the regulating services provided by landscapes with natural flooding regimes. This requires a revision of land use practices and reflects a gradual movement toward integrated landscape planning, whereby water is recognised as a natural, structural element. The societal debate about plans to build in deep-lying polders and other hydrologically unfavourable areas, and new ideas on floating cities, indicate considerable engagement of both public and private parties with the issue of sustainable landscapes and water management. However, although such innovative ideas have been adopted in policy, they take time to implement, as there is considerable social resistance.

29. Draws on materials from SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level'.
30. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

ANNEXES

Annex I: Acronyms

CBOs	Community Based Organisations
CCA	Climate Change Adaptation
CDKN	Climante and Development Knowledge Network
CSOs	Civil Society Organisations
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EM-DAT	Emergency Disasters Database
EbA	Ecosystem based Adaptation
GCM	Global Climate Model
GDP	Gross Domestic Product
IFIs	International Financial Institutions
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
LDCs	Least Developed Countries
NGOs	Non-Governmental Organisations
SIDS	Small Island Developing States
SREX	Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
UNFCCC	United Nations Framework Convention on Climate Change

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 3 and 4.

Table 3: Observed changes in temperature and precipitation extremes since the 1950s[31]

Table 3 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)[32]	Trends in minimum temperature (warm and cold nights)[33]	Trends in heat waves/ warm spells[34]	Trends in heavy precipitation (rain, snow)[35]	Trends in dryness and drought[36]
West Africa	Significant increase in temperature of warmest day and coolest day in large parts Insufficient evidence in others	Increasing frequency of warm nights (decrease in cold nights in large parts) 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 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 Lack of literature on trends in cold nights	Insufficient evidence	Insufficient evidence	Limited data, spatial variation of the trends

31. Period 1961 to 1990 used as a baseline.
32. 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.
33. 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.
34. 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.
35. 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.
36. 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 4: Projected changes in temperature and precipitation extremes, including dryness, in Africa

Table 4 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[37] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[38]	Trends in minimum temperature (the frequency of warm and cold nights)[39]	Trends in heat waves/ warm spells[40]	Trends in heavy precipitation (rain, snow)[41]	Trends in dryness and drought[42]
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 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 Some evidence of increase in heavy precipitation in southeast regions	Increase in dryness, except eastern part 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

37. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
38. 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.
39. 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.
40. 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.
41. 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.
42. 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 5 and 6.

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 5: Observed changes in temperature and precipitation extremes since the 1950s[43]

Table 5 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)[44]	Trends in minimum temperature (warm and cold nights)[45]	Trends in heat waves/ warm spells[46]	Trends in heavy precipitation (rain, snow)[47]	Trends in dryness and drought[48]
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 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 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 Insufficient evidence for Malay Archipelago	Increase in warm nights (decrease in cold nights) for northern areas 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 6: Projected changes in temperature and precipitation extremes, including dryness, in Asia

Table 6 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[49] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[50]	Trends in minimum temperature (the frequency of warm and cold nights)[51]	Trends in heat waves/ warm spells[52]	Trends in heavy precipitation (rain, snow)[53]	Trends in dryness and drought[54]
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 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 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

43. Period 1961 to 1990 used as a baseline.
44. 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.
45. 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.
46. 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.
47. 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.
48. 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.
49. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
50. 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.
51. 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.
52. 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.
53. 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.
54. 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 7 and 8.

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 7: Observed changes in temperature and precipitation extremes since the 1950s[55]

Table 7 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)[56]	Trends in minimum temperature (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	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 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

55. Period 1961 to 1990 used as a baseline.
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 with respect to the 1961 to 1990 reference period.
57. 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.
58. 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.
59. 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.
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.

Table 8: Projected changes in temperature and precipitation extremes at the end of 21st century[61]

Table 8 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[62] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[63]	Trends in minimum temperature (the frequency of warm and cold nights)[64]	Trends in the heat waves/warm spells[65]	Trends in heavy precipitation (rain, snow)[66]	Trends in dryness and drought[67]
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 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 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

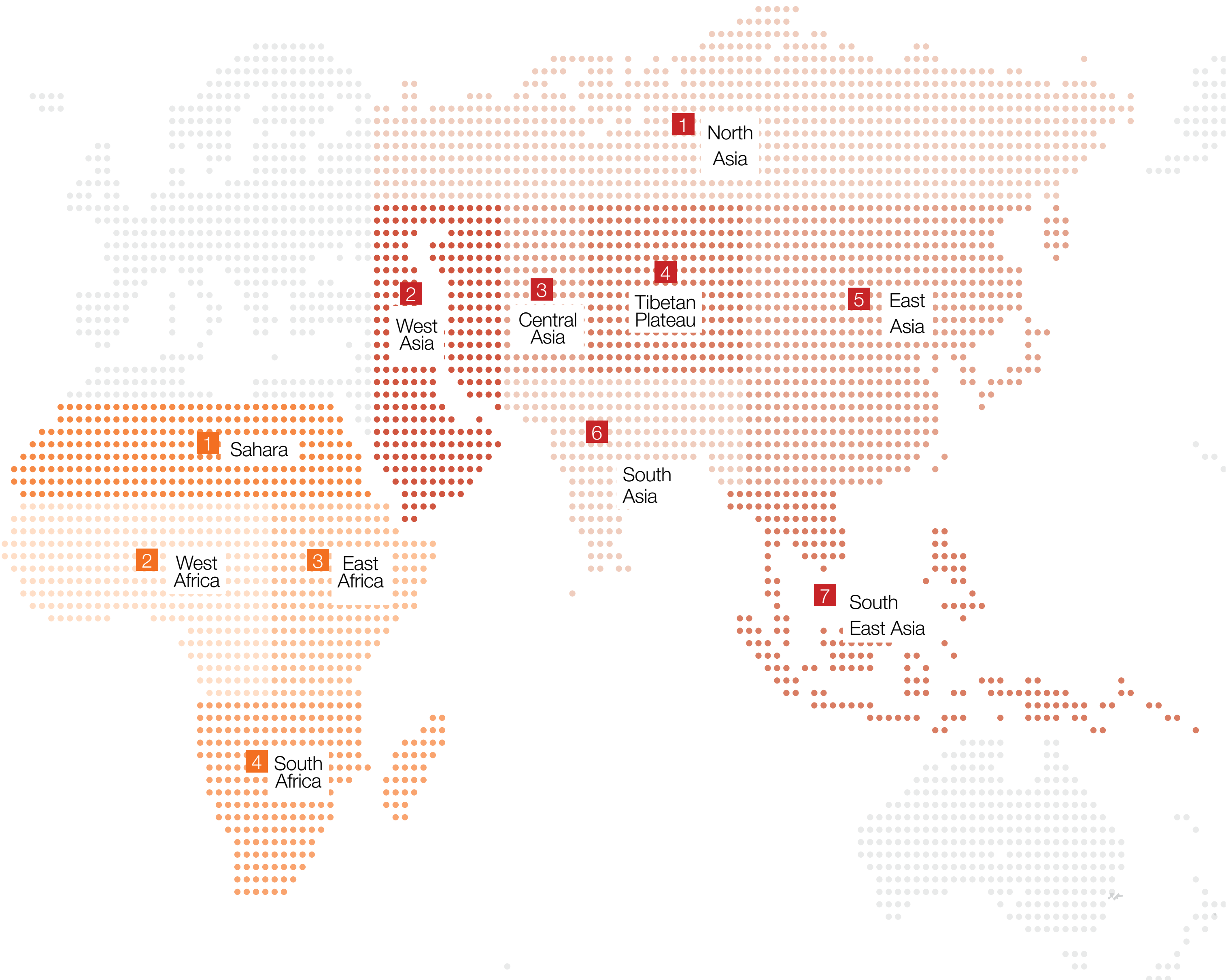
61. Projections are for the end of the 21st century vs end of the 20th century (e.g. 1961 to 1990 or 1980 to 2000 vs 2071 to 2100 or 2080 to 2100) and for the A2/A1B emissions scenario.
62. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
63. Refers to the number of warm 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.
64. 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.
65. 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.
66. 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.
67. 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.

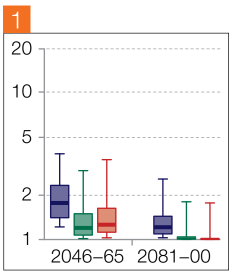
Annex III: Return period maps

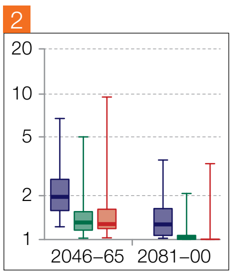
(a) Temperature

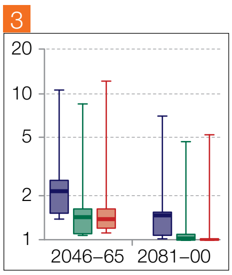
The temperature graph shows how often the hottest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[68]

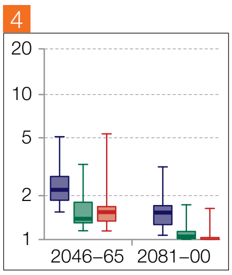
For example the hottest day experienced in the last 20 years at the end of the 20th century will occur at least biannually by 2046-65 across the continent and under both the A1B and A2 scenarios by 2100, every year, everywhere. What is now an extreme will become normal.

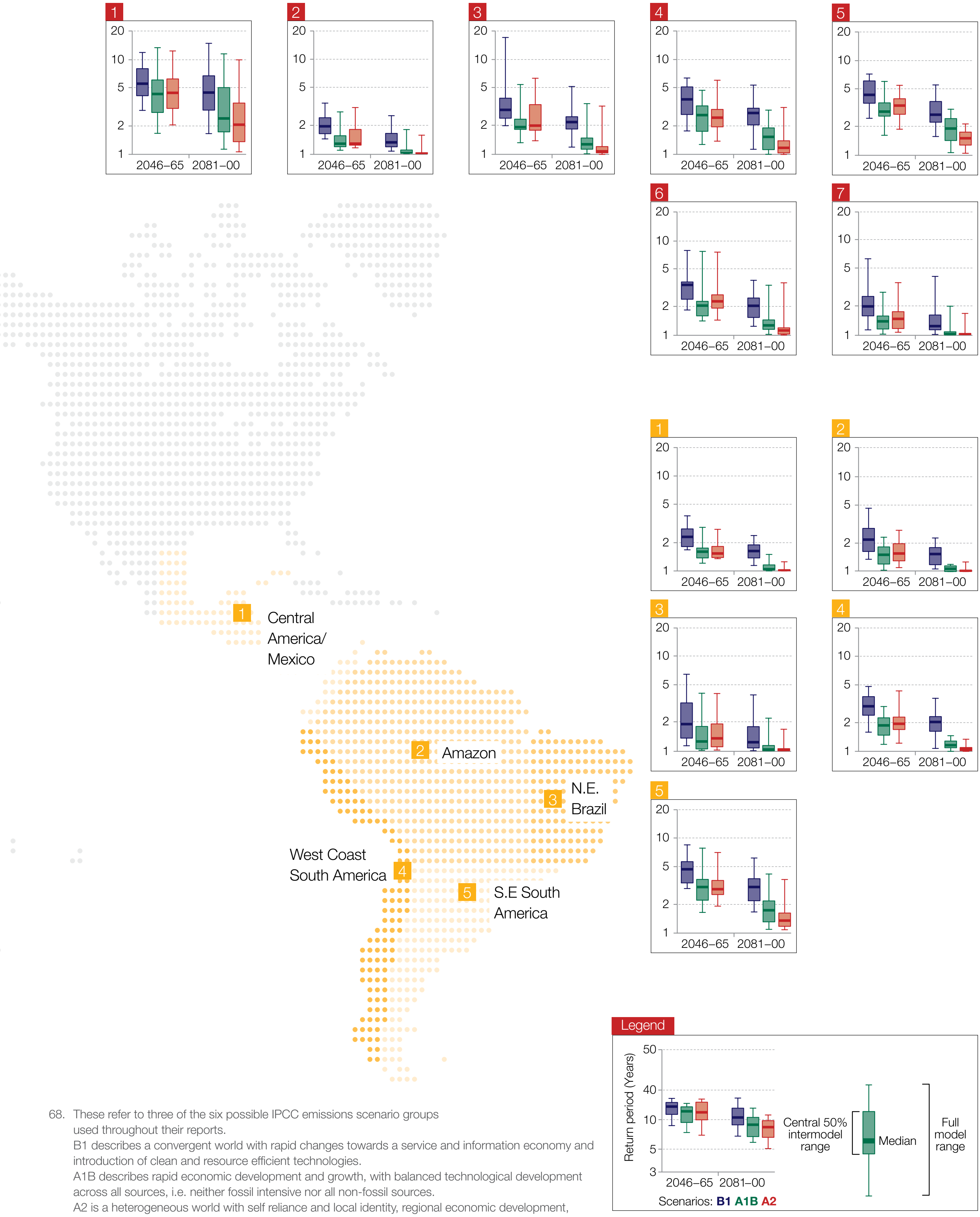








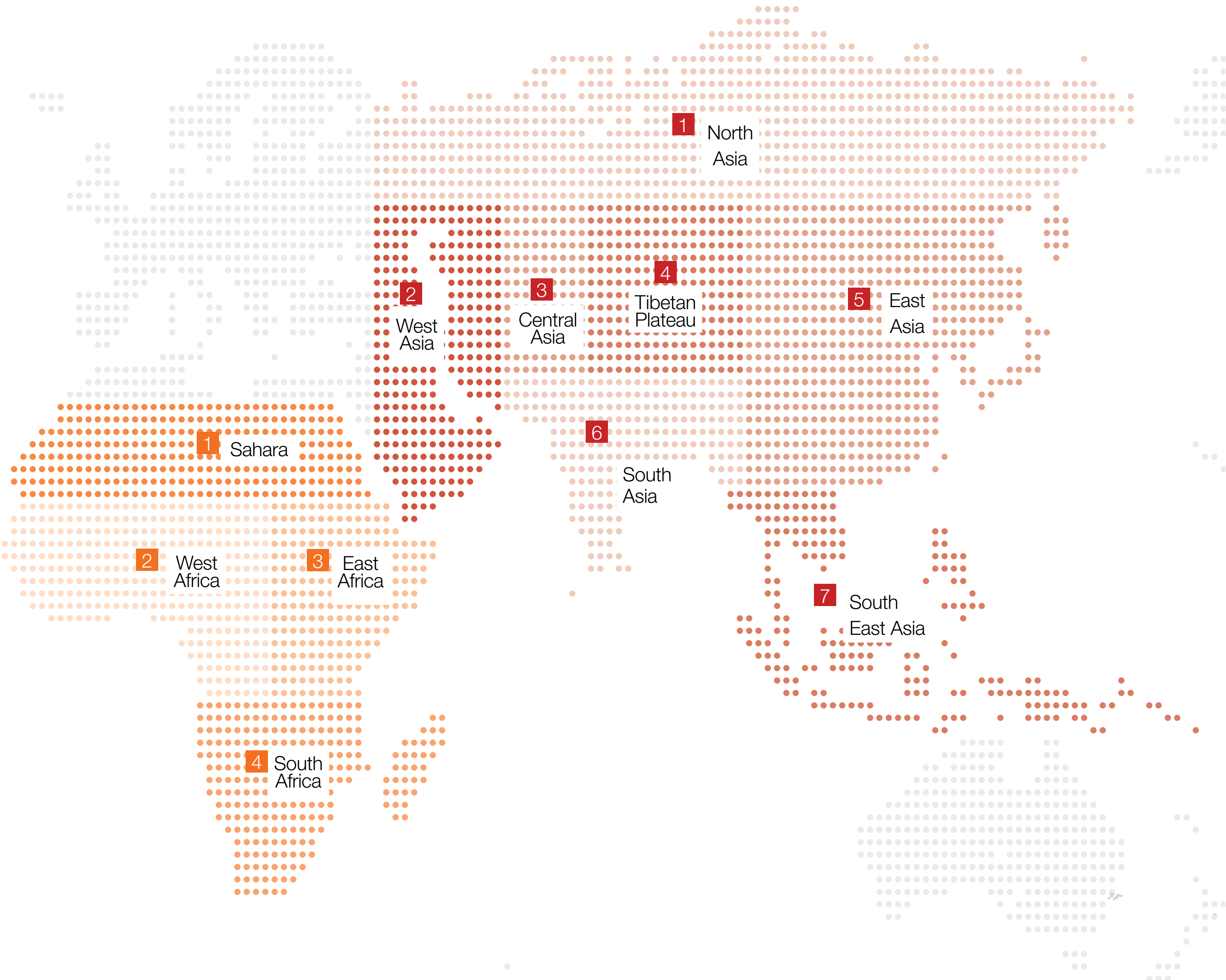


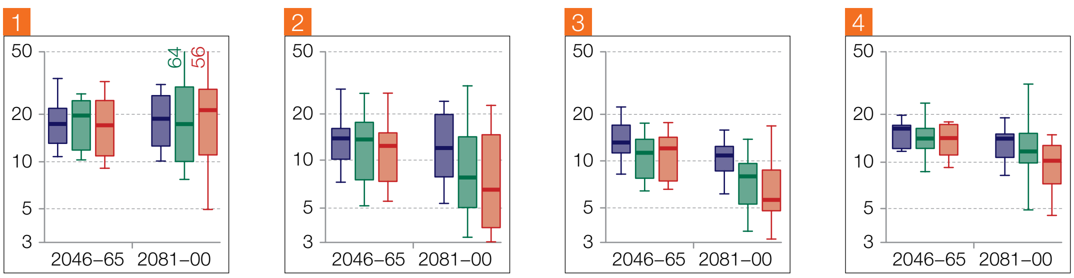


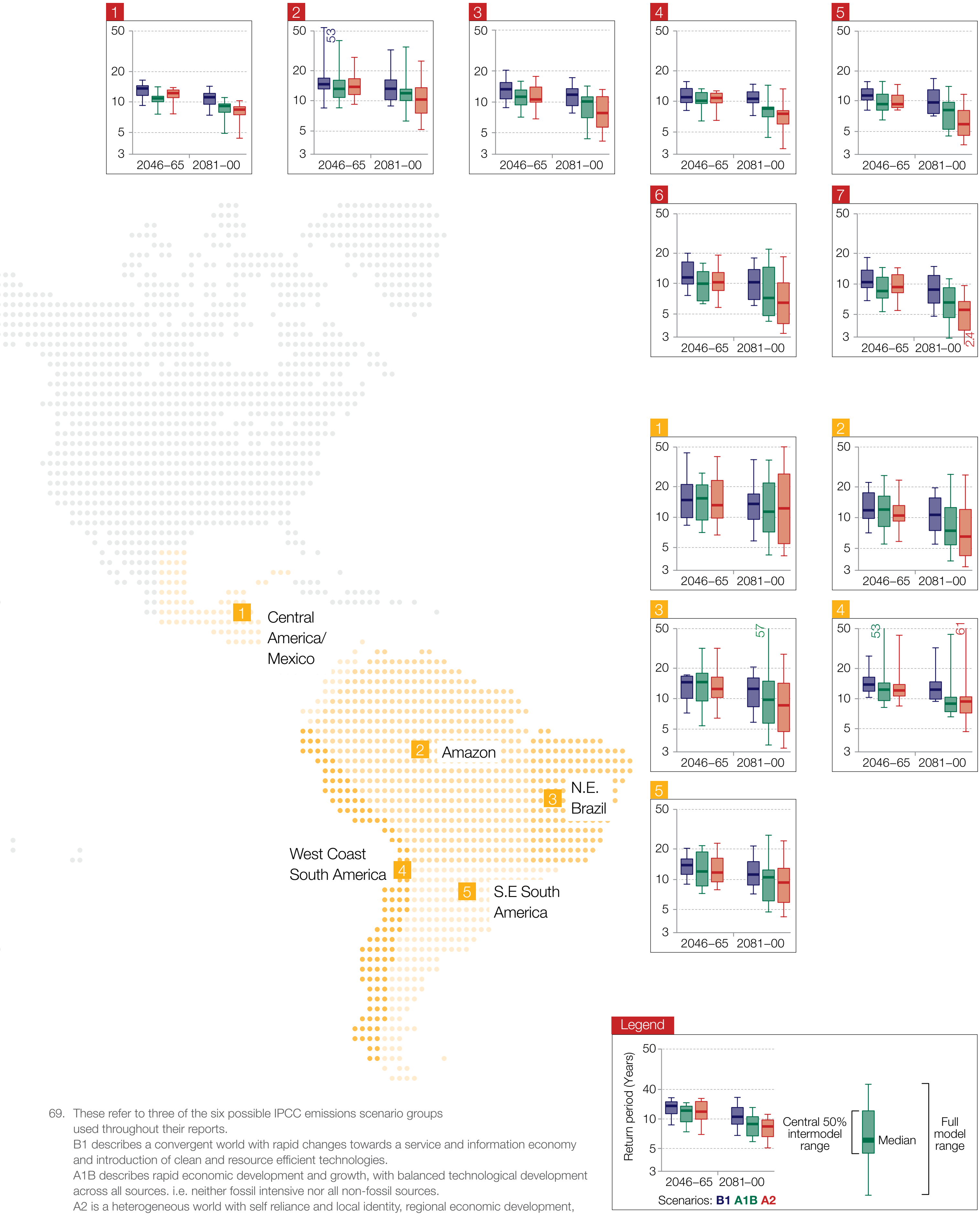
68. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development 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.[69] 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.



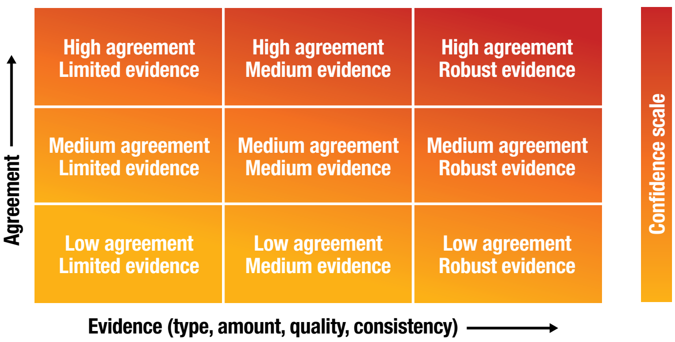




69. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development 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[70]	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

70. 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).

Climate & Development
Knowledge Network

Overseas Development
Institute

Agulhas
Applied Knowledge

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: 978-1-907288-89-0