Climate & Development
Knowledge Network

Managing Climate Extremes and Disasters in the Health Sector:

Lessons from the IPCC SREX Report

Contents

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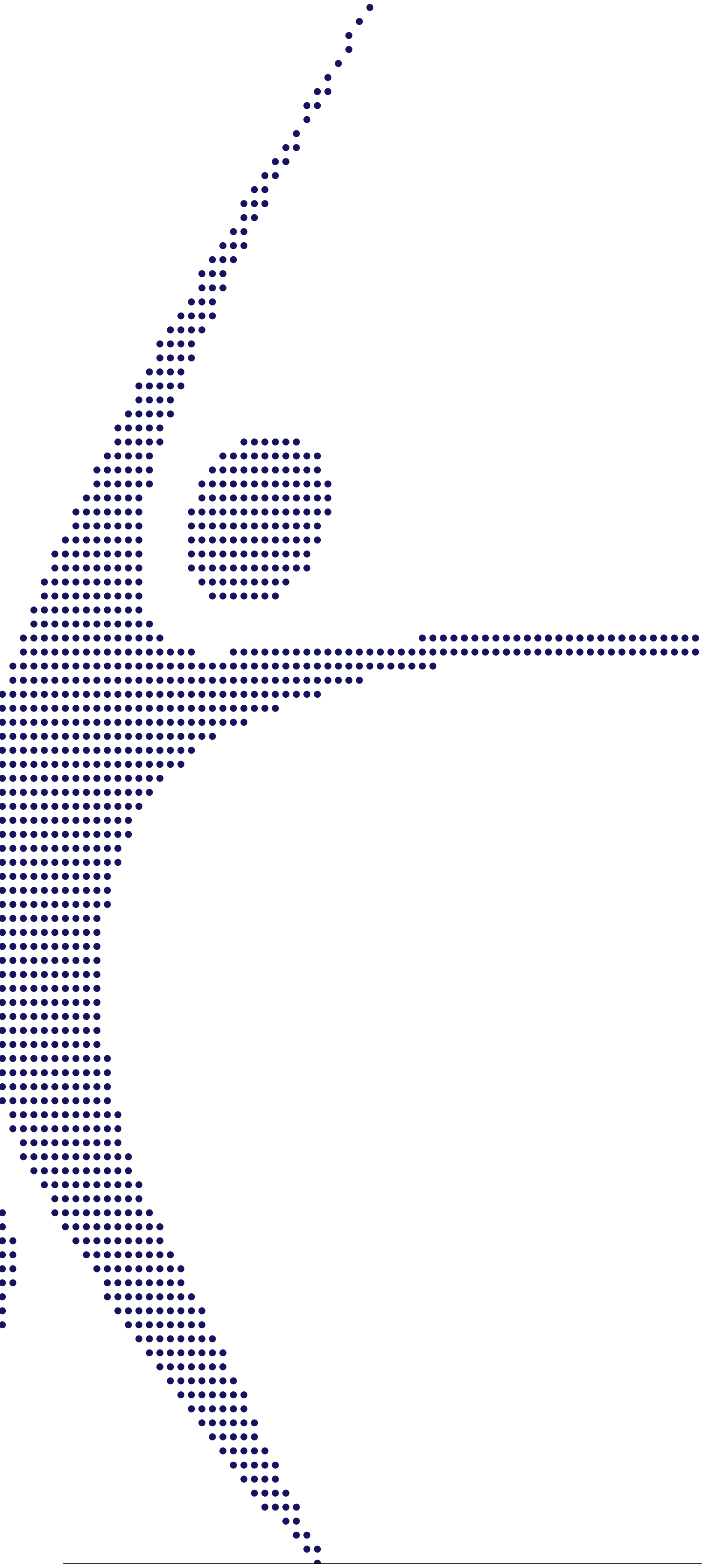


1. Introduction to SREX

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 health. 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 health.

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 health 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 public health policy-makers and planners, or indeed anyone whose work contributes to public health, this brief should prompt discussion, and understanding of several questions:

1. Why are extreme events a critical public health issue?
2. How is the public health sector affected by the risk of extreme events?
3. What actions can be taken to manage these risks?

1.2 Ten key messages

Key overarching summary messages from SREX, which are relevant to all sectors, 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.
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.

5. High levels of vulnerability, combined with more severe and frequent weather and climate extremes, may result in some areas 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 early warning systems and improvements to health surveillance.

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 do the SREX findings mean for the health sector?

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. This will have a direct impact on people's security, livelihoods and health in the future, including through increased length, frequency and/or intensity of heatwaves, 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. Extreme events such as floods can cause deaths, injuries and disability, and can be followed by infectious diseases (such as cholera), and malnutrition due to crop damage and disruption of food supply. Other health impacts of extreme events may be indirect, but long lasting, and are often associated with mental health impacts such as stress, anxiety, and depression.

Extreme climate and weather events can also negatively impact the critical infrastructure needed to protect human health. There is high confidence that changes in the climate could seriously affect water management systems[3], which will affect sanitation and health. Extreme events may cause failures in hospital or health centre building structures, and can also prevent people accessing health services, for example during a storm or flood.

Those most likely to experience difficulty accessing health services during or after an extreme event are individuals already considered vulnerable with respect to their health – such as children, the elderly, pregnant women, and those who may need additional response assistance including people with disabilities. In addition, as those with the least resources often have low health status and the least ability to adapt, the poor and disenfranchised are also the most vulnerable to climate-related health impacts. Extreme events can therefore exacerbate health inequalities.

Importantly, 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 health infrastructure, services, outcomes and inequalities. These include:

- assessing risks and maintaining information systems, particularly public health surveillance systems;
- developing strategies to support coping and adaptation, including building the capacity of communities to prevent, prepare, respond to, and recover from extreme events;
- learning from experience in managing risk; and
- linking local, national and international approaches.

If extreme climate events increase significantly 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 health surveillance and early warning systems into development planning and policy-making.

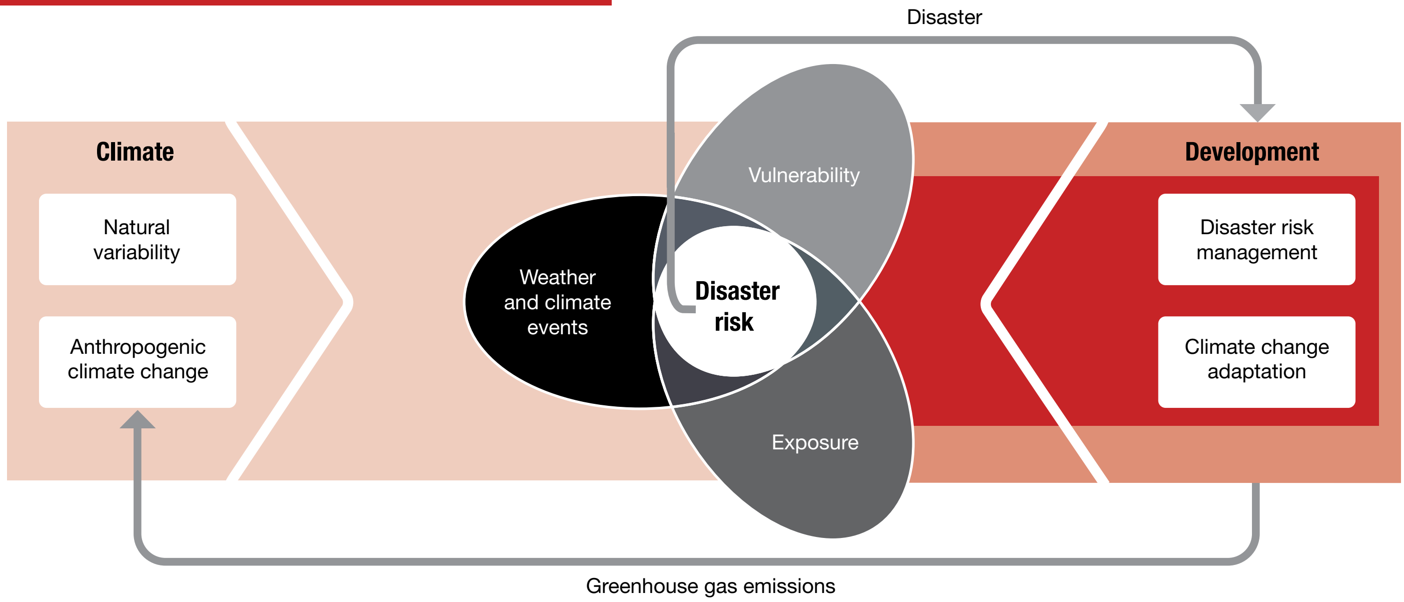
Finally, there must be consideration that, in some cases, today's climate extremes will be tomorrow's 'normal' weather. Tomorrow's climate extremes may therefore stretch our imagination and challenge our capacity to manage change as never before.

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 climate extremes, can contribute and combine to create disaster risk, hence the need for both DRM and CCA within development processes.

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



2.1 Changes in extreme events[4]

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 defined in SREX 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[5]).

Many of the projected increases in extreme weather and climate events will have both direct and indirect impacts on people's security, livelihoods, and health. Some of the trends most relevant to health include[6]:

- Observations since 1950 show changes in some extreme events, particularly daily temperature extremes, and heatwaves.
- It is virtually certain that increases in the frequency of warm daily temperature extremes and decreases in cold extremes will occur throughout the 21st century on a global scale. It is very likely – 90 to 100% probability – that heatwaves will increase in length, frequency, and/or intensity over most land areas.
- 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.

4. 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'.
5. SREX Section 3.1.2 has a full explanation.
6. See Annex IV: IPCC uncertainty guidance, which shows the probabilities attached to particular terms such as 'likely' or 'very likely'.

- There is evidence, providing a basis for 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[7].
- It is very likely that average sea level rise will contribute to upward trends in extreme coastal high water levels.
- It is likely that the average maximum wind speed of tropical cyclones (also known as typhoons or hurricanes) will increase throughout the coming century, although possibly not in every ocean basin.

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. This is available at Annex II.

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 heatwaves 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.

2.2 Disaster risk, exposure and vulnerability[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, health, demographic, cultural, institutional, and governance factors. High vulnerability and exposure are generally the outcome of skewed development processes, for example, environmental mismanagement, rapid and unplanned urbanisation, failed governance, and a scarcity of livelihood options. Low health status due to inadequate access to health services can also contribute significantly to vulnerability.

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 a reflection of:

- the susceptibility of what is exposed to harm (loss or damage) from the event; and
- its capacity to avoid, resist and transfer risks, and to respond to and recover from the event.

Individuals and communities are therefore differentially exposed and vulnerable based on inequalities expressed through levels of wealth, education, disability, and health status, as well as gender, age, class, and other social and cultural characteristics. Lack of resilience and capacity to anticipate, cope with, and adapt to extremes and change are important causal factors of vulnerability, as illustrated by recent extreme events such as the Australian heatwaves and wildfires (Box 2).

7. 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.
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'.

Box 2: Health status and vulnerability to wildfires in Australia[9]

An episode of extreme heatwaves began in South Australia on 25 January 2009. In Melbourne, Victoria, the temperature was above 43°C for three consecutive days, peaking at 45.1°C (the second highest temperature on record). During the 12 years between 1998 and 2007, Victoria had experienced warmer than average temperatures and a 14% decline in average rainfall.

On 7 February 2009, the temperatures spiked again, and by early afternoon wind speeds were reaching their peak. This led to a power line breaking and sparking a wildfire that would later generate extensive pyrocumulus cloud and become one of the largest, deadliest, and most intense firestorms ever experienced in Australia's history. A major wind change occurred late afternoon across the fire ground, turning the northeastern flank into a new wide fire front, catching many people by surprise.

Many people were not well-prepared physically or psychologically for the fires, and this influenced the level of loss and damage they incurred. Levels of physical and mental health also affected people's vulnerability. Many individuals with ongoing medical conditions, or special needs because of their age or disabilities, struggled to cope with the extreme heat and were reliant on others to respond safely. In total, 980 people died over the four days of the heatwave. Reported deaths of people aged 65 and older more than doubled compared to the same period a year before.

2.3 Consequences of climate extremes for health[10]

This section builds on the information presented so far and highlights how extreme climate and weather-related events – such as heatwaves, floods, droughts, and cyclones – directly and indirectly influence human health, well-being, and security.

Changes in extreme events and impacts of climate change influence the morbidity and mortality of many populations now, and will do so even more in future. A range of vector-borne illnesses have been linked to climate, including malaria, dengue, Hantavirus, Bluetongue, Ross River Virus, and cholera. Cholera, for example, has seasonal variability that may be directly affected by climate change (see Box 3 below).

Vector-borne illnesses have been projected to increase in geographic reach and severity as temperatures increase, though such shifts depend on a variety of human interventions like deforestation and land use. Areas of habitation by mosquitoes and other vectors are moving to areas previously free from them, though malaria epidemics, for example, can also occur when people with little immunity move into endemic regions.

Box 3: Climate change and cholera transmission

Cholera is one of a handful of diseases whose incidence has been directly associated with climate variability and long-term climate change. One driver of cholera's presence and pathogenicity is the El Niño-Southern Oscillation (ENSO), which brings higher temperatures, more intense precipitation, and enhanced cholera transmission. ENSO has been associated with cholera outbreaks in coastal and inland regions of Africa, South Asia, and South America. There is concern that climate change will work synergistically with poverty and poor sanitation to increase cholera risk[11].

Zimbabwe has had cholera outbreaks every year since 1998, with the 2008 epidemic the worst the world had seen in two decades, affecting approximately 92,000 people and killing over 4,000. Weather appears to have been crucial in the outbreak, as recurrent point-source contamination of drinking water was almost certainly amplified by the onset of the rainy season. In addition to its size, this epidemic was distinguished by its urban focus and relatively high case fatality rate (CFR; the proportion of infected people who die) ranging from 4 to 5%. Most cholera outbreaks have CFRs below 1%. Underlying structural vulnerability – with shortages of medicines, equipment, and staff at health facilities throughout the country – compounded the effects of the cholera epidemic[12].

9. Draws on SREX Chapter 9, Murray, V. et al, 'Case Studies'.
10. Draws on material from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
11. SREX Chapter 9, Murray, V. et al, 'Case Studies' p.508.
12. SREX Chapter 9, Murray, V. et al, 'Case Studies' p.509.

Floods can cause deaths and injuries among those directly exposed, and can be followed by infectious diseases (such as cholera, explored in Box 3 above, and other diarrhoeal diseases), and malnutrition due to crop damage and interruptions to food supply. In Dhaka, Bangladesh, the severe flood in 1998 was associated with an increase in diarrhoea during and after the flood, and the risk of non-cholera diarrhoea was higher among those from a lower socioeconomic group who were not using tap water. Floods may also lead to shifts in disease ecology, e.g. a geographical shift of malaria epidemic regions by changing breeding sites for vector mosquitoes. For example, outbreaks of malaria were associated with changes in habitat after the 1991 floods in Costa Rica's Atlantic region.

Drought can affect water security, as well as food security (through reduction of agricultural production), with resultant impacts on malnutrition, morbidity, and mortality. Drought can also increase or decrease the prevalence of mosquito-borne infectious diseases such as malaria, depending on the local conditions, and is associated with meningitis. Drought can also contribute to forest fires. The direct effects of fire on human health can include burns and smoke inhalation, with indirect effects potentially resulting from poorer water quality, loss of vegetation on slopes, increased soil erosion, and resulting increased risk of landslides.

Heat stress: Heat is the leading weather-related cause of death in many high-income settings. However, heat extremes can claim casualties even in tropical countries, where people are acclimatised to heat. The relationship between daily temperature and mortality in mid- and low-income countries has been evaluated and higher mortality was observed on very hot days in most cities, including tropical cities such as Bangkok in Thailand and Delhi in India. People living in informal settlements and structures are generally more exposed to high temperatures. Both heatwaves and extreme cold weather spells are associated with impacts on mortality and morbidity, as well as more indirect impacts on human health e.g. through changes to the physical environment. Concentrations of air pollutants, such as particulate matter and ozone, are often elevated during heatwaves, with adverse affects on cardiovascular and respiratory health.

Examples of **indirect health impacts from extreme weather events** include illnesses or injury resulting from disruption of infrastructure designed to meet basic needs like medical services; exposure to infectious or toxic agents after extreme events like cyclones or flooding, which is often exacerbated by substandard and overcrowded housing; stress, anxiety, and mental illness, and increased susceptibility to infections, after evacuation or geographical displacement; and disruption of socioeconomic structures and food production that leads to increases in malnutrition that might not manifest themselves until months after the event. Indirect health impacts are therefore a potentially large, but under-examined, outcome of extreme weather events that lead to a substantial underestimation of the total health burden.

There is a growing body of evidence that the **mental health impact from extreme events** is substantial. Often overshadowed by the physical health outcomes of an event, the psychological effects can be long lasting and can affect a large portion of a population. An extreme event may affect mental health directly through acute traumatic stress, with common outcomes of anxiety and depression. It can also have indirect impacts during the recovery period associated with the stress and challenges of loss, disruption, and displacement. Furthermore, indirect mental health impacts could even affect individuals not directly associated with an event, like grieving friends and family of those who die, or rescue and aid workers who suffer post-traumatic stress disorder (PTSD).

Long-term mental health impacts are not often adequately monitored, but the body of research conducted after natural disasters in the past three decades suggests that the burden of PTSD among persons exposed to disasters is substantial. A range of other stress-related problems such as grief, depression, anxiety disorders, somatoform disorders, and drug and alcohol abuse can endure long after the causative event[13].

13. For more on mental health and extreme events see: Psychological first aid: Guide for field workers: http://whqlibdoc.who.int/publications/2011/9789241548205_eng.pdf;
IASC Mental health and psychosocial support in humanitarian emergencies: What should humanitarian health actors know: http://www.who.int/entity/mental_health/emergencies/what_humanitarian_health_actors_should_know.pdf; and
Scaling up the community based health workforce for emergencies:
http://www.who.int/entity/workforcealliance/knowledge/publications/alliance/jointstatement_chwemergency_en.pdf.

3. Future impacts

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

3.1 Increasing exposure to hazards affecting health

Changes in the frequency, intensity, spatial extent and duration of weather and climate events, alongside increases in population growth and density in many areas, mean that greater numbers of people are likely to be exposed in future to hazards that affect their health, such as temperature extremes, flooding, drought, and cyclones.

Recent modelling gives us much more information about what to expect in terms of changes in average daily temperatures globally. Annex III provides more detail.

Populations exposed to water-related hazards such as flooding are already significant and likely to increase. For example, 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 levels, as set out in Figure 2.

Changes in population size strongly influence changes in exposure to hazards. For example, it is estimated that currently about 1.15 billion people live in tropical cyclone-prone areas. The physical exposure (yearly average number of people exposed) to tropical cyclones is estimated to have increased from approximately 73 million in 1970 to approximately 123 million in 2010. Figure 3 provides the modelled change in human exposure at constant hazard levels (without forecast of the influence of climate change on the hazard). It shows that the average number of people exposed to tropical cyclones per year globally would increase by 11.6% from 2010 to 2030 from population growth only. In relative terms, Africa has the largest percentage increase in physical exposure to tropical cyclones. In absolute terms, Asia has more than 90% of the global population exposed to tropical cyclones.

3.2 Increasing economic losses

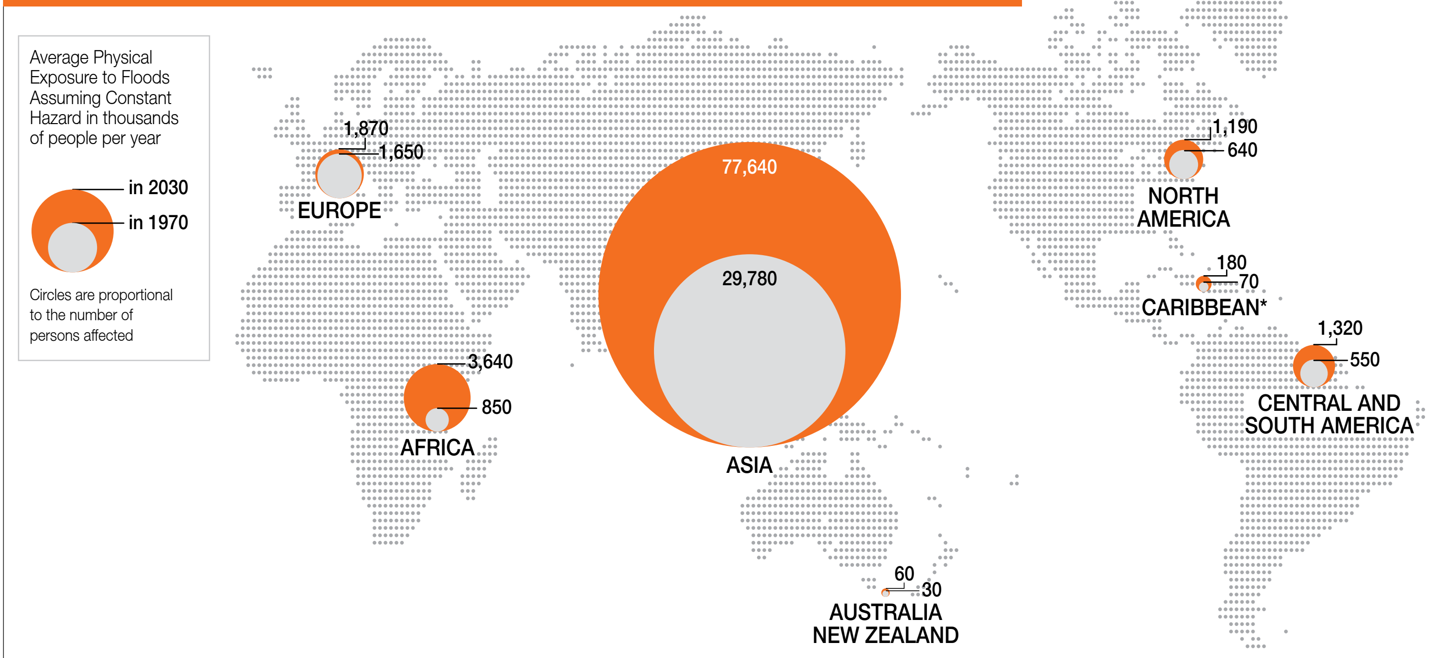
There is high confidence that economic losses from weather and climate related disasters are increasing, albeit with large inter-annual variability. Costs arise due to the economic, social, and environmental impacts of a climate extreme or disaster. Annual accumulated estimates have ranged from a few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

To date, in small exposed countries, especially small island developing states, losses expressed as a percentage of GDP have been particularly high, exceeding 1% in many cases and 8% in the most extreme cases, averaged over both disaster and non-disaster years for the period from 1970 to 2010.

Future increases in loss could have a devastating impact on social development, health, and well-being.

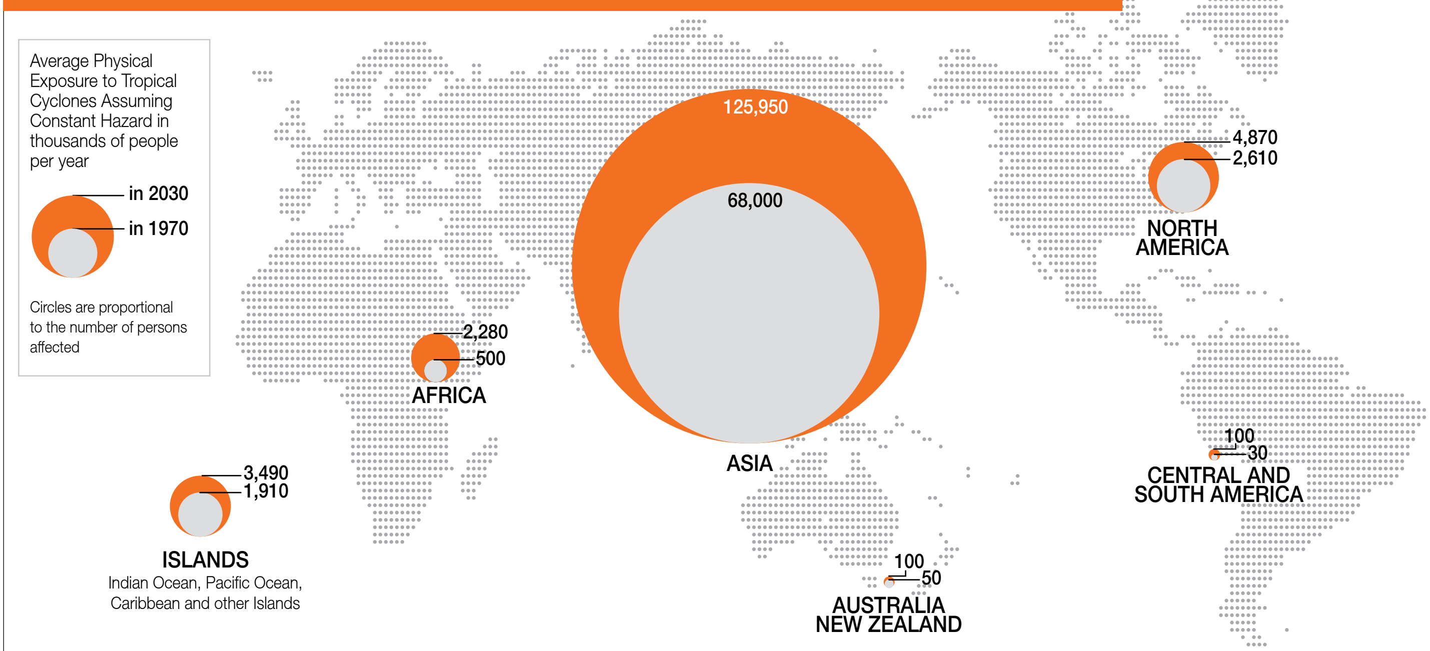
The human and economic toll from disasters can be greatly amplified by the long-term loss in incomes, health, education, and other forms of capital resulting from the inability of communities to restore infrastructure, housing, sanitation and hygiene, and livelihoods in a timely way. The vulnerability of households and communities can therefore worsen over time (particularly for those with limited access to healthcare, and no or limited insurance).

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.

Figure 3: Average physical exposure to tropical cyclones assuming constant hazard (in thousands of people per year)



3.3 Impacts on health infrastructure and services

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, tourism and health.

Public health measures, healthcare and other services required for preventing and mitigating adverse health impacts from an extreme weather event include:

- surveillance and control activities for infectious diseases;
- access to safe water and improved sanitation;
- food security;
- solid waste management and other critical infrastructure;
- maintenance of hospitals and other health care infrastructure;
- provision of mental health services;
- sufficient and safe shelter to prevent or mitigate displacement; and
- effective warning and information systems.

Such services are key to reducing and managing the risks to public health presented by extreme events.

Extreme climate and weather events can directly and negatively impact the critical infrastructure needed to protect human health. There is high confidence that changes in the climate could seriously affect water management systems[14], which will affect sanitation and health. Extreme events may also cause failures in hospital or health centre building structures and damage to valuable medical equipment, and can also prevent people accessing health services, for example during a storm or flood.

3.4 Impacts on health inequalities

Those most likely to experience difficulty accessing health services during or after an extreme event are individuals already considered vulnerable with respect to their health – such as children, the elderly, pregnant women, and those who may need additional response assistance including the disabled, those living in institutionalised settings, those from minority cultures, people with limited proficiency in the local language, those with no access to transport, with chronic medical disorders, or with pharmacological dependency. The issues are explored in more detail in Box 4.

Box 4: Climate change, vulnerability, and health inequalities

Health inequalities are of concern when considering the impacts of climate change and extreme events, as those with the least resources often have the least ability to adapt, making the poor and disenfranchised more vulnerable to climate-related health impacts. The impact of disaster events can be greater for those with pre-existing health conditions as they may be more susceptible to additional injuries. Chronic health conditions or disabilities can make individuals more susceptible to infection, illness, and injury in the short-term, and to chronic illnesses and mental health conditions in the longer-term.

Increasing numbers of elderly people will become exposed to climate change impacts in the coming decades, particularly in OECD countries where populations are ageing most rapidly. By 2050, it is estimated that one in three people will be older than 60 years in OECD countries, and one in five at the global scale. The elderly are made vulnerable to climate change-related hazards by characteristics that also increase vulnerability to other social and environmental hazards (thus compounding overall vulnerability): deterioration of health, personal lifestyles, social isolation, poverty, and inadequate access to health and social infrastructures. Social risk factors combined with hearing loss, and mental capability or mobility issues mean older people are less able to receive warning messages or take protective actions, and are more reluctant to evacuate. However, older people have more accumulated experience and wisdom on specific disasters and extreme events as well as the ability to transfer coping strategies based on their experiences.

It is estimated that 66.5 million children are affected annually by disasters. Research on disaster impacts among children focuses on short- and long-term physical and psychological health impacts. Vulnerability to these impacts is due in part to the less-developed physical and mental state of children, and therefore differential capacities to cope with deprivation and stress in times of disaster. Most literature points toward higher mortality and morbidity rates among children due to climate stresses and extreme events. This is especially acute in developing countries, where climate-sensitive health outcomes such as malnutrition, diarrhoea, and malaria are already common and coping capacities are lowest.

Recent studies conducted in Bolivia, Indonesia, Mexico, Mozambique, Nepal, the Philippines, and Vietnam provide evidence of how extensive (low impact/high frequency) disasters negatively affect children's education, health, and access to services such as water and sanitation. Extensive disasters led to an increased incidence of diarrhoea in children under five years of age in Bolivia, an increased proportion of malnourished children under three in Nepal, an increased infant mortality rate in Vietnam, and an increase in the incidence of babies born with low birth weight in Mozambique.

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

4. Managing the risks of climate extremes and disasters[15]

This section considers the range of responses required in order to try to better manage the risks presented by climate extremes and disasters for the health sector.

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. 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, to national, 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, community-based organisations and communities themselves. Effective national systems would ideally have each actor performing to their accepted functions and capacities. National and sub-national government 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 health infrastructure, services, outcomes, and inequalities. 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

The first step in managing risk is to assess and characterise it. Managing risk 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 hazards, people, assets, vulnerabilities, risks, disaster impacts, and service capacity, in order to support DRM.

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 to health. Such information includes health surveillance data, demographic data, and core health indicators including mortality rates.

Before, during, and in the immediate aftermath of extreme events, the sharing of information is vital. However, it can also be very challenging, as explained in Box 5.

Box 5: Challenges communicating risk: the case of heatwaves in Europe

During the first two weeks of August 2003, temperatures in Europe soared far above historical norms. The heatwave stretched across much of Western Europe, but France was particularly affected. The European heatwave had significant health impacts. Initial estimates were of costs exceeding €13 billion, with a death toll of over 30,000 across Europe. It was estimated that excess mortality over the entire summer could have reached 70,000, with approximately 14,800 excess deaths in France alone. The severity, duration, geographic scope, and impact of the event were unprecedented in recorded European history.

Efforts to minimise the public health impact of the heatwave in 2003 were hampered by denial of the event's seriousness and the inability of many institutions to instigate emergency-level responses. Afterwards, several European countries quickly initiated plans to prepare for future events. France, the country hit hardest, developed a national heatwave plan, surveillance activities, clinical treatment guidelines for heat-related illness, identification of vulnerable populations, infrastructure improvements, and home visiting plans for future heatwaves. These steps may have contributed to a lower than expected number of excess deaths during the next major heatwave that hit France in 2006.

One particularly difficult aspect of heatwave preparedness is communicating risk. In many locations, people are unaware of the level of risk and heatwave warnings go largely unheeded. Even when information is distributed through pamphlets and media outlets, behaviour of at-risk populations often does not change. Research shows that communication about heatwave preparedness centered on engaging with communities results in increased awareness compared with top-down messages. Older people, in particular, engage better with prevention campaigns that allow them to maintain independence and do not specifically focus on their age (as many heat warnings do).

15. 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 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

4.2 Developing strategies to support coping and adaptation

There is strong evidence that weather-related mortality risk is highly concentrated in countries with low GDP and weak governance. How well a community responds to and survives disaster depends upon the resources that can be used to cope. These can be self-generated at the local level, as the example of the Garifuna women of Honduras in Box 6 shows.

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.

Box 6: Local level DRM in Honduras: the role of Garifuna women

The Garifuna women of Honduras have focused on livelihood-based activities to improve nutrition and ensure food security by reviving and improving the production of traditional root crops, building up traditional methods of soil conservation, carrying out training in organic composting and pesticide use and creating the first Garifuna farmers' market. In collaborative efforts, sixteen towns now have established tool banks, and five have seed banks. Through reforestation, the cultivation of medicinal and artisanal plants, and the planting of wild fruit trees along the coast, they are helping to prevent erosion and are reducing community vulnerability to hazards and the vagaries of climate.

This approach, which combines livelihood based recovery, DRM and adaptation has had wide ranging benefits. The Garifuna women have improved their communities' nutrition, incomes, natural resources, and risk management, and have built up their asset base.

4.3 Learning from experience in managing risk

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 a key component for living with uncertainty and extreme events. It is nurtured by building the right kind of social and institutional space for learning and experimentation, which allows for competing worldviews, knowledge systems, and values, and facilitates innovative and creative adaptation. Allowing time for reflection is important because it provides the necessary space to develop and test theories and strategies under ever-changing conditions. It is through such learning processes that individual and collective empowerment can emerge and potentially be scaled up to trigger transformation. Some entry points for learning are identified in Box 7.

Box 7: Learning from local health communications for DRM

Communications that include social, interpersonal, physical, environmental, and policy factors can foster civic engagement and social change, which is fundamental to reducing risk. A participatory approach highlights the need for multiple pathways of communication, which engender credibility, trust, and cooperation. One such pathway is engaging with community leaders or opinion formers in accessing social networks through which to distribute information.

Another approach used in health communications is the 'community drama' in which community members engage in plays to communicate health risks. Such communication projects can educate households and communities (for example, about climate change, extreme events, and their impacts on health), and can stimulate the kinds of community action necessary for disaster preparedness.

Indeed, the community-based health workforce is important in all phases of DRR and DRM. Their skills need to be recognised, revitalised and strengthened to manage health emergencies in hazard-prone communities.

4.4 Linking local, national, and international approaches

Integration of local knowledge with additional scientific and technical knowledge can improve DRM and adaptation. This self-generated knowledge can uncover existing capacity and identify important shortcomings. 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, improvements in housing stock, water supply, sanitation, irrigation and drainage systems, and health surveillance, and by supporting the community-based health workforce to integrate emergency work with primary health care.

Indeed, DRM and preventive public health are closely linked and largely synonymous. Strengthening and integrating such measures, along with economic development, should increase resilience against the health effects of extreme weather and facilitate adaptation to climate change. Such integrated approaches are visible in Bogota, São Paulo and Santiago where urban adaptation efforts are working to support existing DRM strategies.

National systems – from community to central levels – 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 management. 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 – e.g. the Caribbean Mainstreaming Adaptation to Climate Change project, which was implemented from 2004 to 2007. A set of features has been identified that make efforts to systematically manage disaster risk more successful. These are captured in Box 8.

Box 8: Features of successful DRM

- **Risks are recognised as dynamic and are mainstreamed, so are integrated into policy and strategy.**
- **Legislation for managing disaster risk is supported by clear regulations – such as the International Health 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 sound information, such as health surveillance data, 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 such as capacity building and conservation measures.**

International actors can also play a useful enabling role in risk management, for example by exercising convening power and coordinating initiatives, supporting the provision of public goods, offering technical assistance, and sharing experience. International agencies may also facilitate the pooling of information and expertise to develop toolkits, databases, and systems – such as early warning systems – that can help countries and regions to manage risk (see Box 9). Globally negotiated frameworks on CCA and DRR, such as the UNFCCC and the Hyogo Framework for Action, are complemented by sector and issue-specific policy and regulatory frameworks, such as the International Health Regulations (affecting the way that epidemics of climate-sensitive infectious diseases such as cholera are managed across borders) and the codes of practice of international humanitarian organisations (such as the Code of Conduct for the International Red Cross and Red Crescent Movement and NGOs in Disaster Relief).

For health, important international actors include the World Health Organisation (WHO), the World Bank, and other UN agencies such as UNICEF, as well as the major bilateral donors and foundations engaged in the health sector, and global health partnerships (such as the Global Fund to fight AIDS, TB and Malaria).

Box 9: The role of international actors in developing early warning systems

Different hazards and different sectors often require unique preparedness, warnings, and response strategies. For example, the needs and responses behind a warning of a drought, a tornado, a cyclone, or a fire are very different. Some hazards may represent singular extreme events, sequences, or compound combinations of hazards, while other hazards can be described as 'creeping' or accumulations of events (or non-events). For example, the World Meteorological Organisation (WMO), national meteorological and hydrological services, the World Health Organisation (WHO), the Food and Agriculture Organisation (FAO), the Red Cross, and others, recognise that combinations of weather and climate hazards can result in complex emergency response situations. They are working to establish multi-hazard early warning systems for complex risks such as heatwaves, and early warnings of food safety threats and disease outbreaks.

5. Conclusions: what does this mean for decision-makers in the Health sector?[16]

This final section considers the implications for health policy and decision-makers in more detail. As climate change impacts become more severe, their effects 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[17]

DRM has historically operated under the premise that future climate will resemble that of the past. Climate change now adds greater uncertainty to the assessment of hazards and vulnerability. This will make it more difficult to anticipate, evaluate, and communicate disaster risk.

Sustainable development involves finding pathways that achieve a variety of socioeconomic and environmental goals, preferably without sacrificing any one for the sake of the others.

The relationships between adaptation, DRM, and sustainability are highly political. Successful reconciliation of multiple goals 'lies in answers to questions such as who is in control, who sets agendas, who allocates resources, who mediates disputes, and who sets the rules of the game[18].'

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

There is a need to mainstream adaptation 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 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.

16. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
17. Draws on material from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
18. 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.

5.2 Developing adaptation strategies: the importance of national systems[19]

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 the short- and longer-term actions needed to resolve the underlying causes of vulnerability and to understand the nature of changing climate hazards.

It is vital to note that the processes of DRM and preventive public health are closely linked, and largely synonymous. Strengthening and integrating these measures, alongside economic development, should increase resilience against the health effects of extreme weather events and gradual climate change.

Climate change is, however, far too big a challenge for any single national government ministry to address. Achieving adaptation and DRM objectives while attaining health and other 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. Effective adaptation and risk reduction coordination between all sectors may only be realised if all areas of government are coordinated from the highest political and organisational level; therefore national systems need to be at the core of countries' capacity to meet climate challenges. Greater efforts are required to both address the underlying drivers of risk and generate political will to invest in DRR and national DRM systems.

For the health sector, a range of adaptation strategies are set out in Table 1, ranging from low-regrets to win-win, which address greenhouse gas reductions as well as adaptation and risk reduction, and which have broader developmental benefits.

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

Table 1: Range of adaptation strategies at national level

'Low regrets' actions for current and future risks	('Low regrets' options plus…) Preparing for climate change risks by reducing uncertainties (building capacity)	('Preparing for climate change' risks plus...) Reduce risks from future climate change	Risk transfer	Accept and deal with increased and unavoidable (residual) risks	'Win-win' synergies for greenhouse gas reduction, adaptation, risk reduction, and development benefits
• Community/urban and coastal zone planning, building standards and guidelines; cooling shelters; safe health facilities; retrofits for vulnerable structures; health facilities designed using updated climate information. • Strengthen health surveillance; early warning weather/climate-health systems, heat alerts and responses; capacity for response to early warnings. • Prioritise disaster risks; disaster prevention and preparedness; public education campaigns; food security. • Strengthen disease surveillance and control; improve health care services, personal health protection; improve water treatment/ sanitation; water quality regulations; vaccinations, drugs, repellents; development of rapid diagnostic tests. • Monitor air and water quality; regulations; urban planning. • Better land and water use management to reduce health risks.	• Research on climate-health linkages and adaptation to climate change; develop new health prediction systems for emerging risks; research on landscape changes, new diseases, and climate; urban weather-health modelling. • Education, disaster prevention and preparedness.	• New food and water security and distribution systems; air quality regulations, alternate fuels. • New warning and response systems; predict and manage health risks from landscape changes; target services for most at risk populations. • Climate proofing during refurbishment and maintenance of national health services and facilities. • Address needs for additional health facilities and services.	• Extend and expand health insurance coverage to include new and changed weather and climate risks. • Government reserve funds.	• National plan for heat extremes and emergencies. • New disease detection and management systems. • Enhanced prediction and warning systems for new risks.	• Use of clean and sustainable renewable energy and water sources; increase energy efficiency; air quality regulations; clean energy technologies to reduce harmful air emissions (e.g. cooking stoves). • Design sustainable infrastructure for climate change and health.

5.3 Building long-term resilience: from incremental to transformational

Extreme climate and weather events are predicted to increase significantly in coming decades. CCA and DRM are therefore 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.

5.4 Planning for an uncertain future

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 timescales.

Among the most successful DRM and adaptation efforts are those that have facilitated the development of **partnerships** between local leaders and other stakeholders, including public health professionals. 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.

Some practical suggestions for 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. The European heatwaves of 2003 and 2006 (see Box 5) showed how enhancing public health response capacity, augmenting early warning systems, and applying known strategies for protecting health from the threat of extreme heat in new settings had demonstrable impacts on heat-related mortality, and quickly shifted the region's coping range with regard to extreme heat.

Research improves our knowledge, especially when it includes integration of natural, social, health, and engineering sciences. Addressing knowledge gaps through enhanced observation and research can reduce uncertainty and help in designing effective adaptation and risk management strategies.

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. There is also a need for better coordination and accountability within governance hierarchies and across sectors, and between international actors where they are engaged.

International actors can help by providing an institutional framework to support experimentation, innovation and flexibility, financing risk transfer, and supporting funding for adaptation. In the health sector, they can offer technical (and sometimes financial) assistance to strengthen public health systems, and address human resource constraints in the health sector.

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. Public health has a wide range of interventions for preventing and containing outbreaks of cholera and other infectious diseases, and several other potentially effective interventions are being developed. 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.

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.

ANNEXES

Annex I: Acronyms

CBOs Community Based Organisations

CCA Climate Change Adaptation

CFR Case Fatality Rate

CSOs Civil Society Organisations

DRM Disaster Risk Management

DRR Disaster Risk Reduction

ENSO El Nino Southern Oscillation

GDP Gross Domestic Product

IFIs International Financial Institutions

LDCs Least Developed Countries

LECZ Low Elevation Coastal Zone

MDTF Multi-donor Trust Fund

NGOs Non-Governmental Organisations

OECD Organisation for Economic Co-operation and Development

PPCR Pilot Programme for Climate Resilience

PTSD Post-Traumatic Stress Disorder

SREX The Special Report on Managing the Risks of Extreme events and Disasters to Advance Climate Change Adaption

UNFCCC United Nations Framework Convention on Climate Change

WHO World Health Organisation

Annex II: Changes in climate extremes

Key

Symbols

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

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Africa

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

Table 2: Observed changes in temperature and precipitation extremes since the 1950s[20]

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

Region and Sub-region	Trends in maximum temperature (warm and cold days)[21]	Trends in minimum temperature (warm and cold nights)[22]	Trends in heat waves/ warm spells[23]	Trends in heavy precipitation (rain, snow)[24]	Trends in dryness and drought[25]
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

20. Period 1961 to 1990 used as a baseline.
21. 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.
22. 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.
23. 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.
24. 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.
25. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

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

Table 3 shows projected changes in temperature and precipitation extremes, including dryness, in Africa. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[26] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[27]	Trends in minimum temperature (the frequency of warm and cold nights)[28]	Trends in heat waves/ warm spells[29]	Trends in heavy precipitation (rain, snow)[30]	Trends in dryness and drought[31]
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

26. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
27. 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.
28. 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.
29. 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.
30. 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.
31. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Asia

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

Key

Symbols

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

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Table 4: Observed changes in temperature and precipitation extremes since the 1950s[32]

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

Region and Sub-region	Trends in maximum temperature (warm and cold days)[33]	Trends in minimum temperature (warm and cold nights)[34]	Trends in heat waves/ warm spells[35]	Trends in heavy precipitation (rain, snow)[36]	Trends in dryness and drought[37]
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 5: Projected changes in temperature and precipitation extremes, including dryness, in Asia

Table 5 shows projected changes in temperature and precipitation extremes, including dryness, in Asia. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[38] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[39]	Trends in minimum temperature (the frequency of warm and cold nights)[40]	Trends in heat waves/ warm spells[41]	Trends in heavy precipitation (rain, snow)[42]	Trends in dryness and drought[43]
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

32. Period 1961 to 1990 used as a baseline.
33. 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.
34. 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.
35. 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.
36. 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.
37. 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.
38. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
39. 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.
40. 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.
41. 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.
42. 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.
43. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Latin America and the Caribbean

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

Key

Symbols

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

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Table 6: Observed changes in temperature and precipitation extremes since the 1950s[44]

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

Region and Sub-region	Trends in maximum temperature (warm and cold days)[45]	Trends in minimum temperature (warm and cold nights)[46]	Trends in heat waves/ warm spells[47]	Trends in heavy precipitation (rain, snow)[48]	Trends in dryness and drought[49]
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

44. Period 1961 to 1990 used as a baseline.
45. 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.
46. 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.
47. 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.
48. 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.
49. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Table 7: Projected changes in temperature and precipitation extremes at the end of 21st century[50]

Table 7 shows projected changes in temperature and precipitation extremes, including dryness in Latin America. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[51] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[52]	Trends in minimum temperature (the frequency of warm and cold nights)[53]	Trends in the heat waves/warm spells[54]	Trends in heavy precipitation (rain, snow)[55]	Trends in dryness and drought[56]
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

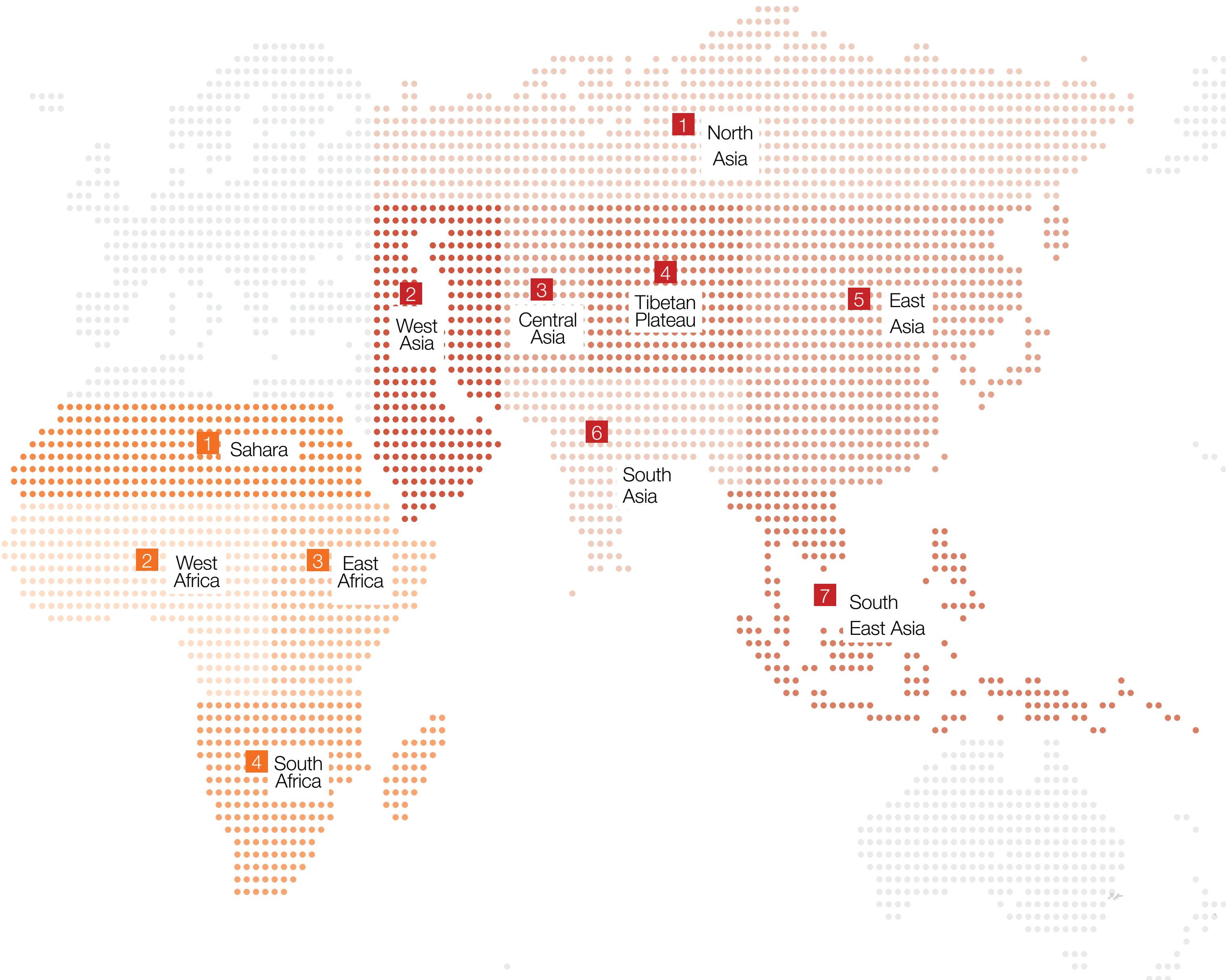
50. Projections are for the end of the 21st century vs end of the 20th century (e.g. 1961 to 1990 or 1980 to 2000 vs 2071 to 2100 or 2080 to 2100) and for the A2/A1B emissions scenario.
51. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
52. Refers to the number of warm 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.
53. 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.
54. 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.
55. 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.
56. 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.

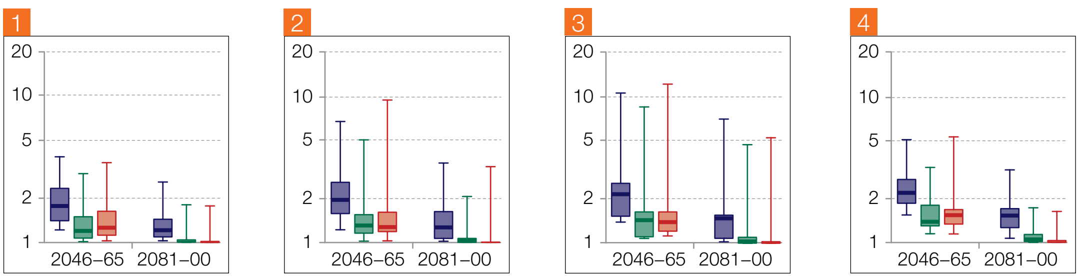
Annex III: Return period maps

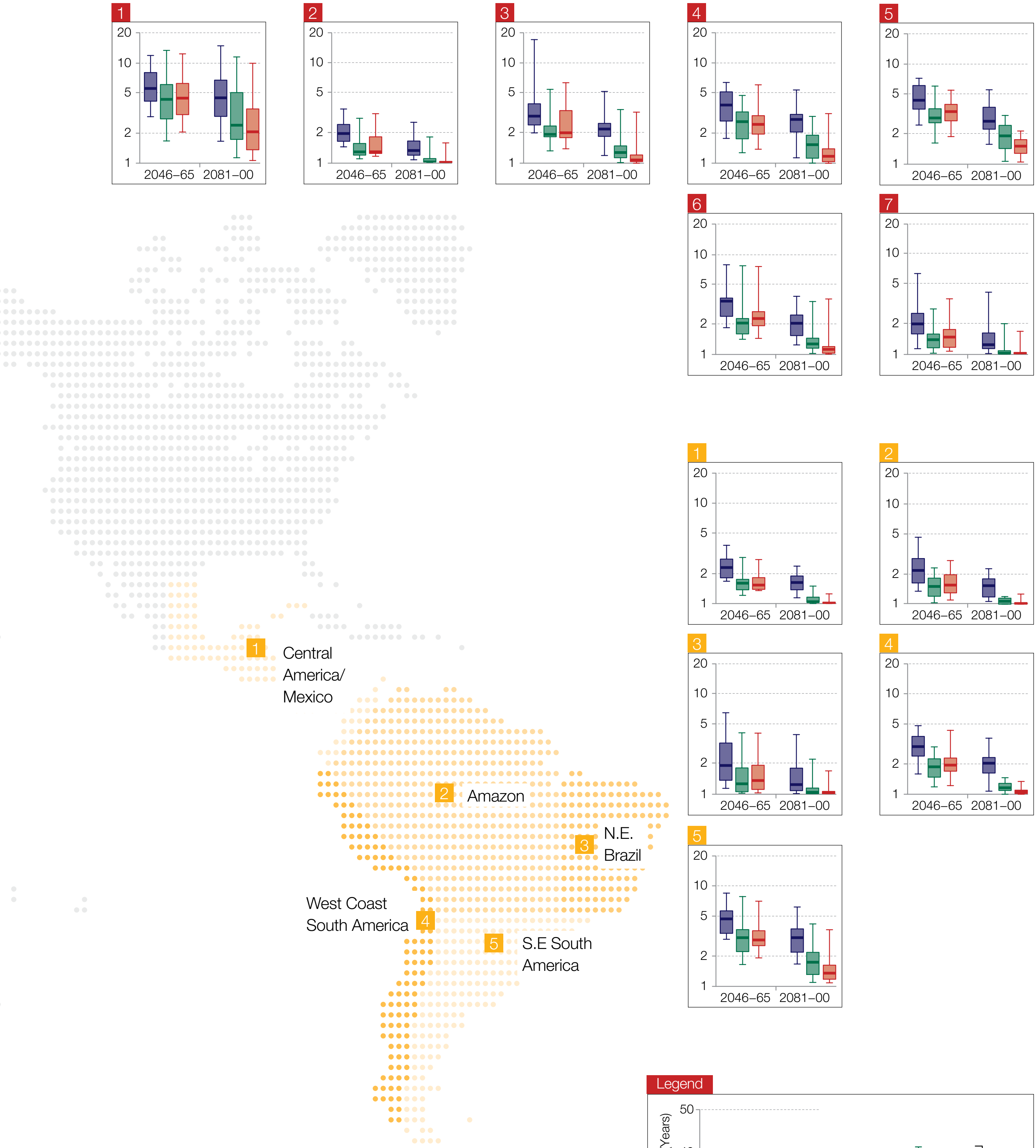
(a) Temperature

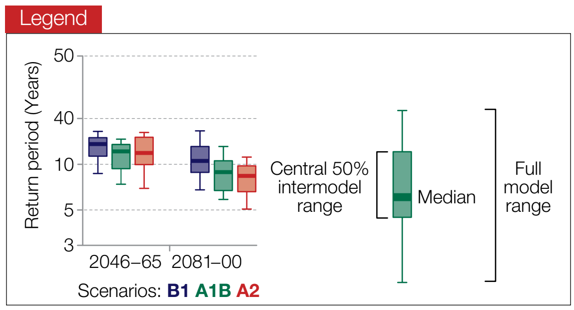
The temperature graph shows how often the hottest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[57]

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 Africa and under both the A1B and A2 scenarios by 2100, every year, everywhere. What is now an extreme will become normal.





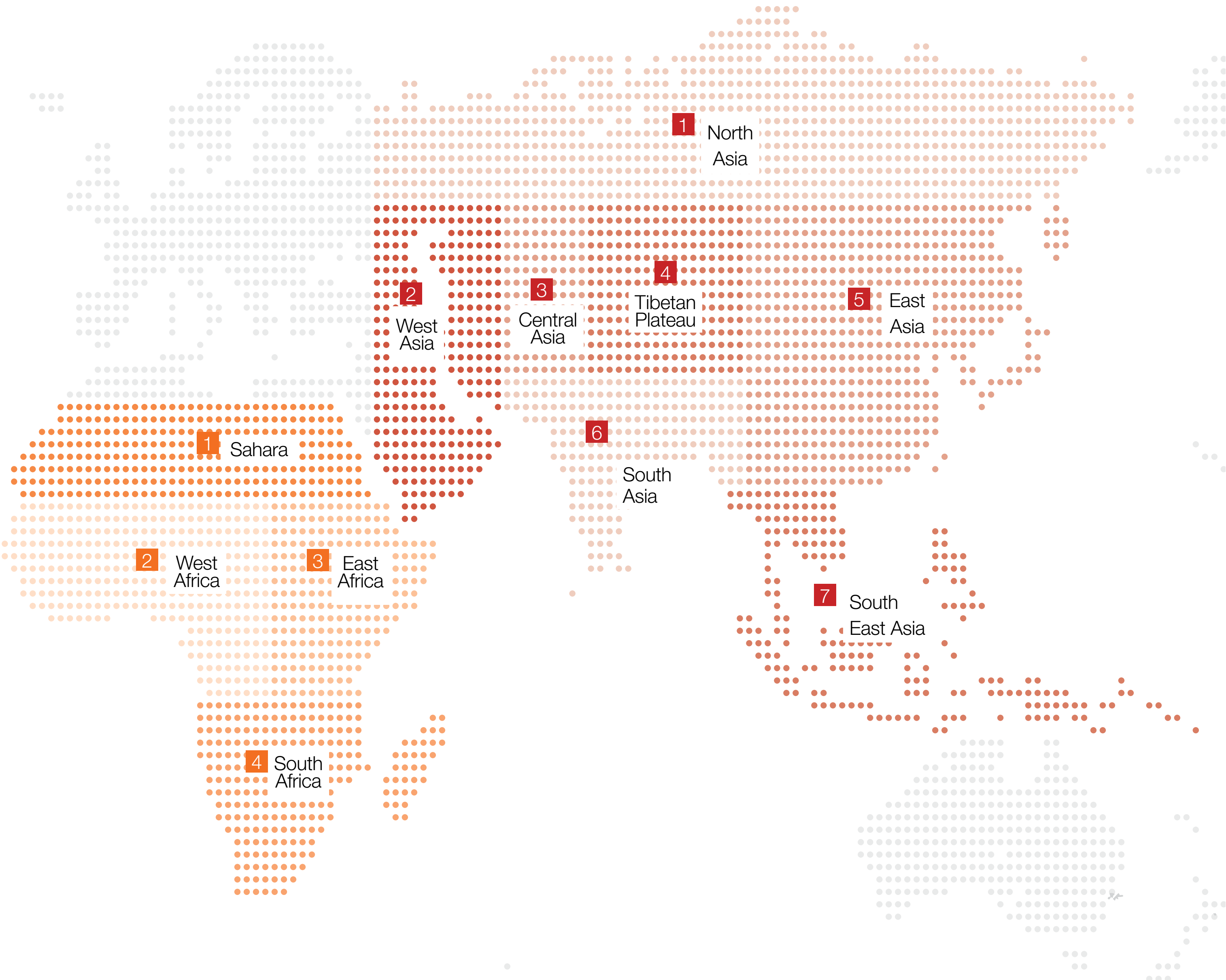


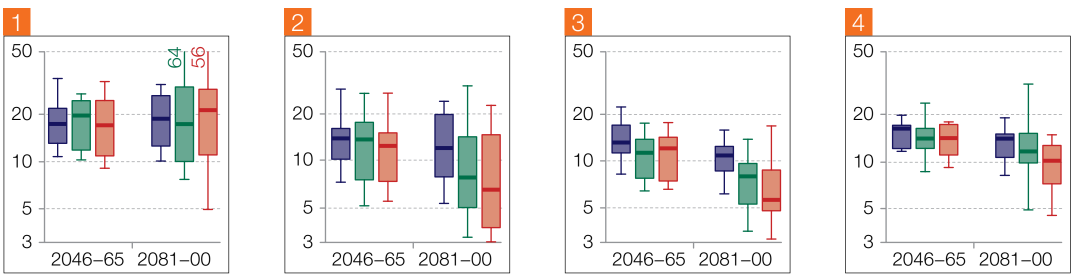


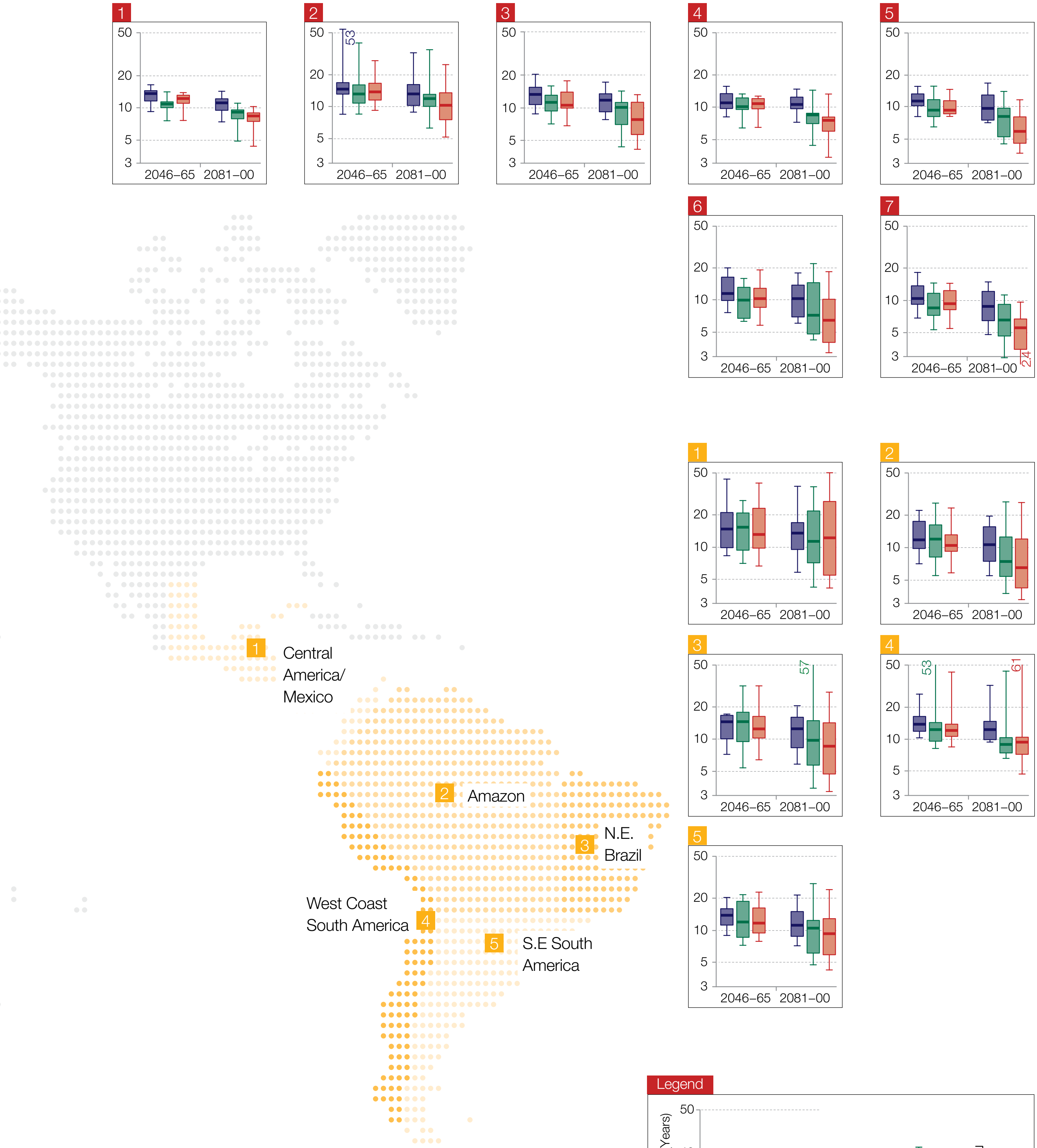
57. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development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

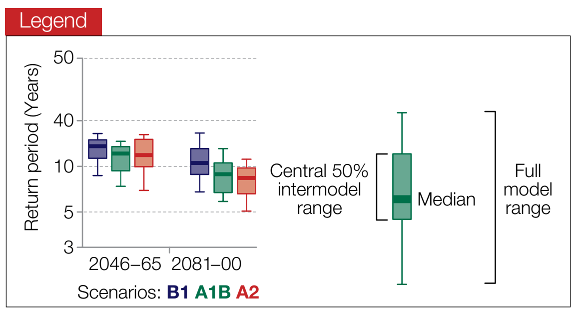
(b) Precipitation

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.[58] 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.





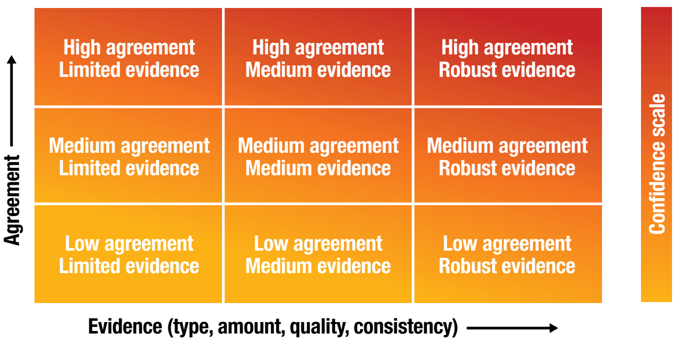




58. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development 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[59]	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

59. 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.

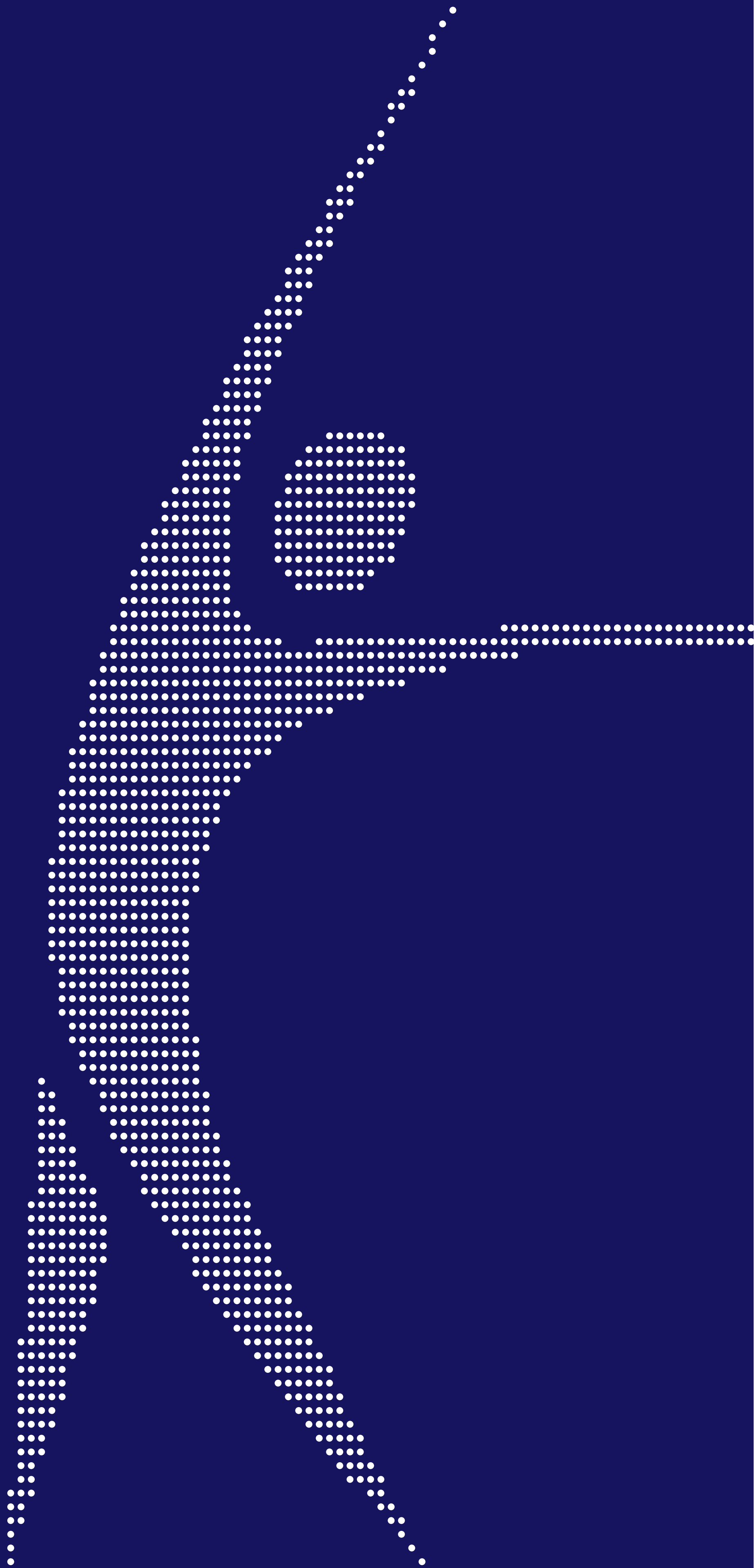
Disaster risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that 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).



CDKN Climate & Development Knowledge Network

odi Overseas Development Institute

Agulhas Applied Knowledge

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