



Chapter 3

Drought risks

An Australian lake bed drying up due to drought.
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Chapter 3 Drought risks

Unlike the risks associated with tropical cyclones and floods, those associated with drought remain less well understood. Drought, therefore, is often a less visible risk. Losses and impacts are not systematically captured, global standards for measuring drought hazard are only slowly being introduced, and there are difficulties regarding data collection.

As a result, comprehensive assessments of drought risks are only just beginning and, as yet, there is no credible global drought risk model. Case studies indicate that the impacts of drought can only be partly attributed to deficient or erratic rainfall, as drought risk appears to be constructed over time by a range of drivers. These include: poverty and rural vulnerability; increasing water demand due to urbanization, industrialization and the growth of agribusiness; poor soil and water management; weak or ineffective governance; and climate variability and change.

Such drivers are increasing vulnerability and exposure, and translate drought hazard into risk. Impacts and drivers may be strongly interrelated but, as many relate to poor, rural households, there is currently little political or economic incentive to address the risk. Yet, strengthening drought risk management, as an integral part of risk governance, will be fundamental to sustaining the quality of life in many countries during the coming decades. This chapter is only a first step in presenting the complexities of global drought risk. Understanding and revealing the full spectrum is a challenge that must be addressed in the years to come.

3.1 Drought risk in the Navajo Nation

The dramatic case of the Navajo Nation in the south-western United States of America shows that much of what are characterized as drought impacts are only partly due to lack of rainfall. Factors including political marginalization and rural poverty have helped to translate meteorological drought into a widespread disaster for the entire people.

Between 1999 and 2009, the Navajo Nation experienced a drought of historic proportions. Many springs sampled for a 1999 water-quality study had run dry by 2002 and have remained dry ever since. Wells and aquifers became so saline that they could no longer be used for drinking, by humans or livestock. More than 30,000 cattle perished between 2001 and

2002 alone, and entire communities ran out of water (Redsteer et al., 2010). Though the drought officially began in 1999, data suggest that it may have begun in 1996 or even 1994; the uncertainty due to large portions of the reservation being poorly monitored.

Some of the causes of this disaster were not directly due to decreasing rainfall during the drought period. Annual snowfall has been decreasing during the past 80 years (Figure 3.2), and by the 1960s more than 30 major rivers and bodies of water upon which the Navajo relied for livestock and agricultural production had dried up (Figure 3.1) (Redsteer et al., 2010). Since then, the soil has become drier due to higher temperatures during the warmest months, further increasing water stress (Weiss et al., 2009).

However, it was factors like political marginalization and rural poverty that translated meteorological drought into a disaster for the Navajo people. The Navajo reservation was established in 1868 in a vast and remote region spanning four states (Arizona, Colorado, New Mexico and Utah). The majority of the

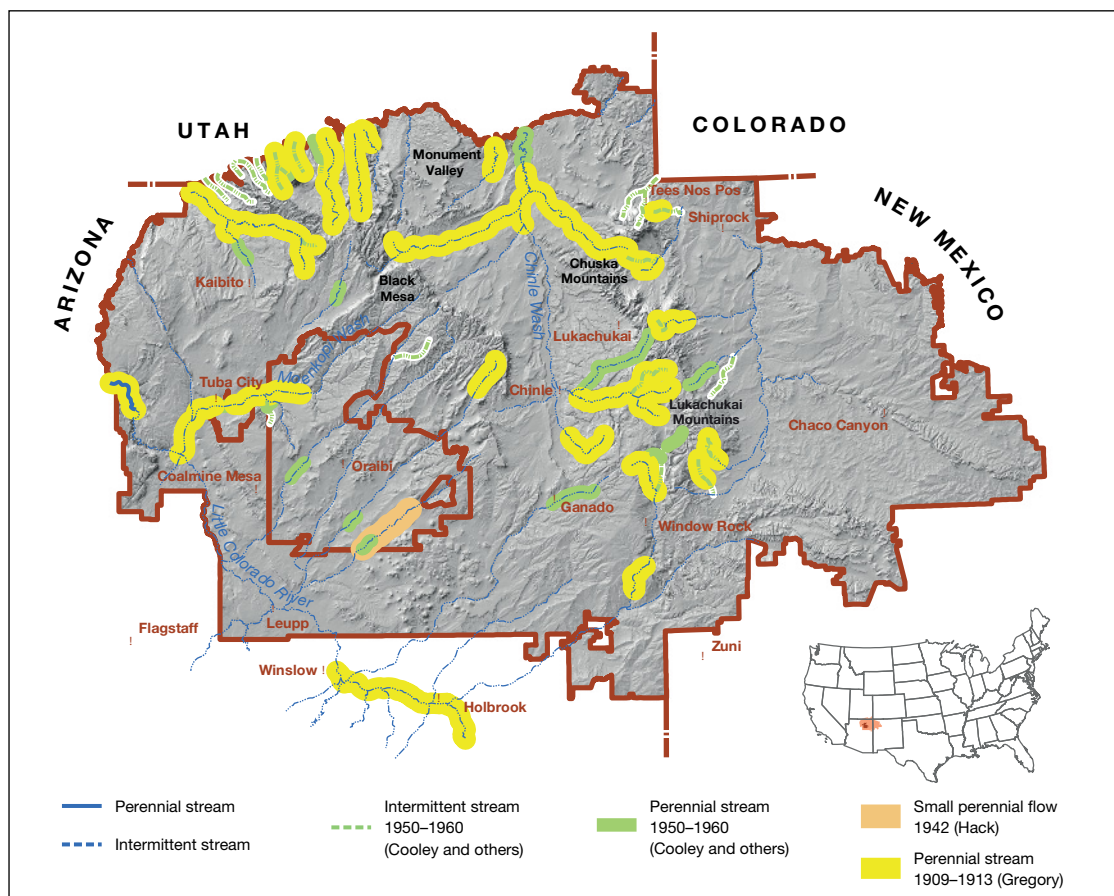
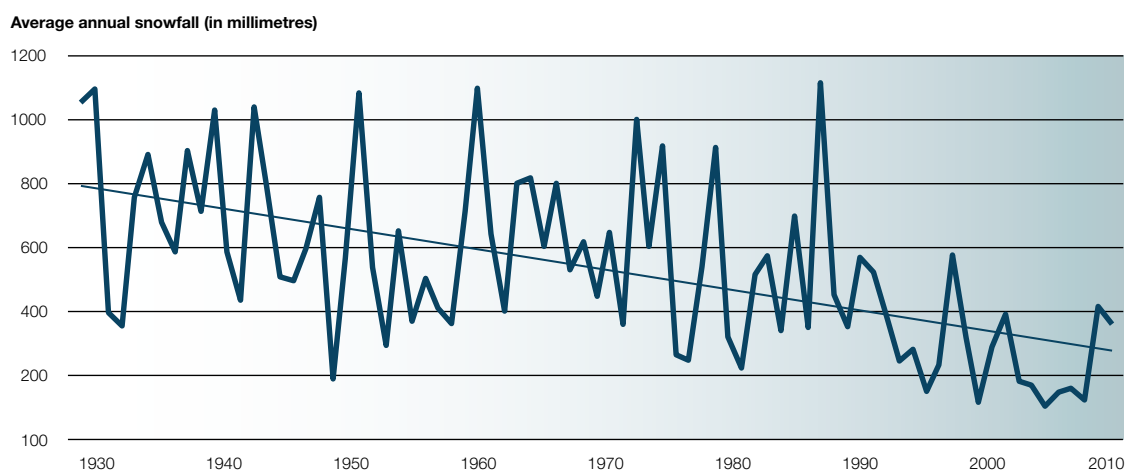


Figure 3.1
Navajo Nation
and its historic
stream-flow

Figure 3.2
Average annual
snowfall at 25
weather stations on
or near the Navajo
Nation (1930–2010)



(Source: Redsteer et al., 2010)

reservation occupies the driest third of the Navajo's traditional homeland, because ranchers had claimed the best rangelands for themselves (Redsteer et al., 2010). During the 1930s, the government began requiring permits to raise livestock, limiting the numbers each family could own, and demanding that they had to remain within one of 20 newly demarcated grazing districts (Young, 1961; White, 1983; Kelley and Whiteley, 1989). This final restriction interrupted a traditional Navajo drought impact management practice of moving livestock across district boundaries to less drought affected areas (White, 1983; Kelley and Whiteley, 1989; Iverson, 2002). Some Navajo traditions and practices also increased drought risk, such as their continued preference of cattle over other species, added to by US Government and Navajo Nation policies that require families to have livestock in order to validate traditional land use rights, even if they have lived on the same land for generations (Redsteer et al., 2010). Even with grazing restrictions, herds have exceeded the carrying capacity of the land since the 1960s (Young, 1961; Redsteer et al., 2010).

Such policies in a context of decreasing water availability led to endemic poverty even before the last drought began. In 1997, average annual per capita income was less than US\$6,000, and 60 percent of the Navajo lived in poverty, in houses without water and electricity. Savings mitigate drought impacts, but because the Navajo often invest their savings in livestock, this safety net is in itself vulnerable to drought (Redsteer et al., 2010). Risk drivers, such as

inappropriate development, badly managed water resources, weak local governance and inequality, all played their part in translating the most recent meteorological drought into a further series of cascading losses and impacts.

3.2 Drought hazard

Meteorological drought is a climatic phenomenon rather than a hazard per se, but it is often confused with other climate conditions to which it is related, such as aridity. It only becomes hazardous when translated into agricultural or hydrological drought, and these depend on other factors, not just a lack of rainfall.

Unlike the risks associated with tropical cyclones and earthquakes, drought risk remains poorly understood. Although meteorological drought is increasingly well characterized, the measurement of agricultural and hydrological drought remains a challenge (see Box 3.1 for definitions). Far less attention has been given to identifying, let alone addressing, the underlying risk drivers. Attempts to build credible global drought risk models have proved elusive, and drought losses and impacts are not systematically recorded. Despite increasing evidence of the magnitude of drought impacts, few countries have developed drought risk management policies or frameworks,

and the political and economic imperative to invest in reducing drought risk remains weakly articulated.

Box 3.1 Types of drought

There are three general types of drought: meteorological, agricultural and hydrological. Meteorological drought refers to a precipitation deficit over a period of time. Agricultural drought occurs when soil moisture is insufficient to support crops, pastures and rangeland species. Hydrological drought occurs when below-average water levels in lakes, reservoirs, rivers, streams and groundwater, impact non-agricultural activities such as tourism, recreation, urban water consumption, energy production and ecosystem conservation.

(Source: Wilhite and Buchanan-Smith, 2005; UNISDR, 2009)

Meteorological droughts are usually defined as deficiencies in rainfall, from periods ranging from a few months to several years or even decades. Long droughts often change in intensity over time and may affect different areas. For example, the 1991–1995 meteorological drought in Spain migrated from west to east and then south (Figure 3.3).

Until the recent adoption of the Standard Precipitation Index (SPI) (see Box 3.2), there was no agreed global standard to identify and measure meteorological drought. National weather services used different criteria, making it difficult to establish exactly when and where droughts occur.

The application of the SPI could strengthen the capacity of countries to monitor and assess meteorological drought. Despite its simplicity, many countries have difficulty using it due to an insufficient number of rainfall stations in some areas, due to the low priority awarded to hazard

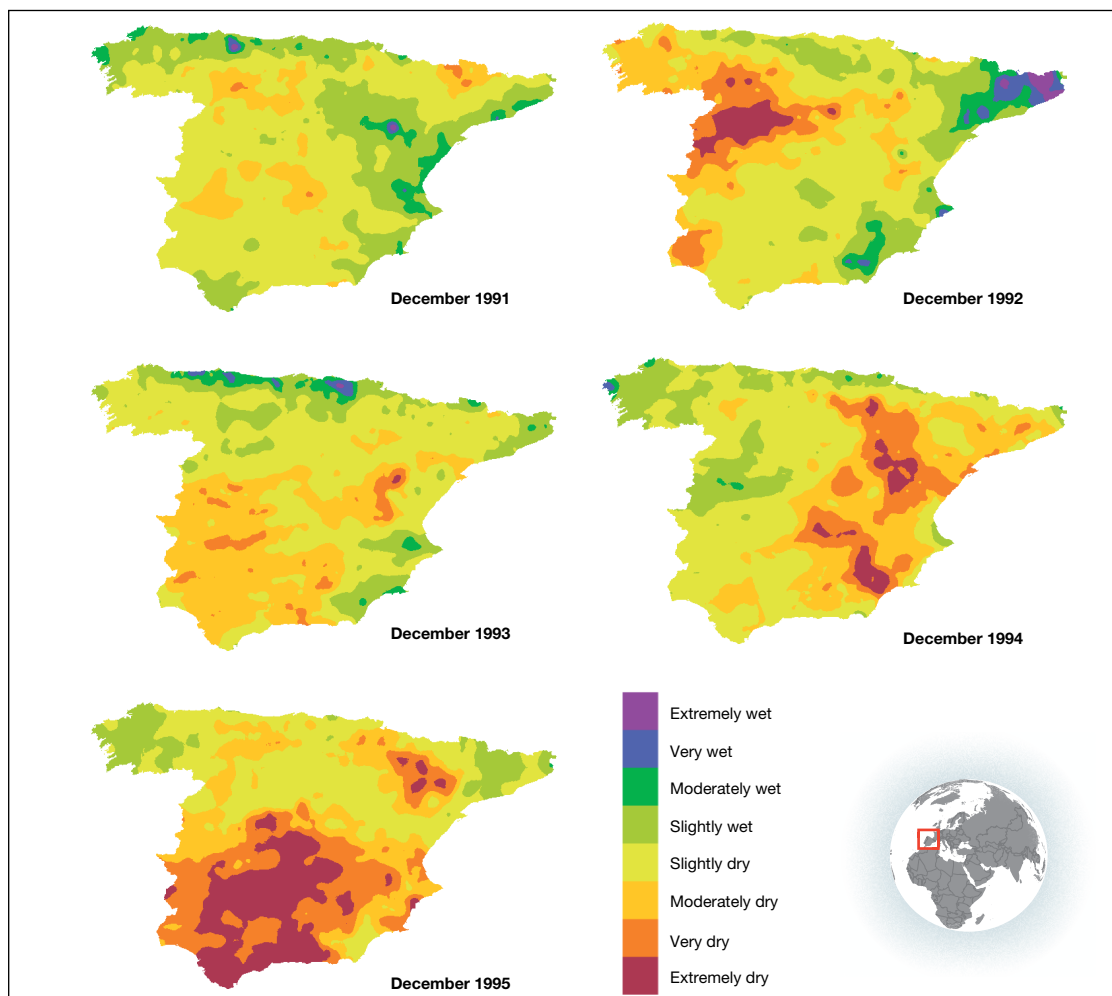


Figure 3.3
12-month
Standardized
Precipitation Index
in Spain during
the 1991–1995
drought

(Source: Mestre, 2010)

Box 3.2 Measuring meteorological drought

The World Meteorological Organization (WMO) adopted the Standardized Precipitation Index (SPI) in 2009 as a global standard to measure meteorological droughts, via the 'Lincoln Declaration on Drought Indices'. It is encouraging use by national meteorological and hydrological services in addition to other indices used in each region, and will be considered for acceptance by the World Meteorological Congress at its Sixteenth Session in June 2011.

The Standardized Precipitation Index (McKee et al., 1993, 1995) is a powerful, flexible and simple index based on rainfall data, and it can identify wet periods/cycles as well as dry periods/cycles. The SPI compares rainfall over a period – normally 1–24 months – with long-term mean precipitation at the same location (Guttman, 1994; Edwards and McKee, 1997).

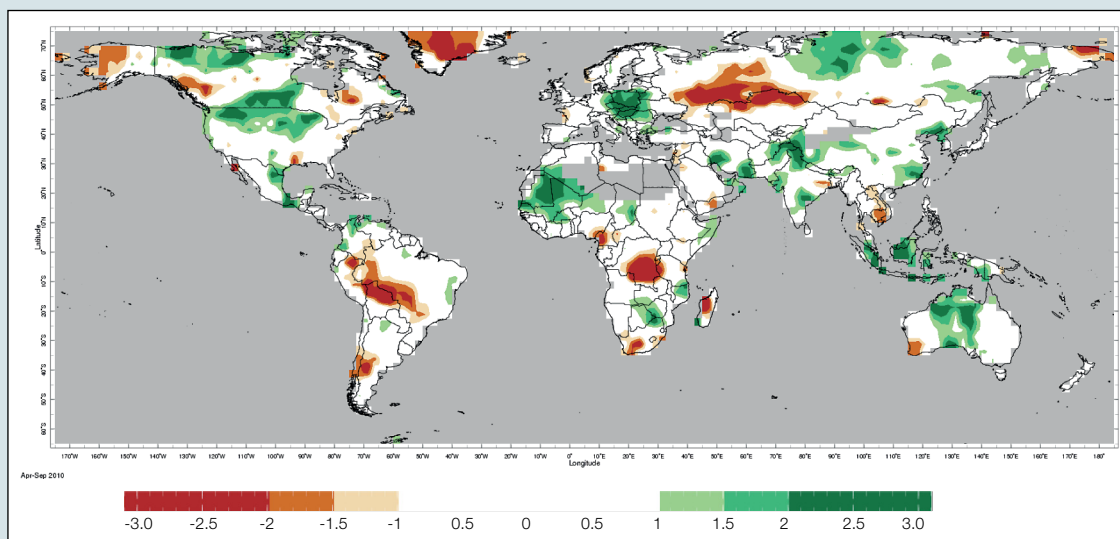
However, at least 20–30 years (optimally 50–60 years) of monthly rainfall data is needed to calculate the SPI (Guttman, 1994). Given the lack of complete data series in many locations, and that many drought-prone regions have insufficient rainfall stations, interpolation techniques may need to be applied to temporal and geographic gaps. Table 3.1 shows how an SPI of 3 months can be used to calculate the probability of different levels of droughts severity.

Table 3.1 Drought probability using a 3-month Standardized Precipitation Index

SPI	Category	Number of occurrences per 100 years
0 to -0.99	Mild dryness	33
-1.00 to -1.49	Moderate dryness	10
-1.5 to -1.99	Severe dryness	5
< -2.0	Extreme dryness	2.5

Figure 3.4 shows the global distribution of meteorological dryness/wetness at the end of September 2010, using a 6-month SPI. This map highlights in red the droughts in Russia associated with wildfires (discussed in Chapter 1) and western Brazil, a normally humid climate.

Figure 3.4
Interpolated
global map
using a 6-month
Standardized
Precipitation Index
(April–September
2010)



(Source: IRI, 2010)

(Source: Sivakumar et al., 2010)

monitoring in government budgets. The number of rainfall stations maintained by Spain's national meteorological agency, AEMET, for example, has declined to almost half of the peak of the mid-1970s (Figure 3.5) (Mestre, 2010).

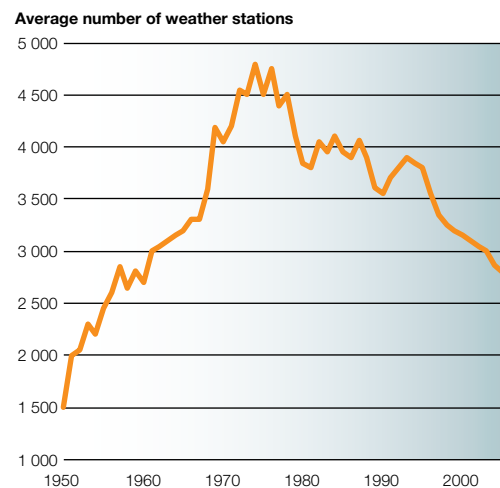
In Central America, more weather stations are located nearer to the Pacific coast (Figure 3.6), presenting an obstacle to making accurate SPI calculations on the Caribbean side required for regional drought monitoring and planning (Brenes Torres, 2010). Remote sensing can partly fill this gap, but SPI models still need to be calibrated using physical rainfall data (Dai, 2010). Because meteorological drought is a climatic phenomenon, rather than a hazard per se, additional data is required to identify and measure drought hazard.

Experts have now reached a consensus that agricultural drought should be measured using composite indices that consider rainfall, soil moisture, temperature, soil and crop type, stream-flow, groundwater, snow pack, etc., as well as historical records of drought impacts (WMO, 2010).¹ However, such indices require data that is available only in a handful of countries at present, mostly in North America and parts of Africa. Work is also ongoing to identify indicators of hydrological drought, but this is also challenged by data constraints and modelling complexities.²

3.3 Drought impacts

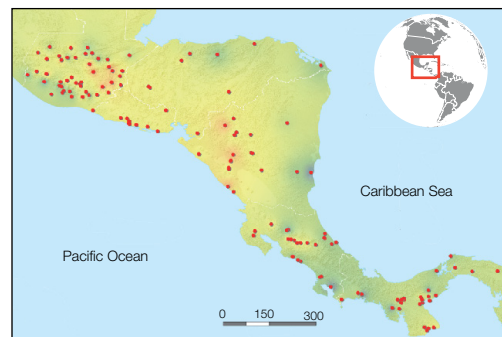
Drought losses and impacts are systematically reported in only a few countries, even though there are clear and significant impacts on agricultural production, rural livelihoods, and urban and economic sectors. Droughts also contribute to migration, conflict and ecosystem decline.

In internationally reported droughts since 1900, more than 11 million people have died with over 2 billion affected (EM-DAT, 2010b), more than by any other single physical hazard.



(Source: Mestre, 2010)

Figure 3.5
Average number of rainfall stations maintained by AEMET by year in Spain



(Source: Brenes Torres, 2010)

Figure 3.6
Distribution of weather stations in Central America

Most of the drought-related mortality recorded in EM-DAT, however, occurred in countries also experiencing political and civil conflicts. Also, since the 1990s, internationally recorded drought mortality has been negligible, with only 4,472 fatalities from 1990 to 2009 (EM-DAT, 2010b). Drought impacts are poorly recorded internationally. Reasons include the lack of visible damage outside of the agriculture sector, the high proportion of indirect losses compared to direct losses, and the highly complex nature of drought mortality, which is highly livelihood-dependent (Below et al., 2007).

Due to the absence of systematic data, it is impossible to provide a global assessment of patterns and trends in drought impacts and loss. Available evidence, however, provides a good indication of the magnitude and inter-relatedness of impact on mortality, rural livelihoods, food security, agricultural production, economic and urban development, migration, conflict, the environment and public spending (Table 3.2).

Table 3.2 Evidence of agricultural and hydrological drought impacts across the world

Mortality and well-being	<p>Internationally, drought mortality risk is currently severely under-recorded, and drought mortality may be significantly higher than reported, with many fatalities going unrecorded or attributed to other causes. For example, in Mozambique only 18 deaths were reported internationally between 1990 and 2009. In contrast, Mozambique's disaster loss database recorded 1,040 deaths for the same period (EM-DAT, 2010b; INGC, 2010).</p> <p>Poor rural households with livelihoods that depend on rain-fed agriculture are more vulnerable to drought and less able to absorb and buffer the losses. Consequences include increased poverty, reduced human development and negative impacts on health, nutrition and productivity (de la Fuente and Dercon, 2008; UNISDR, 2009), declining purchasing power and increasing income inequality (Rathore, 2005). As with the Navajo, poor rural households can rarely mobilize sufficient assets to buffer crop and livestock losses, while droughts tend to undermine household and community coping mechanisms because large numbers of households are affected simultaneously and for long periods.³</p>
Rural livelihoods, food security and agricultural production	<p>In the Caribbean, the 2009–2010 drought saw the banana harvest on Dominica reduced by 43 percent, agricultural production in Saint Vincent and the Grenadines 20 percent below historic averages, and onion and tomato yields in Antigua and Barbuda decline by 25–30 percent.</p> <p>Australia experienced losses of US\$2.34 billion during the 2002–2003 drought, reducing national GDP by 1.6 percent. Two thirds of the losses were agricultural, the remainder attributed to knock-on impacts in other economic sectors (Horridge et al., 2005).</p> <p>During the 2002 drought, food grain production in India dropped to 183 million tonnes, compared to 212 million tonnes the previous year (Shaw et al., 2010).</p> <p>In the 2007–2008 drought in the Syrian Arab Republic, 75 percent of the country's farmers suffered total crop failure, and the livestock population was 50 percent below the pre-drought level more than a year after the drought ended (Erian et al., 2010).</p> <p>Mozambique is one of the few countries with a disaster database that systematically records drought losses (INGC, 2010), so the real scale of drought risk becomes visible. Since 1990, drought events damaged 8 million hectares of crops (half of which were destroyed) and affected 11.5 million people (Figure 3.7). Thus, international under-reporting of drought losses undermines the visibility of drought risk and the political and economic imperative for its reduction, and also hides the significant implications for livelihoods of small-scale farmers, especially elderly and women farmers and female-headed households.</p>
Urban and economic development	<p>Droughts reduce water supplies for domestic and industrial use, and for power generation, affecting cities and non-agricultural sectors of the economy. During the 1991–1992 drought in Zimbabwe for example, water and electricity shortages and a decline in manufacturing productivity of 9.5 percent resulted in a 2 percent reduction in export receipts (Robinson, 1993; Benson and Clay, 1998). The overall cost to the economy of the drought-driven decline in energy production was more than US\$100 million and 3,000 jobs (Benson and Clay, 1998).</p> <p>In 2008, a severe drought in the south-eastern United States of America threatened the water supplies for cooling more than 24 of the nation's 104 nuclear power reactors. The 2003 European drought and heat wave reduced France's nuclear power generation capacity by 15 percent for five weeks and also led to a 20 percent reduction in the country's hydroelectric production (Hightower and Pierce, 2008). In the middle of Spain's 1991–1995 drought, hydroelectric production was reduced by 30 percent and 12 million urban residents experienced severely restricted water availability (Mestre, 2010).</p>
Migration	<p>Droughts are associated with migration. In the Syrian Arab Republic, a million people left rural areas for cities after successive crop failures from 2007–2009 (Erian et al., 2010). In response to both recurring droughts and marginal rural livelihoods, half of all rural Mexicans migrated to urban centres during the twentieth century (Neri and Briones, 2010).</p> <p>In Rajasthan, India, droughts regularly lead to forced migration, increased debt and borrowing, reduced food consumption, unemployment and poorer health (Rathore, 2005). Given that drought occurred in 47 years in the past century, this implies a profound impact on rural livelihoods.</p> <p>Migration leads to changing household decision-making patterns, often resulting in an increase in female-headed households. Case studies from Jordan and Lebanon show that family dynamics and women's public roles may also change significantly as a result of drought-associated migration (Erian et al., 2010).</p>

Conflict	<p>Droughts contribute to the likelihood of conflict by causing displacement and migration, increasing competition for scarce resources and exacerbating ethnic tensions, and by encouraging poor rural farmers to join armed resistance groups (Barnett and Adger, 2007; Reuveny, 2007). Since the 1950s, droughts precipitated waves of migration and contributed to intense conflicts in India and Bangladesh, and droughts during the 1980s and 1990s were a factor that precipitated ethnic conflict and border skirmishes between Mauritania and Senegal (Reuveny, 2007).</p> <p>A 1,100-year analysis of drought in equatorial East Africa found evidence of drought-induced famine, political unrest and large-scale migration during the six centuries before 1895 (Verschuren et al., 2000). They may have also helped precipitate the 1910 Mexican Revolution (Neri and Briones, 2010). More recently, droughts were associated with riots in Morocco during the 1980s (Swearingen, 1992) and contributed to Eritrea's secession from Ethiopia in 1991 (Reuveny, 2007).</p>
Environment	<p>Droughts affect habitats, bodies of water, rivers and streams, and can have major ecological impacts, increasing species vulnerability and migration, and loss of biodiversity (Lake, 2003; NDMC, 2006; Shaw et al., 2010). Between 1999 and 2005, droughts contributed to the loss of at least 100,000 hectares of salt marshes along Florida's coastline (Silliman et al., 2005). In Spain, the 1991–1995 drought indirectly resulted in the draining of wetlands, causing saltwater intrusion of coastal aquifers; and the area affected by forest fires in southern Spain increased by 63 percent compared to the previous decade (Mestre, 2010).</p>
Public spending	<p>Downstream impacts indicate increased competition and conflict between different sectors of water users and a need for increased government spending on relief and compensation. In Andhra Pradesh, India for example, rice irrigation increasingly relies on pumped groundwater. As energy for pumping is subsidized by the government, this results in even lower groundwater levels, and rice cultivation also drains state funds and contributes to periodic blackouts (Lvovsky et al., 2006). The cost of food and non-food assistance provided in response to the 1991–1992 drought in ten southern African countries exceeded US\$950 million, and during the 2007–2009 drought in Kenya, 70 percent of the population of one region depended upon food aid (Holloway, 1995; Galu et al., 2010).</p>

3.4 Drought risk drivers

The impacts of drought point to a multitude of drivers that turn lower than average precipitation, limited soil moisture and low water levels into disaster events for vulnerable populations and economies. In the absence of a credible global drought risk model, case studies from around the world were commissioned for this report to identify factors that increase vulnerability and exposure, and that could translate drought hazard into risk in different situations.

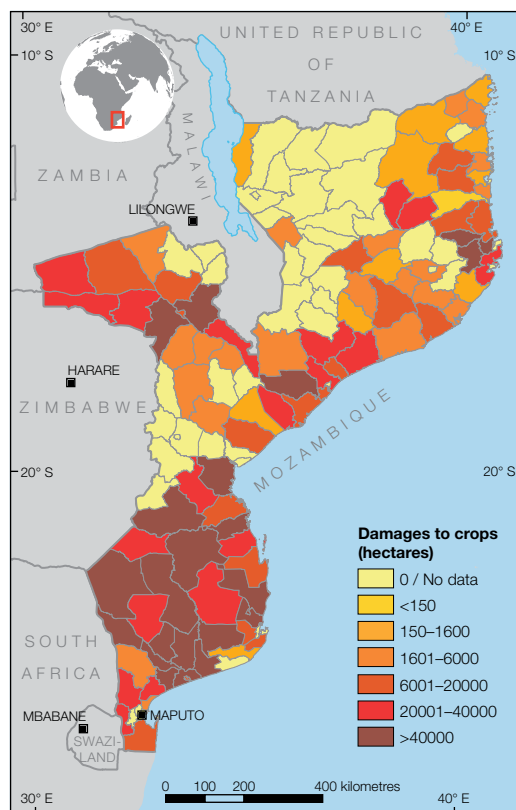


Figure 3.7
Drought-related crop damage in Mozambique, 1990–2009

(Source: INGC (*Instituto Nacional de Gestão de Catastrofes*), 2010)

3.4.1 Decreasing rainfall, climate variability and climate change

Rainfall has been decreasing in many regions in the past century. In areas with increasing water stress, even less intense drought episodes are now manifesting as agricultural or hydrological droughts. Areas that are most stressed in normal times will be the first to suffer drought impacts when deficiencies in rainfall occur (Table 3.3).

3.4.2 Poverty and rural vulnerability

Case studies from all regions confirm the findings from the *2009 Global Assessment Report*, that drought risk is intimately linked to poverty and rural vulnerability (Table 3.4) (UNISDR, 2009). From Brazil and Mexico to India and South Africa, they highlight that poor rural households whose livelihoods depend on rain-fed subsistence agriculture are very exposed and vulnerable to drought and least able to buffer and absorb its impacts. Rural poverty is thus both a cause and a consequence of drought risk. In many places, as the example of the Navajo Nation highlighted, people may have been forced to occupy marginal drought-

exposed land, and may be unable to access irrigation technology or drought-resistant seeds that could reduce their vulnerability. Limited access to affordable credit and insurance further constrains their resilience.

For example, sub-Saharan Africa's water storage facilities are severely under-developed, with an average per capita storage capacity of 200 cubic metres per year, compared to 1,277 cubic metres for Thailand and 5,961 for North America (Grey and Sadoff, 2006; Foster and Briceno-Garmendia, 2010). Averages hide significant variations, however, with Ethiopia and South Africa having storage capacities of 38 and 687 cubic metres, respectively. The total capital needs for the development of adequate water infrastructure in sub-Saharan Africa for 2006–2015 was estimated to be approximately US\$15 billion (Foster and Briceno-Garmendia, 2010).

For vulnerable rural households, even minor drought episodes can lead to yield losses and can have devastating impacts on already precarious and non-diversified livelihoods. Barely subsisting even in good years, many are unable to mobilize the necessary assets to

Table 3.3 Evidence and estimates of climate variability and change as a driver of drought risk

Climate scenarios in India	Maharashtra, India, is home to nearly 100 million people, with most working in the agriculture sector, mostly in small-scale and marginal farming (ECA, 2009). Agriculture here depends on rainfall for much of its water supply, so even a small decline in precipitation can threaten the food security of millions of people. An analysis of 22 climate models indicates that droughts that occur once every 25 years may return as often as once every 8 years in the coming decades (ECA, 2009).
Small-scale farmers affected by changing climates in sub-Saharan Africa	The IPCC Fourth Assessment Report reports that in South Africa, net crop revenues may fall by 90 percent by 2100, particularly affecting small-scale farmers (Boko et al., 2007). Parts of Mali already receive 200 mm less annual rainfall than 50 years ago, and a range of climate scenarios suggests increased drought frequency during the coming decades could reduce agricultural and livestock production by as much as US\$300 million per year (ECA, 2009).
China's crop losses due to climate variability and change	Between 2004 and 2007, Chinese farmers lost nearly US\$8 billion of crops to drought (McKinsey Climate Change, 2009). In the drought-prone north and north-east, annual crop losses to drought could be 6–7 percent of the total yield by 2030 due to expected decreases in precipitation during critical months of the growing season. In such a scenario, annual drought losses could be as high as US\$9 billion in north-eastern China alone (McKinsey Climate Change, 2009).

Table 3.4 Evidence of poverty and vulnerability as drivers of drought risk

Lack of irrigation and water storage in Kenya and Brazil	<p>In Kenya's Mwingi district, 70–80 percent of the population depend on rain-fed agriculture and livestock production for both food and income, and 60 percent subsist on US\$1 per day or less (Galu et al., 2010). Therefore, when drought occurs it can wipe out income and investments, leaving communities with limited means to buffer losses. During the 2008–2009 drought, for example, 70 percent of the population depended on food aid, and although this relief successfully averted a food security crisis, it reveals the extreme vulnerability of rural agricultural and agro-pastoral livelihoods (Galu et al., 2010).</p> <p>In Ceará, Brazil, agricultural drought risk is concentrated amongst smallholder farmers whose livelihoods depend entirely on rain-fed agriculture, and who do not hold water rights or have access to irrigation and water-storage infrastructure. As a result, per capita GDP in such rural communities is only one third of those in urban settlements along the coast, and Human Development Index values of rural districts are less than 0.65, compared to 0.70 for Brazil as a whole (Sávio Martins, 2010; UNDP, 2010).</p>
Expansion of intensive cash crop production and urbanization in Mexico	<p>Mexico's water management and land tenure policies date back to the 1910 revolution and are based on communal ownership of land and water by smallholder farmers, known as ejido, 25 percent of whom live in abject poverty. The expansion of intensive market agriculture and urbanization has led to the forced sale of water rights, pushing the rural poor to farm marginal lands more intensively, increasing their drought risk further still (Fitzhugh and Richter, 2004). Today, the ejido cannot compete with large farmers and agribusinesses, and in Sonora their agricultural drought risk is increasing as nearly 75 percent of irrigation water is now allocated to this sector (Neri and Briones, 2010).</p>
Limited access to credit in Honduras	<p>In Honduras, 67 percent of the rural population are subsistence farmers, but only 2 percent have access to formal credit, which could facilitate investment in better equipment and provide protection from drought impacts (Brenes Torres, 2010). Drought losses in Honduras and other Central American countries cause increased school drop-out rates, rural debt, rural-to-urban migration, forced sale of lands, and increased unemployment (Brenes Torres, 2010).</p>

buffer losses, and their welfare declines further still. Such impacts are self-reinforcing. They are most pronounced in poor communities, and each drought erodes livelihoods further, leaving households and communities more vulnerable to future droughts and other hazards (Wilhite and Buchanan-Smith, 2005). At the macro level, institutions may have little capacity to provide drought relief or compensation, or may have little accountability with ethnically and politically discriminated communities (Wilhite and Buchanan-Smith, 2005), with the result that agricultural drought impacts can turn into food security crises (Devereux, 2007).

3.4.3 Increasing water demand due to urbanization, industrialization and the growth of agribusiness

Urban and economic development per se is not a driver of drought risk. However, much development is planned and authorized without taking water availability into account, or

without taking adequate measures for water management and conservation (Table 3.5). Case studies highlight that in already water-stressed areas and countries, the growth of intensive agriculture, urban development, tourism and other economic sectors leads to increased and conflicting demands for often declining water resources. This is a key driver of both hydrological and agricultural drought risk, but is seldom taken into account in development planning (Wilhite and Pulwarty, 2005).⁴

Competition for freshwater already exists and it is expected to increase as water demand continues to grow, alongside population growth and economic development. These two processes determine the relationship between water supply and water demand to a much greater degree than climate change (Vörösmarty et al., 2000). Total global annual water demand has tripled since 1960, and is currently increasing by 64 billion cubic metres every year (WWAP, 2009a). This growth has not happened evenly. Developed countries consume

Table 3.5 Evidence of accelerating water demand as a driver of drought risk

Accelerated water demand in the United States of America	Phoenix, Arizona, is running dry. Already by the 1940s, demand for water driven by population growth and economic development was outstripping supply (Fitzhugh and Richter, 2004). The Salt and Verde Rivers were dammed to increase availability but soon both rivers had run dry except after rains. While continuing to draw excessively from the region's aquifers, Phoenix began to transfer water from the Colorado River in 1980. By 2025, the city's population is expected to grow by another 50 percent (Fitzhugh and Richter, 2004), meanwhile, the IPCC Fourth Assessment Report indicates that this region will experience even more frequent and severe droughts (IPCC, 2007).
Impact of economic growth in China	China's economic growth has coincided with water shortages in the northern part of the country (WWAP, 2009a). Between 1949 and 2006, annual water demand in the Yellow River Basin increased from 10 to 37.5 billion cubic metres. This was driven by the expansion of irrigated agriculture which grew in area from 8,000 to 75,000 km ² in the 50 years to 2000, and hydropower plants that now produce 40 TWh per year to meet growing demand from China's industrial sector (WWAP, 2009b). The impacts of such growth have made the region highly vulnerable to droughts. In the 1990s, springs in Jinan, "the city of springs", ran dry and from 1995 to 1998 there was no flow at all in the lowest 700 km of the Yellow River for 120 days of the year (WWAP, 2009b).
The effects of a growing leisure and tourism industry in Spain and the Caribbean	<p>Per capita water use in the tourism industry is often 3 to 10 times greater than local demand (Fernandez and Graham, 1999), and overall consumption by the tourism sector is increasing dramatically (Iglesias et al., 2007; Farrell et al., 2010). As competition for water increases, it is often agriculture that loses out.</p> <p>In Spain, second homes and golf courses, alone, have increased water demand by 30 million cubic metres per year (Iglesias et al., 2007). Additionally, tourism leads to large seasonal variations in water use that can lead to hydrological droughts in peak seasons, often coinciding with drier, sunnier periods (Farrell et al., 2010). In the Mediterranean, the seasonal tourism industry increases overall annual water demand by at least 5–20 percent in affected communities (Iglesias et al., 2007; WWAP, 2009a).</p> <p>In Mallorca, the annual number of tourists almost doubled from 1989 to 2000 to 8 million, outnumbering the local population by more than 10 to 1. This meant that during the drought in the mid-1990s, the Government of Spain was forced to ship freshwater from the mainland at a cost of €42 million (Garcia and Servera, 2003; Iglesias, 2007).</p> <p>In the eastern Caribbean, many islands are already water scarce, with less than 1,000 cubic metres of water per capita per year. However, the 2009–2010 agricultural drought was due less to lack of rainfall than to restrictions imposed on agriculture as water was allocated to other sectors (Farrell et al., 2010).</p>

more water per capita than most developing countries (Figure 3.9), and global trade has allowed some countries to externalize their water consumption. For example, Europe is a large importer of cotton, a water-intensive crop grown in many water scarce regions, defined as those with less than 1,700 cubic metres of water per person per year (WWAP, 2009a). By 2025, 1.8 billion people will live in countries or regions with water scarcity, and by 2030 nearly half of the world's population will live in areas with high water stress (UN-WATER, 2007; OECD, 2008).

Demand for industrial water use tends to increase with relative wealth. It can rise from less than 10 percent of total national demand in low- and middle-income countries to nearly

60 percent in high-income countries (WWAP, 2009a). Economic development, and tourism in particular, increases competition for water resources often in already water-stressed areas such as southern Spain or the eastern Caribbean.

3.4.4 Inappropriate soil and water management

Agricultural droughts have been recorded in parts of Bangladesh where mean annual rainfall is 2,300 mm, in Lao People's Democratic Republic where rainfall is 3,200 mm, and in Cambodia where an SPI of +2.7 corresponds to an excess of water and potential flooding (Shaw et al., 2010). However, Table 3.6 shows that precipitation and SPI values do not reflect water availability in reservoirs, rivers and

Box 3.3 Trends in aridity since 1900

Evidence indicates that the world has become increasingly dry during the past century. Certainly since the 1970s, aridity has increased in parts of Africa, southern Europe, East and South Asia and eastern Australia, shifting baseline precipitation data and further complicating the ability to monitor droughts (Trenberth et al., 2007; Dai, 2010). For example, from the 1950s to the 1980s, the percentage of the land surface classified as 'dry' was 10–14 percent, rising to 25–30 percent during the past decade (Dai, 2010). One reason is that warmer air and surface temperatures have increased evaporation.

Century-long global precipitation trends measured using the monthly Palmer Drought Severity Index (Figure 3.8) reveal a general drying trend in Sahelian and southern Africa, central Brazil, southern Europe, Iran (Islamic Republic of), Indonesia, north-east China, and north-east Australia (Trenberth et al., 2007).

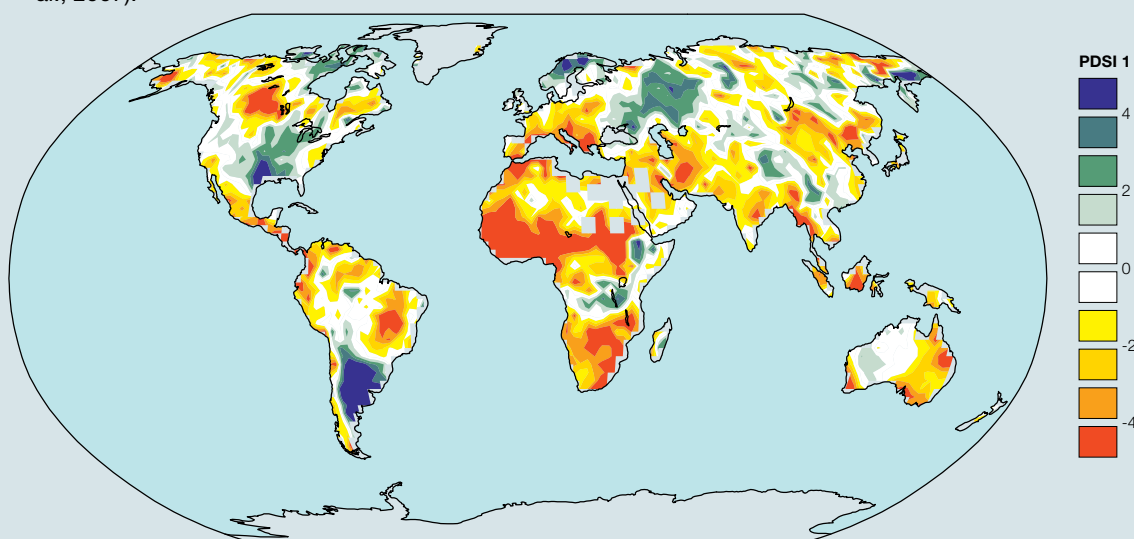


Figure 3.8
Global precipitation trends since 1900 measured using the Palmer Drought Severity Index (PDSI)

(Source: Adapted by UNISDR from Dai et al., 2004)

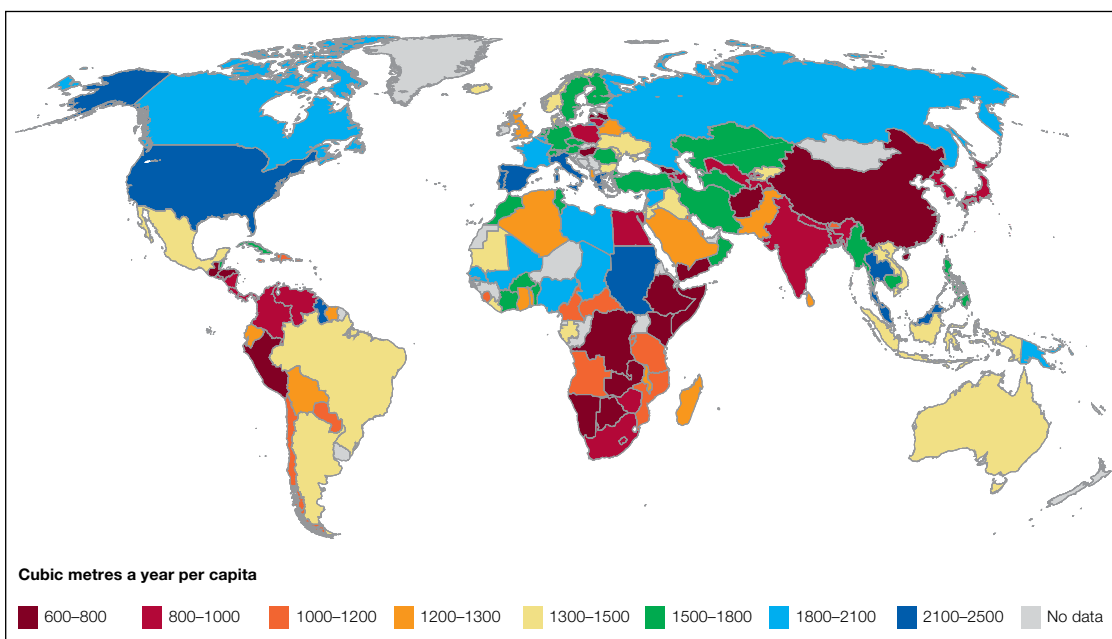


Figure 3.9
Average national water consumption per capita (1997–2001)

(Source: Hoekstra and Chapagain, 2008 (modified and cited in WWP, 2009a))

Table 3.6 Evidence of inappropriate water and soil management as drivers of drought risk

Introduction of water-intensive crops in Saudi Arabia	In the 1970s, the Government of Saudi Arabia instituted a policy of self-sufficiency in wheat production and subsidized production accordingly. From 1972 to 1991, land used for agricultural production grew from 0.4 million to 1.6 million hectares (Saudi Arabia, 1992), and by the early 1990s it had become the world's sixth-largest wheat producer. In 1992, domestic wheat production of 4.25 million tonnes easily surpassed national demand of 1.22 million tonnes (Abderrahman, 2001; Karam, 2008). This depended upon irrigation and extraction of ground water that from 1980 to 1992 grew from 1,850 to 29,826 million cubic metres per year (Saudi Arabia, 1990; Dabbagh and Abderrahman 1997), threatening the country with unprecedented drought. The wheat self-sufficiency policy became so expensive and drained aquifers so dramatically that it was eventually abandoned. Saudi Arabia now intends to depend completely on imported wheat by 2016 (Karam, 2008).
Shifting production patterns and deforestation in Viet Nam	Rainfall in the Ninh Thuan province of Viet Nam has been increasing over time. Droughts have become more common, however, because rainfall is becoming more variable and demand for water is increasing, and is expected to increase, in every sector of the economy (Shaw et al., 2010). Agricultural demand is the largest contributor to water withdrawals, and is predicted to grow by 150 percent between 2015 and 2020, while demand for aquaculture, industry and environment needs will double. Deforestation and shifting production patterns (e.g., more shrimp farming) have further reduced supply and increased demand. In the past 40 years, per capita annual water availability in Ninh Thuan has fallen from 17,000 to 4,600 cubic metres (Tinh, 2006), leading to a 'water war' between agriculture, aquaculture, industry and tourism.
Overgrazing and rangeland management in Mexico	The management of rangeland is equally challenging for effective drought risk management. Many ranchers overgraze, and in Sonora, Mexico, herd sizes may be double to triple the carrying capacity of the land (Neri and Briones, 2010). This problem was observed in the Navajo Nation despite restrictions on herd size, which has as much to do with choice of livestock as the environmental conditions (Redsteer et al., 2010).

canal systems, highlighting once again why meteorological drought is not always an accurate indicator of drought hazard.

3.4.5 Weak or ineffective risk governance

Case studies highlighted weak or ineffective risk governance capacities to address drought risks, and few countries besides Australia and India have developed national drought risk policies or frameworks (Table 3.7). Progress is nonetheless being made in drought risk management, especially in forecasting, early warning, preparedness, response and the development of compensatory mechanisms such as insurance and temporary employment programmes. Early warning is a crucial component of drought risk management, and seasonal forecasts and climate models inform decisions about what and when to plant. However, insurance and risk transfer mechanisms may not always be available to poor rural households who most need them to offset their risks. Also, compensatory measures like

drought relief may actually reward poor resource management and punish planners who employ proactive drought mitigation policies that leave them ineligible for assistance (Wilhite and Pulwarty, 2005).

3.5 From drought hazard to drought risk

Given that drought impacts are not systematically recorded and the data constraints for modelling drought hazard, it is still not possible to develop global drought risk models. Building such models at all scales is important to increasing the visibility of the risk and for building political and economic imperatives for drought risk management.

Table 3.7 Evidence of low risk governance capacity as a driver of drought risk

Low priority given to drought by governments in Mexico	Of the 16 million hectares of agricultural land in Sonora, Mexico, 87 percent are rain-fed and highly vulnerable to agricultural drought and account for 70 percent of agricultural production (Neri, 2004; Neri and Briones, 2010). Nevertheless, there is no drought early warning system or any systematic recording of drought impacts. A stakeholder survey revealed that this was not due to a lack of meteorological data or an inability to create seasonal drought forecasts, but reflected the low priority given by the authorities to drought risk management and poor rural communities (Neri and Briones, 2010). In Sonora, there is no drought risk management policy framework, and issues such as water resources and rangeland management fall through the cracks between the civil protection authorities who focus on emergency response, and other government departments.
Fragmented responsibilities for drought risk management in Viet Nam	In Viet Nam, government institutions address the risks associated with annual floods and tropical cyclones, but they are less well equipped to reduce and manage drought risks. Responsibility for drought risk is centralized within the national government, but the management of drought risk drivers falls between different institutions responsible for managing forests, agriculture, water and land use (Shaw et al., 2010).
Weak local drought risk governance capacities in Bangladesh	North-western Bangladesh receives 1,329 mm of rainfall per year, half the national average, and is prone to frequent droughts which local governments are mostly ill-equipped to manage. Drought risk relates to household resilience, but also to the institutional capacity of local governments. The local governments of Tanore and Shibganj have very low institutional resilience. They have not incorporated drought risk into disaster management plans, not developed effective drought risk management policies, training or demonstration programmes, and have weak coordination with other government institutions and NGOs (Shaw et al., 2010; Habiba et al., 2011). Even during droughts, local disaster management committees in these sub-districts have not engaged in public awareness programmes or run household level disaster drills.
Conflict and excess water use in Morocco	The lack of effective drought risk management is often aggravated by inadequate institutional and financial capacities, particularly in local government (Shaw et al., 2010). To manage scarce groundwater more efficiently during droughts, Morocco enacted a series of reforms, which included the privatization of water rights during the 1990s. The new policies conflicted with tribal customs and religious views and, due to the government's inability to ensure compliance, overexploitation of groundwater continued (Doukkali, 2005).

In the same way that meteorological drought is not synonymous with drought hazard, agricultural and hydrological drought hazard are not synonymous with risk. As with other hazards, the translation of drought into risk depends on factors related to vulnerability and exposure.

Developing models for drought similar to those already used to analyse risk trends for tropical cyclones and floods (see Chapter 2) is still not possible due to lack of sufficient and suitable data, and previous attempts to model global drought risk (see Box 3.4) produced unsatisfactory results.

Initiatives such as the National Drought Monitor in the United States of America, FEWS Net, AGRHYMET, and the Sahara and Sahel Observatory (OSS) in Africa, the International Water Management Institute's (IWMI) PODIUM and FAO's AquaCrop models, and

studies by the World Bank in India (Box 3.5), show how drought risk can be modelled in specific contexts when data is available. Systematically accounting for drought losses and impacts and building credible drought risk models at all scales, from local to global, is important to increasing the visibility of drought risk and building political and economic imperatives for its reduction.

As this chapter has shown, drought risk is at least in part socially constructed, and characterized by numerous feedback loops between the different drivers. For example, the lack of systematic recording of drought losses and impacts, particularly those affecting poor and vulnerable rural households, contributes to its reduced political and economic visibility, reflected in only weak imperatives to address underlying risk drivers and strengthen risk governance. Policies to promote economic and urban development in water-scarce areas may

Box 3.4 Modelling global drought risk

The mortality drought risk index proposed by UNDP (UNDP, 2004) was unsuccessful because most droughts do not produce fatalities, and most internationally recorded drought mortality is concentrated in countries experiencing conflict or political crisis. Only weak correlations were found between the population exposed to meteorological drought and the mortality attributed to drought (UNDP, 2004). Drought impacts on human development could provide more suitable criteria than mortality for calculating human risk. However, while such impacts are sometimes recorded in certain locations (de la Fuente and Dercon, 2008), systematic national data is not available to calibrate a global risk model.

A World Bank study (Dilley et al., 2005) was more successful in that it produced global risk maps for both mortality and economic loss risk. Risk was calculated as a function of the exposure to meteorological drought of population density and national agricultural GDP, with a proxy indicator of vulnerability calibrated using recorded mortality and economic losses for each geographic and income region. The accuracy of the results is questionable, however, given that meteorological drought is not a good representation of hazard and, as described above, mortality is not an adequate metric to model impacts on humans.

Box 3.5 Modelling agricultural drought risk

A study by the World Bank (Lvovsky et al., 2006) quantified long-term agricultural and macro-economic impacts of droughts in Andhra Pradesh, India, using catastrophe modelling techniques with a range of drought risk management strategies. By analysing meteorological and agricultural data over 30 years, the effect of mild, moderate and severe droughts was measured on five different crops (rice, groundnut, sunflower, maize and sorghum) in the eight most drought-prone districts of Andhra Pradesh, including average annual and probable maximum losses.

First, the frequency and severity of meteorological drought at different locations was modelled using historic data and a stochastic weather generator (WXGEN) simulating 500 years of weather. Modelled droughts were classified using a seasonal (June–December) SPI computation and validated against historical data. Vulnerability and exposure were analysed using crop-yield and planting-area models to quantify damages to each crop based on the intensity and duration of droughts. Drought impacts on livestock production were also tested but results were inconclusive. The crop-yield model incorporated 47 parameters calibrated to the crops and environmental conditions in each district. The planting-area model was used to capture rainfall variability, including both irrigated and rain-fed cultivation.

Average yield and average annual losses for each crop for the 500-year time series were then computed, and the effect of drought intensity and duration on each crop converted to monetary losses based on market prices. Compared to simulated ‘normal’ years, analysis revealed that production losses exceeded 5 percent every 3 years, 10 percent every 5 years, 15 percent every 10 years and 25 percent every 25 years. Individual farmers and especially small farmers may experience much greater losses depending on their crop mix and the severity of drought in their particular location.

(Source: Lvovsky et al., 2006)

transfer drought risk to smallholder farmers. Drought-relief programmes that compensate for short-term impacts may increase dependence on relief and increase vulnerability in areas that may become more drought-prone with climate change.

International efforts to develop and apply standards for drought identification and monitoring are an important starting point to address drought risk. They need, however, to go alongside the development of mechanisms to systematically account for drought losses and impacts, and that comprehensively assess and estimate drought risks as a crucial next step to raising the profile of drought risk.

Forecasting, early warning and compensatory measures such as insurance are critical elements of drought risk management. However, to address the underlying drivers of drought risk, countries will have to strengthen and reorient other risk governance capacities, particularly those related to development planning and land and water management. There are often powerful political disincentives against addressing issues such as water rights and land use, but with ever-increasing drought impacts and losses, the imperative to seriously manage drought risk may soon outweigh these disincentives.

Notes

- 1 At a meeting in June 2010 convened by the World Meteorological Organization and the United Nations secretariat of the International Strategy for Disaster Reduction hosted by the Hydrographic Confederation of Segura.
- 2 Work is underway to develop a composite hydrological drought index that takes into account factors including stream-flow, precipitation, reservoir levels, snow pack, and groundwater levels.
- 3 The multiple impacts of hazards on vulnerable livelihoods were addressed in detail in the *2009 Global Assessment Report* (Chapters 3 and 4) and its background papers (de la Fuente and Dercon, 2008; Sabates-Wheeler et al., 2008; UNISDR, 2009), with a specific emphasis on how drought and rural poverty interact with each other in a way that locks in the vulnerability of these communities.
- 4 Some exceptions to this are more strict building standards to reduce water use. For example, approximately 40 percent of the benefits generated through New York City's Green Infrastructure Plan (2010) to improve water quality and reduce water consumption and runoff, will be achieved through new development (New York City, 2010).