Abstract

Droughts are silent killers, with the potential to cause enormous losses to society as a whole and to the insurance industry. Many loss-bringers are unseen, and the result of secondary events. This makes it difficult to assess the losses involved. Insurance against drought is particularly important in the agricultural sector, but in practice only feasible with governmental involvement. Some crop insurance schemes have proven quite successful and have gained importance in recent years, both in developed and developing countries. As drought is not only a consequence of unusual weather conditions, but also subject to the way in which water resources are managed, overall awareness is a key factor in being prepared to cope with the resulting risk, and in avoiding catastrophic consequences.

Keywords: Droughts; Drought disasters; Drought insurance; Drought losses; Loss statistics; Resilience; Water resources’ management

1. Introduction: the significance of droughts

In the past half-decade, water-related natural disasters have dominated the headlines much more frequently than earthquakes and tropical cyclones. However, while floods provide spectacular images and volleys of loss estimates for short periods of time, droughts tend to trundle along in the background of the world’s media coverage, and only pop up briefly in the news every now and then before fading into oblivion again. Nevertheless, drought is globally one of the most significant natural disasters in terms of spatial extent, duration and long-term socioeconomic and environmental impact (United Nations Development Programme (UNDP), 2013) and ‘the unremitting stress of drought, famine and deepening poverty threatens to create social strains, in turn creating the potential for involuntary migration, the breakdown of communities, political instability and armed conflict’ (Ban, 2010). It seems that despite modern technologies, from satellite observation and communication to cooperation partnerships and computerized optimization of water use, drought events are still occurring frequently all over the world and in almost every region.

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The Global Risks Report 2016 (World Economic Forum (WEF), 2016) states that water crises will constitute the biggest risk to the world in the coming decade. This topic has already been recognized as the front-runner with respect to impacts in 2015, and it ranks third in 2016. ‘Water crises’ risk is followed by ‘failure of climate change mitigation and adaptation’, ‘extreme weather events’, ‘food crises’, and ‘social instability’. These five items look like they have been copied from a ‘wanted poster’ describing droughts. They are closely interconnected.

2. What constitutes a drought?

2.1. The nature of drought

Drought cannot be defined in absolute terms. It is an exceptional deviation from the regional rainfall norm, and signifies a prolonged and abnormal moisture deficiency. Annual rainfall of just 500 mm in one region instead of the normal 1,000 mm can lead to a serious drought there, while 500 mm in another region would mean twice the normal rainfall. Yet deviation from the mean is not the only relevant factor, with variability in water yield and deviation from normal seasonal distribution being equally important. Therefore, drought must always be seen in the context of normally prevailing local and regional conditions.

Droughts are caused not only by the current weather situation. They are often the result of previous conditions, and have a very strong tendency to persist. The probability of a drought occurring depends on many factors – among other things, on the supply of water stored in aquifers, the soil, and in reservoirs and lakes at the beginning of a dry period. Deficits accumulate in dry years, which consequently cannot be compensated for in subsequent years with just average precipitation levels; above-average rainfall is needed to achieve recovery. This means that an extreme shortage could easily arise in the event of a moderate – albeit non-critical – shortage of water in the previous year. Droughts are usually exacerbated by higher rates of evaporation due to excessive temperatures, intense sunshine, low humidity and sometimes high winds.

Droughts are events that unfold slowly and usually affect a relatively large area. Problems arise gradually, and people tend to become aware of a drought only when it has fully developed. Hence, no steps are taken to adapt to the situation unless a critical stage has either already been reached or is imminent. To a large extent, however, whether a dry period becomes a drought depends on how water resources are managed in the area concerned. Typically, suitable measures are taken in those areas in which droughts are relatively common. Areas that are rarely affected by drought, but in which water is permanently in short supply, pose a greater problem. In such areas, a crisis may arise within a short span of time as there is no buffer. Given the large-scale impact, losses in many, if not all, sectors of society can be very severe.

There are also cases when drought affects only a limited area. Several years ago the Spanish city of Barcelona had to be supplied with water by tankers as the local water sources had fallen dry (Keeley, 2008), and most recently Atlanta in the USA was brought to its knees by drought conditions in a relatively small watershed from which the city drew its water supply (Goodman, 2007). Another example is the drought in Brazil’s metropolitan São Paulo (Braga & Kelman, 2016). In these and many other cases there was a lack of water management systems flexible enough to overcome unexpected periods of shortage – but sometimes also simply mismanagement.
The problem of drought as opposed to permanent aridity is that both nature and humans, in particular with respect to agriculture, have not adapted to temporary dryness, and consequently have difficulties coping with it. Drought therefore must not be viewed as a merely physical phenomenon or natural event. Its impacts on society result from the interplay between natural conditions and the demands people place on the water supply.

More than any other climate feature, climate change will alter the occurrence of extremely dry and hot weather conditions, in many (most) parts of the world (Intergovernmental Panel on Climate Change (IPCC), 2013). Climate change is responsible for a shift to warmer days, including a change in the proportion of extremely high temperatures. This makes the topic even more worthwhile to concentrate on when we prepare for a livable and sustainable future for billions of people.

2.2. Drought definitions

Due to the relative nature of drought, there are several definitions, each of them relating to a specific point of view.

Meteorological drought is the temporary imbalance between actual precipitation (or soil moisture) and the average over a given time span. It tends to be localized and short-term, but its influences may be severe on plants (crops). For example, a country such as Bangladesh, which is known for its severe floods, actually fears the absence or delay of (some) rainfall even more.

A hydrological drought affects the entire water resources’ system in a region, consisting of surface water, snowpack and artificial storages (reservoirs), as well as soil moisture and groundwater. It represents the cumulative effect of prolonged deficits in precipitation. Meteorological droughts usually precede hydrological droughts, but are not a prerequisite. They are often ‘co-sponsored’ by humans overexploiting the water resources, which may take a long time to recover, as aquifers, in particular, are often replenished very slowly. There are also sub-types of hydrological droughts, such as soil moisture drought and groundwater drought.

Agricultural drought relates to a specific kind of crop, depending on various factors including the type of crop and its ability to store water, the stage of the growth cycle, soil type, temperature, etc. It describes the water stress on a crop determined by water supply and evapotranspiration, which may arise from both unexpected lack of rainfall or bad planning of the water demand during the growth cycle, e.g. by planting the crop too early or too late. Agricultural drought may lead to poor yield, but also to total crop loss.

Socioeconomic drought links human activity with the above drought definitions, which are described by purely physical/biological characteristics. In very general terms, it may be described as a failure of the water supply to meet the water demand of a – local, communal, regional or national – society. Both sides may contribute to this type of drought: the supply side through lack of rainfall, and the demand side through overuse of existing resources. This is the type we are talking about in the context of drought disasters.

Further characterizations of droughts refer to duration, geographical extent and severity. While seasonal droughts usually cause only material losses and temporary, but potentially severe, inconvenience, multi-year droughts (‘megadroughts’) have led to mass migrations of people throughout history and an irreversible loss of species. The larger drought-affected regions become, the more difficult it is to assist them with external supplies, in particular in areas with poor transport infrastructure. Recurrent droughts in a region may lead to desertification, i.e. the degradation of land that transforms originally productive land into wasteland.
Drought severity is commonly described by way of indices, which are mostly based on meteorological parameters. The indices consider relative rather than absolute conditions and enable comparisons of spatially different regions and their ‘normal’ climate.

The Palmer Drought Severity Index (PDSI) (Palmer, 1965) is one of the most commonly used indices. Precipitation and temperature data for the current and preceding months, as well as the locally available water content of the soil, are included in the calculations. The PDSI can be used to define long-term droughts (months) and evaluate their impact on agriculture. It is a standardized parameter that is calibrated to the local climate. Its advantage is that different parts of a country can be compared with each other. Integrating the PDSI over a year and over the entire area of a country, and then presenting it as a time series of annual values, allows us to identify drought periods extending to several years.

3. Droughts do not come alone

The principal consequence of drought – lack of water – is not the only impact. And it is not only lack of precipitation that causes it. As a rule, droughts are linked to heatwaves. Hence, excessive temperatures, intense sunshine, low humidity and sometimes high winds often exacerbate evaporation rates and thus ‘consume’ water. The simultaneous occurrence of heat and lack of water also intensifies the physiological stress for humans, animals and plants. One immediate consequence is the drastically increased wildfire hazard. The loss of fertile soil – if not expressed in the form of a dust storm – is a less spectacular, yet still severe, feature. In certain regions, subsidence occurs when soils shrink, potentially causing great damage.

Lack of drinking water for people and animals is the most critical potential consequence of a drought. In developed countries, this problem can practically always be avoided with the help of technical means (e.g. water trucks). In sparsely populated, remote areas, there may be no solution, thus making drought a deadly threat to people – and animals (pets and livestock).

Households and businesses are the first to feel the impact of restrictions placed on the use of water, e.g. for non-essential cleaning and watering purposes, such as washing the car or watering lawns and gardens. These restrictions gradually become more and more drastic until they finally affect hygiene.

Some branches of industry require enormous amounts of water for the production process, especially for cleaning and cooling. Food products cannot be produced without water.

As regards infrastructure, it is mainly heat that can cause physical damage. The asphalt pavement on roads and highways becomes soft and buckles. Metal items, including railway tracks and pipes, expand and buckle, with the consequence that trains may deraile and water lines burst. Electric power transformers can fail or sustain damage, causing interruptions to power supplies. Levees may dry out and crack, with the damage inflicted potentially remaining unknown until the next flood.

High temperatures are also responsible for many other impacts. They can impair human health and even cause death. Dehydration, strokes, cardiovascular and breathing problems, lack of sleep, fatigue, nervousness and general stress are among the most common complaints (Steuer & Kron, 2012).

In agriculture, water is vital for plant growth and survival, as well as for a good harvest. This sector is probably the most affected of all.

Insofar as river transportation can be operated at all, only smaller cargoes can be carried when water levels are low. The vessels are also obliged to travel at lower speeds, and there is often not enough width for two vessels to pass one another owing to narrowing of the navigable channels.
Hydroelectric power production is impaired, as rivers carry less water, and water levels in reservoirs are low. Thermal power plants require large amounts of cooling water, and its unavailability consequently leads to a reduction in power generation. High temperatures in summer increase demand for power.

In addition to the shortages created by falling water levels in aquifers, rivers and lakes, the process of providing a safe drinking water supply also becomes more complex at higher water temperatures. Biological purification of sewage can be impaired if dilution is inadequate. Discharge rules may be violated. This results in greater pollution levels in rivers and lakes.

Heat and drought are a source of stress for wildlife and plants. In extreme cases, plants wither, animals die, and ecosystems are affected.

The water quality in rivers and lakes suffers in general. If the discharge drops while the load of pollutants remains the same, their concentration in the water increases, potentially harming aquatic life and plants. Water temperature rises. Pollutants and toxic material increasingly settle, as flows decrease. In future floods, these constituents are reactivated from the sediments, and may cause poisonous surges.

Access to rivers and lakes can be impeded by low water levels, making some recreational activities impossible. Pathogen counts in the water may also rise at high temperatures.

Dry soil is very easily eroded by wind, and the resulting dried-out vegetation no longer acts as a buffer against erosion. When it subsequently rains, the water causes erosion damage as it runs off. Prolonged droughts may lead to irreversible loss of fertile soil and eventually to desertification.

Apart from the direct adverse effect of dust on human and animal health, dust storms may contain pesticides, pollen, fungi and other substances that irritate human lungs and eyes. Dust particles can cause a variety of health problems, including asthma, especially in children, the elderly and those already suffering from respiratory or cardiovascular disease. While most particles from windblown soils are large and deposited quickly, very fine dust remains in the air for long periods.

The danger of wildfires rises with each hot and dry day.

Clayey soil shrinks when it dries. This can lead to subsidence damage.

The degradation of groundwater near coasts allows salt water to intrude and to lastingly spoil the aquifer. Coastal wetlands may be affected, damaged, or even disappear, which can have dramatic consequences for natural coastal protection.

Finally, water rights’ disputes arise. These may occur between farmers, businesses, communities and entire nations, potentially leading to warlike conflicts.

While many of the above are temporary consequences and no longer relevant when the period of heat and drought ends, they may be irreversible in some cases.

4. Drought loss statistics and related problems

Hardly any other type of natural disaster is as difficult to comprehend as drought. For a hazard event such as landslide, the beginning and the end of the event, the area affected and the loss generated are completely clear, and the event can be described individually.

A drought is just the contrary. The problem starts with the following question: when does a drought begin, and when does it end? It is definitely not the last rainfall that marks the beginning, nor the first rainfall that marks the end. Droughts – in the sense of damaging events – develop slowly from dryness. It is only when looking back in time that we can determine when the one gradually transformed into the other. To specify the exact date is never possible, although this is usually quite an important factor in the...
context of insurance. The area concerned cannot – in most cases – be defined with accurate boundaries. And even the overall consequences are subject to uncertainty and subjective assessment.

With no time window for accumulation defined, and given that indirect losses (long-term business influences, loss of jobs, etc.) are sometimes much greater than direct losses (failure of crops, direct consequences of water shortages, etc.), estimating drought event losses becomes very difficult. Therefore, all loss figures relating to droughts have to be treated with great caution.

This considerable uncertainty must be taken into account when drought events are compared and represented in statistical terms. However, the order of magnitude of severity can nevertheless be gleaned from rough estimates.

4.1. Statistical data on droughts

As a globally operating reinsurance group, Munich Re reports droughts (i.e. those that cause losses) in its NatCatSERVICE database, together with the losses from all other types of natural disasters (Kron et al., 2012; Wirtz et al., 2012). Currently more than 30,000 individual loss events are stored in this global database. The information on each event comprises direct losses (damage), represented by overall losses and insured losses. In addition, it describes in a semi-quantitative way the characteristics of an event, such as the area, people, and infrastructure affected, special features such as noteworthy business interruption cases, and others. Some examples of entries are shown in Figure 1.

The number of fatalities, which is reported for other types of disasters, is not included for drought because associating the death of a person directly to drought is rarely possible; it is usually heat or famine that kills people.

Drought events listed in the database are very often linked to heatwave entries, and losses comprise many of the features displayed in Section 3, except wildfire and subsidence. In particular, it is not possible to distinguish and separately record the material losses. Tables 1 and 2 show drought events since

<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Region</th>
<th>Direct overall losses (US$ m)</th>
<th>Insured losses (US$ m)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun – Sep</td>
<td>United States</td>
<td>AR, CO, GA, IA, IL, IN, KS, KY, MO, MS, MT, NE, OH, OK, SD, TN, TX, WI, WY</td>
<td>25,000</td>
<td>12,000</td>
<td>Moderate to extreme drought conditions, &gt;60% of the United States abnormally dry. Lack of rain, high temperatures. Low water levels in rivers; reservoirs; wells. Severe losses to (esp. soybeans, corn).</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec 2013 –</td>
<td>Brazil</td>
<td>São Paulo, Minas Gerais, Rio de Janeiro; Espirito Santo</td>
<td>5,000</td>
<td></td>
<td>Severe drought (worst drought in 80 years), lack of rain, high temperatures. Reservoirs, rivers drying up. Hydroelectric power facilities deactivated, blackouts. Severe losses to agriculture (sugar cane, coffee). Water rationing for 4 million people. Affected: &gt;27.6 million.</td>
</tr>
<tr>
<td>Mar 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Entries of drought events (selected examples) in the NatCatSERVICE database. Source: Munich Re NatCatSERVICE 2016.
1980 that were significant in terms of material losses, and the famine and heatwave events with the highest death tolls.

The sequence of inflation-adjusted (2015 values) annual losses from droughts/heatwaves over the past 36 years displays an upward trend (Figure 2). As most of the losses can be attributed to agriculture, the causes of the trend should mainly be found there. One of the main reasons for this is that yields and cultivated areas are significantly greater today than in the past; therefore, the loss potential has also increased. On the other hand, modern agricultural management practices can have a risk mitigating effect.

The two high loss peaks in the time series in Figure 2 are attributable to the severe droughts in the United States in 1988 and in 2012, which alone produced original, i.e. not inflation-adjusted, losses of US$15 bn and US$25 bn respectively. In the period shown, more than a third of all losses (36%) were generated in the USA (Figure 3). This is the same amount as for the remainder of America, Europe and Africa combined. With an 11% share, China is the country with the second-highest losses.

Table 1. Significant droughts in the period 1980–2015.

<table>
<thead>
<tr>
<th>Period</th>
<th>Affected area</th>
<th>Direct overall losses in US$ m (original values)</th>
<th>Insured losses in US$ m (original values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun–Sep 2012</td>
<td>United States (esp. Midwest)</td>
<td>25,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Jan–Dec 1988</td>
<td>United States (esp. Midwest)</td>
<td>15,000</td>
<td>650</td>
</tr>
<tr>
<td>Jul–Aug 2003</td>
<td>Europe</td>
<td>14,000*</td>
<td>1,100*</td>
</tr>
<tr>
<td>Apr–Oct 2002</td>
<td>United States (esp. Great Plains)</td>
<td>10,000*</td>
<td>2,000</td>
</tr>
<tr>
<td>Jan–Dec 2011</td>
<td>United States (esp. TX)</td>
<td>8,000</td>
<td>2,400</td>
</tr>
<tr>
<td>Jan–Jul 1996</td>
<td>United States, Mexico</td>
<td>6,200</td>
<td>500</td>
</tr>
<tr>
<td>May 1999 – Nov 2001</td>
<td>Iran</td>
<td>5,100</td>
<td></td>
</tr>
<tr>
<td>Nov 2011 – Feb 2012</td>
<td>Argentina, Brazil, Paraguay</td>
<td>5,000</td>
<td>185</td>
</tr>
<tr>
<td>Dec 2013 – Mar 2015</td>
<td>Brazil (esp. South)</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Sep 1992 – Jan 1995</td>
<td>Spain</td>
<td>4,500</td>
<td></td>
</tr>
</tbody>
</table>

*Including heatwave and subsidence losses.

Note: The table should not be interpreted as a ranking of the costliest droughts, because 1-year and multi-year events are listed together. Source: Munich Re NatCatSERVICE 2016.

Table 2. Fatalities from selected heatwaves and famines in the period 1980–2015.

<table>
<thead>
<tr>
<th>Period</th>
<th>Event</th>
<th>Affected area</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 1983 – Oct 1984</td>
<td>Famine</td>
<td>Ethiopia</td>
<td>300,000</td>
</tr>
<tr>
<td>Jan 1980 – Dec 1985</td>
<td>Famine</td>
<td>Sudan, South Sudan, Chad</td>
<td>153,000</td>
</tr>
<tr>
<td>Feb 1981 – Nov 1985</td>
<td>Famine</td>
<td>Mozambique</td>
<td>100,000</td>
</tr>
<tr>
<td>Jul–Aug 2003</td>
<td>Heatwave</td>
<td>Europe</td>
<td>70,000</td>
</tr>
<tr>
<td>Jul–Sep 2010</td>
<td>Heatwave</td>
<td>Russian Federation (esp. Moscow)</td>
<td>55,000</td>
</tr>
<tr>
<td>Jun 2010 – Feb 2012</td>
<td>Famine</td>
<td>Somalia</td>
<td>50,000</td>
</tr>
<tr>
<td>Jan 1989 – Apr 1992</td>
<td>Famine</td>
<td>Angola</td>
<td>10,000</td>
</tr>
<tr>
<td>Jan–Dec 1988</td>
<td>Heatwave</td>
<td>United States</td>
<td>5,000</td>
</tr>
<tr>
<td>Jun–Aug 2015</td>
<td>Heatwave</td>
<td>Europe (esp. France, Belgium, Italy)</td>
<td>3,850</td>
</tr>
<tr>
<td>May–Jun 2015</td>
<td>Heatwave</td>
<td>India, Pakistan</td>
<td>3,670</td>
</tr>
</tbody>
</table>

Note: The figures listed are only rough estimates; famine-related fatalities may be influenced by political instability, civil war, etc. Source: Munich Re NatCatSERVICE 2016.
Figure 3 is highly biased with respect to the severity of drought in different regions. A drought event in the USA primarily has an economic impact (and therefore a large percentage in the pie chart), whereas a drought of the same magnitude in an African country may constitute a humanitarian disaster involving famine and migration, but produce relatively small losses in monetary terms. In Africa, hundreds of thousands of people died due to drought-induced famines in the 1980s. But even in the current century – in 2010–2012 – a famine claimed the lives of some 50,000 people in Somalia (see Table 1).

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1 Throughout the paper, the term ‘billion’ or ‘bn’ indicates $10^9$. 

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Fatalities in developed countries are caused by heatwaves. This is one of the natural hazards which – though not recognized by most people – is responsible for the highest death tolls, topped only by massive earthquakes and coastal floods. The heat and drought summer of 2003 in Europe claimed about 70,000 lives in excess of the normal mortality figure (Robine et al., 2007), and in Russia the excess mortality figure amounted to over 55,000 in 2010 (Katsafados et al., 2014). No other single events have claimed as many lives in these regions in a century.

4.2. Loss estimation methods for droughts

The values that were used to create Figures 2 and 3 are based on loss estimates compiled in the Nat-CatSERVICE database. The estimation is performed using different approaches, depending on the information available. Three information situations can be distinguished (when dealing with agricultural losses):

4.2.1. Information on insured losses is available. The loss estimation procedure involving the least uncertainty is scaling up a – known – insured loss ($L_i$). If the percentage of the insured part of the agricultural area ($a_i$ [-]) and the typical portion of the loss retained by the farmers ($D$ [-], estimated value) are known, we can calculate the overall loss ($L_o$ [$\$]) of agricultural crops and thus the non-insured loss as the difference between $L_o$ and $L_i$:

$$L_o = \frac{L_i}{(1 - D) \cdot a_i}$$

(1)

This procedure implies that average insurance penetration in the country regarded is representative of the drought-affected region. In countries with high insurance penetration (e.g. USA, Canada), this method involves only small uncertainties, because the insured portion assumes a great part of the overall loss.

4.2.2. Quantitative information on affected values is available (lost/damaged crops, affected livestock). In countries with low insurance penetration, or where drought losses are not covered by insurance, overall losses ($L_o$ [$\$]) can be estimated using figures published on the lost crop percentage ($l_c$ [-]) in the agricultural area (A [ha]) affected, the average expected yield ($Y$ [tons/ha]), and the instantaneous prices ($P$ [$\$/ton]) for the respective agricultural products:

$$L_o = A \cdot l_c \cdot Y \cdot P$$

(2)

This bottom-up method can also be applied to livestock. The number of perished animals multiplied by the market price for one animal yields the figure for the overall loss in this category. Another approach uses macroeconomic figures, such as the destroyed portion of the countrywide harvest yield, in a top-down method.

4.2.3. Qualitative information on the extent of drought impacts is available. If quantitative information on losses and agricultural data and livestock is not available, the uncertainties may become very large. This applies to most African countries. In such cases, we use qualitative information on the event, such
as the type of affected crops including special crops, dairy cattle and livestock, timber, aquaculture, etc. In addition, we consider indicatory parameters such as affected industry, commerce, private property, lifelines, environment, society, people, as well as duration and spatial extent of the drought, death toll, plus other soft indicators.

The number and degree of these indicators allow us to associate a severity level with a drought event, and thus to compare it with other events whose overall loss is known. From this, we can derive the loss for the current event. Moreover, we might need to modify the resulting value by a country-specific vulnerability factor. As the uncertainty of this estimation method is quite high, we regard the loss value obtained in this way with caution and interpret it as an estimate reflecting an order of magnitude, not a reliable figure.

In some cases, detailed scientific studies are conducted in the aftermath of a drought disaster, or civil/governmental entities investigate impacts and loss figures. In the instances where an external loss estimation has been made, we check its plausibility and completeness by applying one of the above estimation procedures. In practice, it may well be that political motivation leads to biased loss estimates: they are either too high in order to obtain more disaster assistance or too low in order to play down the severity and its impact on the respective region.

5. Insurance of drought

5.1. Affected lines of business

Insurance is the best tool for overcoming a situation in which an extreme event exceeds the normal resistance and protection capacity. It allows people and enterprises to get back on their feet financially and to start to resume normal lives again, the latter being the core factor of resilience. It also protects a state’s budget from extraordinary expenses on top of its own losses in a catastrophic situation and – with respect to globally operating reinsurance companies – spreads the national loss globally, thus mitigating the regional situation.

Agriculture is the sector that uses and benefits most from drought insurance. Firstly, the sector is more directly affected than most others, and therefore more aware of the risk. Secondly, in selected countries crop insurance has a comparably long history with respect to this natural hazard. Agriculture (and related sectors) assumes by far the highest share of insured losses during droughts (note: wildfire losses to property are not considered drought losses). Crop insurance has been established successfully in many countries, and therefore efforts to introduce such schemes are ongoing in many others. Some examples are presented in the case studies described in Section 6.

Property insurance, the line of business that is normally most affected by natural disasters, hardly suffers from droughts – with two exceptions: losses caused by wildfires and subsidence, the latter only applying to the United Kingdom and France. Subsidence resulting from shrinking soils during drought periods can cause billions of dollars of damage to buildings that settle unevenly in these two countries, where the vast majority of houses are covered against this type of loss (see Section 6.6).

Wildfires are conditioned only by drought (Steuer, 2012, 2013) and are a secondary phenomenon, hence they are not discussed here in detail. Other property damage – typically caused by heat rather than by dryness, such as damage to roads and railway tracks – may occur, but does not normally accumulate to significant loss amounts.
More recently, the energy and transportation sectors have become increasingly important, and have shown more and more interest in insurance cover. They seek compensation when they have to stop or reduce business and thus lose profits. However, insurance solutions are still rare and not yet a major factor. Nevertheless, this field of business is most likely to develop in future as extreme summer weather situations are expected to increase in frequency and intensity with global warming.

Recent droughts in Eastern Asia have shown that drought can disrupt the production of electricity and the power supply. Particularly prolonged area-wide power failures have a huge loss potential. A power outage affecting the infrastructure of large cities can have serious consequences for the population as only a few days may suffice to severely disrupt the area-wide supply of essential (or even vital) goods. Industrial and manufacturing production can grind to a standstill if industrial plants and workshops cannot bridge the power failure with electricity from their own generators. Production stoppages in a supplier’s plant can disrupt entire supply chains and impair production by other firms dependent on the supply of precisely these products. Supply shortfalls may also occur when low river levels have a negative impact on barge traffic. Transportation firms and those that depend on the goods transported may suffer losses. The lost earnings may be covered under business interruption and contingent business interruption policies.

In addition to causing economic losses, functional disruptions and disrupted supply chains pose a major threat to public order and security. Consequences such as looting can result in considerable insured losses.

Of course, health (and to a smaller extent, life) insurance is also affected by extreme drought–heatwave events, but it is difficult to come up with quantitative data on how much they cost the health insurance sector. Similarly, casualty insurance may be affected (e.g. if legal requirements such as emission limits of pollutants are exceeded during extreme weather conditions), but one can assume that the contribution of this line of insurance is relatively small.

For the aforementioned two high losses in the USA in 1988 and 2012, the insured portions were 5% (US$650 m) and 50% (US$12 bn) respectively. This large difference reveals the dramatic change in agricultural insurance penetration in the USA in just 25 years. In other markets, penetration has increased significantly too, as the relatively high portions of insured losses from drought disasters in North-east China (US$440 m representing 18% of the overall loss of US$2.5 bn) and in India (US$880 m, or 24% of US$3.7 bn) in 2015 show. The fact that insurance penetration for drought-related events has been increasing rather steeply in recent years is a sign that its positive effects are recognized. In some countries, governments have even implemented subsidy programs to incentivize farmers to buy insurance cover.

5.2. Seasonal and annual climate variability

Contracts between reinsurance and insurance companies are drafted on an annual basis. It is therefore of great interest to know whether the probability of drought in the area to be insured in the upcoming year/season is higher or lower. While other natural hazards may also become more or less likely in a certain climate phase, drought as a slow onset event – and thus one that tends to ‘integrate the weather’ over a longer period – promises better results in long-term forecasting (i.e. with a time horizon greater than 6 months). In the procedure of negotiating contracts, a knowledge edge may be very helpful. One of these climate variations, the El Niño-Southern Oscillation, has been investigated thoroughly, and we are able to produce elevated or reduced drought probabilities for certain regions.
6. Existing insurance schemes related to drought

6.1. Drought insurance for agricultural production

Drought can cause high losses in agricultural production, and may ruin a farmer or even have a significant influence on food security. Thus, drought risk mitigation is of major importance both on farm level and on national level; it is a devastating risk for the farmer and a systemic risk both for the government and for insurers. The term ‘agriculture’ in this context comprises not only crop-growing, but also other types of farming such as forestry (timber), plantations (palm oil, rubber, etc.), animal husbandry, aquaculture and similar branches.

If farmers are aware of their risk, they can implement on-farm risk management measures, such as investment in technology. Crop and livestock production are mainly exposed to drought risks. Crop yield depends on the combination of individual weather-related phenomena encountered during the growing period and applied farming practices. But farmers also have to cope with catastrophic events. In such cases, insurance can contribute to income stabilization, avert ruin and foster resilience.

Depending on the susceptibility of a given crop plant to drought, persistent water shortage causes varying degrees of drought stress and weakens growth. In addition to missing precipitation, high temperatures may adversely affect harvests in several ways. They may impair pollination, increase oxygen uptake at night resulting in increased carbon release and loss of biomass, impede the absorption of fertilizers, etc. Strong sunlight can burn the leaves, reduce carbon assimilation and stunt growth. The full extent of the losses can be established only at the end of the growing season, which is in stark contrast to the situation in conventional property insurance where a loss in most cases is apparent immediately after the damaging event. In extreme cases, plants may suffer irreversible damage or even die.

There are two crop insurance products: individual indemnity-based programs and index-based insurance programs. In multi-peril crop insurance on an indemnity basis, drought is usually covered together with other natural perils. Indemnity-based means that the actual loss incurred is the basis for compensation, usually reduced by a deduction. Other approaches are index-based insurance systems where the indices used are based on meteorological parameters or on regional yield amounts. Weather-index policies for drought pay out if a specific meteorological value, e.g. precipitation, is not achieved in a specific period – irrespective of the actual yield.

The cost of insurance is a major drawback of drought coverage. The insured generally requests a fairly frequently recurring period of payouts, which corresponds to a considerable coverage level and hence to costly premium rates of 5% to 10% of the sum insured. In comparison, earthquake premium rates are typically below 1%.

6.2. Drought insurance for national resilience

Assessing agricultural risks and the risk transfer through insurance is complex. Besides flood and excessive rain events, agricultural drought exposure is one of the most demanding risks to insure due to its systemic risk nature. Both crop and livestock production are key to national resilience. Unfortunately, they are largely exposed to drought and have to be the focus of a country’s resilience strategy.

Public–private partnerships have proved to be successful, as they apply risk-sharing and risk-financing mechanisms between agricultural producers, insurance and reinsurance companies, and governmental public entities. These agricultural insurance schemes are available in many parts of the world.
world, with a very wide range of development stages regarding structures and penetration rates. The largest agricultural insurance markets are in North America (USA, Canada, Mexico), followed by Asia. Europe, the rest of Latin America, Australia and, finally, Africa only add up to a very small portion of the world’s premium volume.

Figure 4 shows the development of total premium volume from agricultural insurance in the United States and China, the two countries with the largest agricultural insurance markets, and India, ranked fourth. In the USA, annual volume has increased almost exponentially during the past 25 years; in China a steady increase has been observed in the past decade, while in India, after several years of increase, take-up currently appears to be stagnating. These increases point to success stories in the three countries, where the agricultural areas amount to roughly four (USA), five (China) and two (India) million square kilometers.

In most public–private agricultural insurance systems, catastrophe risks are financed by governments. With the African Risk Capacity (ARC) (see Section 6.5) for example, sovereign drought risks are transferred to the insurance market. This contributes to the public ability to cope with losses from droughts, especially in developing markets without robust access to international financing systems after disasters.

6.3. United States – national crop insurance system

As the world’s biggest producer of staple foods, the US agricultural sector plays a major part in safeguarding supplies, not only in the United States but throughout the world. Drought losses in agriculture amount to billions of dollars in severe drought years. The peril is the underlying cause for more than a
third of indemnity payments to agriculture in the United States. Consequently, obtaining adequate financial security against such losses is a key support factor for the US farming sector, global food security and agricultural commodity price stability.

The United States has a well-working agricultural insurance scheme that provides multi-peril coverage. This scheme, the Federal Crop Insurance Program, involves the federal government and the private insurance industry. Used in a standardized and centralized way as a policy tool by the government, which subsidizes it, it is advantageous for all parties – the farmer, the government, and the (re)insurance industry.

The fact that crops are so heavily exposed to large-scale, systemic risks, such as drought, that cannot be borne entirely by the private sector has prevented the establishment of a purely private crop insurance market in the United States. The crop insurance scheme offers US farmers a number of key risk management advantages:

- High level of creditworthiness: many farmers are faced with a negative cash flow and have to take out a loan every year to fund the upcoming season’s production costs.
- Excellent marketing opportunities, because it covers the risk that farmers will default on their sales contracts, which normally involve forward sales. In other words, they can at least forward-sell that portion of the yield guaranteed by the crop insurance policy knowing that they will be able to fulfill the contract. If the actual yield is then lower than expected, the indemnity paid under the policy can be used to offset the shortfall.
- In the event of a loss, the indemnification is guaranteed and paid out quickly.

The Federal Crop Insurance Corporation (FCIC) administers the system and is directly accountable to the US Department of Agriculture. The FCIC issues guidelines dealing with claims’ regulation, selects the products, and determines standard conditions of insurance and rates. The system is significantly subsidized by the federal government. Crop insurance providers calculate premiums netted by administration expenses. The expenses are borne by FCIC as a fixed rate. All providers apply the same actuarially sound premium rates, varying by crop type and region. This prevents harmful rate competition among the providers and adverse selection by the farmers. Along with the fact that crop insurers are not permitted to decline cover, this system secures an adequate level of market penetration. Without subsidization, farmers would be unable to afford technically adequate rates, and market penetration would be insufficient. The risks assumed are subject to a profit-and-loss-sharing system between the insurer and FCIC. Apart from underwriting and assuming risk, one of the primary functions of the (specialized) crop insurers is to give farmers competent advice on the various issues involved. The insurers also market and service the policies, estimate losses, and settle claims.

Currently, there are various crop insurance products covering around 100 different crops. Around 300 million acres (1.2 million km²) are insured under the Federal Crop Insurance Program. This corresponds to a market penetration of more than 80%.

This system of providing cover against natural hazards in the US agricultural sector is far more efficient than governmental aid following disasters in other cases. It ensures that cover and indemnity are tailored to the farmer’s individual risk situation, and provides fast claims’ settlements. However, it also benefits the state because farmers pay much of the premium themselves, whereas aid payments are funded entirely by taxpayers. Public–private partnerships of this type also eliminate the need for
state-run disaster relief infrastructure, because this part is provided by the private-sector insurance industry. Despite the contribution of governmental reinsurance, a substantial share of the risk is borne by the individual crop insurers. In a nutshell, the well-functioning – but expensive – US system relies heavily on the private insurance and reinsurance market.

6.4. India – public–private area-yield and weather-index insurance scheme

Index-based insurance is the most common form of agricultural insurance for crops in India. The programs offered are either an area-yield index or a weather-based index insurance. On 1 April 2016, the government launched a new system called Pradhan Mantri Fasal Bima Yojana (PMFBY). PMFBY is set to improve the National Agriculture Insurance Scheme (NAIS), which has operated for over 20 years and is currently the world’s largest single crop insurance program insuring about 30 million of the 120 million Indian farmers in 2015.

NAIS relies on an index-based area approach. Indemnity is based on the realized (harvested) average yield of a defined area, such as a county or district. The insured yield is established as a percentage of the average yield for the area, and typically ranges from 50% to a maximum of 90%. An indemnity is paid if the realized average yield for the area is less than the insured yield, regardless of the actual yield on a policyholder’s farm. This type of index insurance requires historical area-yield data from which the normal average yield and insured yield can be derived.

PMFBY will be implemented by the national government in cooperation with the Indian states. The government has set a steep target of doubling the number of farmers covered under crop insurance to 50% under the new scheme. The scheme provides insurance coverage and financial support to farmers in the event of failure of any of the specified crop plants as a result of natural calamities, pests and diseases. The insurance plan will be handled by the Agriculture Insurance Company of India, the public insurer for agriculture insurance, and ten other private insurance companies.

With PMFBY, the government has started to move from a claims-subsidy regime to a premium-subsidy regime. The premium rates for farmers have been fixed at 2% for summer crops, 1.5% for winter crops, and 5% for annual commercial and horticultural crops. The program is highly dependent on government subsidies, as the fixed premium rates are only about 30% of the actuarially required rates. Like its predecessor, premiums for the PMFBY program will be heavily subsidized, with 50/50 contributions by the respective state and the central government.

With respect to yield loss assessment under the new scheme, there is a high emphasis on the use of new technologies. Smartphones, remote sensing and global positioning system technologies will be used to optimize claims’ payments. The scheme itself is future-proofed but implementation is challenging given the large size of the country and small landholdings.

The second pillar of Indian index insurance is based on weather-station data. Operated by private insurance companies and publicly subsidized, weather-based index insurance policies amount to approximately one-third of the entire premium volume.

6.5. African Risk Capacity (ARC)

Motivated by recurrent catastrophic drought events in the Sahel, ARC Ltd was established in 2014 as a specialized agency of the African Union (AU). The aim of this new sovereign insurance pool is to help AU Member States, by means of modern finance mechanisms, to improve their capacities to better plan,
prepare and respond to extreme weather events and natural disasters, and thus prepare for the food shortage events that affect their vulnerable populations. ARC was established to use risk pooling and risk transfer to create pan-African climate-related response systems for African countries. The scheme currently (2016) covers drought risks in seven countries within the ARC Risk Pool: Gambia, Kenya, Malawi, Mali, Mauritania, Niger, and Senegal.

ARC Ltd was established as a mutual insurance company in the Bermudas, capitalized by KfW and DFID, the German and British Development Banks. ARC enables parametric insurance policies to be acquired by African countries, providing them with post-disaster event financing, which is predictable and has a rapid payout mechanism due to the index-based nature of the policies. The trigger is based on a Water Requirement Satisfaction Index within the Africa Risk View (ARV) model. The model was developed by the UN World Food Programme to calculate the estimated crop losses and drought-response costs from satellite-based rainfall information. As the ARV also serves as an early-warning mechanism, it becomes clear before the end of the season whether a payout will occur. If the early-warning mechanism exceeds a certain level, a ‘Final Implementation Plan’ detailing the use of the payout has to be submitted by the insured country. The ARC pays out on a nationwide level, and the payout is provided only if the government ensures allocation of indemnity to the affected people through this implementation plan. The recipe for success of ARC is the combination of risk assessment and risk modeling, contingency planning (implementation), risk transfer, and its rapid availability of funds. There is considerable potential for growth as other African countries are likely to join the program. Furthermore, there are plans to extend the cover to other hazards such as excess rain and wind.

6.6. United Kingdom and France – subsidence risk

In Western Europe, there is another feature of drought that can become very costly: subsidence. Some clay minerals, in particular montmorillonite, shrink when they dry and swell when they become moist. A sample of pure montmorillonite – also known as bentonite or smectite – can alter in volume by a factor of 15. Natural soils do not contain a high percentage of expansive minerals, but can still change volume by more than 20%. This is potentially damaging for buildings, and can even be destructive.

Vast areas with soils containing a considerable fraction of expansive clays are found in the United Kingdom and in France. The shrinking of soil in a very dry year or in a sequence of dry years often happens unevenly underneath a building due to the irregular distribution of the clay percentage. The consequence is that the building settles unevenly, cracks and/or tilts, and windows and doors jam.

In both countries, damage by subsidence is insured. In France, it is included in the compulsory governmental CatNat insurance scheme, which compensates losses after a government-declared natural disaster – to which a drought with high subsidence damage belongs.

In the UK, subsidence losses are covered by most private property insurance policies. The history of subsidence insurance started there in 1971 when the peril was included in buildings’ insurance, at no extra premium charge. In 1976, an exceptionally dry summer brought a first wake-up call. Insurance companies responded by introducing premiums and deductibles dependent on geographical location; highly exposed properties were barely insurable any longer. Nevertheless, a new peak in losses occurred in 1990–1991 after some dry years, with threefold losses compared with 1976.

Figure 5 shows that there is a clear correlation between summer rainfall and subsequent subsidence losses – typically with a time lag of 1 year. This lag results from the fact that the consequences of settlement often become visible – and are reported to the insurance company – only several months later.
Drought-related subsidence was considered the most expensive natural hazard for the UK insurance industry until the 2007 floods.

7. Drought is not only a natural hazard

‘Droughts are hard to avert, but their effects can be mitigated. […] The price of preparedness is minimal compared to the cost of disaster relief. Let us therefore shift from managing crises to preparing for droughts and building resilience.’

These words of Ban Ki-moon on the World Day to Combat Desertification 2013 (Ban, 2013) clearly state that dry weather conditions are not necessarily the path to drought disaster.

The problem of drought as opposed to permanent aridity is that neither nature nor humans have adapted to such temporary dryness, and consequently have difficulty coping with it. Drought therefore must not be viewed as a merely physical phenomenon or natural event. Its impacts on society result from the interplay between natural conditions and the demands people place on the water supply, and on the vulnerability of the region concerned.

In most cases, drought crises and drought disasters are the consequence of improper management of existing resources – and often even mismanagement. Reasons for these may be poorly developed societal and governmental structures and responsibilities, but also overuse and overexploitation of existing water resources. In this regard, drought is not a hazard that affects societies at different stages of development with different degrees of severity; it can seriously affect any society. The only difference is that in the one case (poor countries), people may die or get sick, in the other (rich countries), they may have to pay.

Many states, regions and cities must take the blame for water-related problems themselves, not shift it to nature. It is a lack of awareness, and sometimes even ignorance, that precedes a crisis. If the people in

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Fig. 5. Summer rainfall in southern England and Wales and insured subsidence losses 1975–2008 (in 2009 values, adjusted for inflation).
charge are sufficiently aware and practice good governance, the risk of drought can be reduced consider-
ably. The term *risk* should be stressed here, in contrast to *consequence*. Reducing risk means acting in
advance, before a crisis starts, while efforts (actions, but often only plans) to mitigate consequences are
typically undertaken when the crisis is already manifest – which is therefore less efficient and carried out
under time pressure.

Everywhere, except in naturally dry countries such as those in the Sahel in Africa where every drop of
water is appreciated, the most important feature in this context is permanent awareness – from the top
level of government to every single citizen – that the availability of sufficient water is not a law of
nature. Water is a natural resource that – like most other resources – is limited. If societies include
this perception in their everyday actions, the biggest step towards the sustainable use of water resources
has already been taken. This behavior includes avoiding the careless, wasteful use and pollution of water
(even if it is available in plentiful quantity), water-consuming production lines (crops, industries), exces-
sive settling in areas with water scarcity (for example Las Vegas), overexploiting groundwater and
surface water bodies, etc. To stop or slow such developments, let alone reverse them, is always more
difficult than not being too lavish in the first place.

Contingency plans, monitoring the weather situation, and early-warning systems with strictly
enforced rules and restrictions are also needed. The capacity to better forecast upcoming dry conditions,
for instance, enables farmers to prepare for possible droughts in advance. Natural climate variabilities
such as El Niño or La Niña are associated with distinct regions where reduced precipitation is more
likely, and thus allow the regions concerned to prepare for and react to possible consequences at an
early stage. New technologies such as remote-sensing are developing rapidly and can assist in agricul-
tural management regarding plot identification, yield estimations, assessment of the vegetation status
and loss estimations, to name but a few.

In many developing countries, farmers retain the risk of crop losses. Their risk management often
only consists of diversifying their income sources by planting a variety of crops and by additionally
breeding livestock. Implementing further risk management systems and tools is key for drafting sustain-
able development strategies, but also for adapting to the changing climate.

Insurance is the last but not least important component of drought management. As a remedy, it
covers the loss, but as a prophylactic measure it also provides planning security. A farmer will not
be ruined by a disastrous drought, but will be given a financial cushion with which to restart his or
her life. Sovereign risk insurance schemes can be a first step towards implementing a market system.

8. Conclusion

Droughts are silent killers, with the potential to cause enormous losses to society as a whole and to the
insurance industry in particular (Höppe, 2013). Outside the agricultural sector, losses may initially
remain insignificant. However, they can suddenly spiral if developments triggered by a drought,
especially in combination with extreme heat, cause events such as power blackouts. Climate change
will certainly intensify extreme drought situations in many parts of the world.

In agricultural insurance, a system approach in the form of public–private partnerships is needed. This
structure can provide the adequate legal, institutional and organizational framework in which insurance
products and other risk management tools can work efficiently, and in favor of all parties involved. A
national agricultural insurance system must involve the different production sectors, and address the
interests of all stakeholders (producers, government, lending institutions and the insurance industry). Its main objective is to make insurance cover available to the majority of production sectors and farmers.

Overall awareness is a key factor in being prepared to cope with drought and avoid catastrophic consequences. While extremes of dry weather are not avoidable, disasters are. They are the net result of the effects of extreme weather events and the response to them. Effective prevention measures are both achievable and indispensable, but they will never provide complete protection. If societies, from governments to individuals, are prepared for frequent and normal extremes, and the residual risk from rare events is transferred to the finance industry, we can achieve enough resilience to guarantee sustainable living.

References


