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Benefits of action and costs of inaction: Drought mitigation and preparedness – a literature review

Nicolas Gerber and Alisher Mirzabaev

Contents

About the authors

Nicolas Gerber and Alisher Mirzabaev are economists and senior researchers at the Center for Development Research, University of Bonn, Germany. Both authors are consultants to the Integrated Drought Management Programme (IDMP).

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Abstract

This review of available literature on the benefits of action and costs of inaction of drought mitigation and preparedness shows that significant progress has been made over the past decade in improving understanding of droughts and their impacts. However, significant gaps in research, policy and practice remain, particularly regarding the merits of risk management compared with traditional crisis management approaches.

The findings highlight the need for mutually compatible methodologies as a means of comprehensively assessing drought costs and impacts. Presently, many available estimates of drought costs are partial and difficult to compare. The problem is compounded by the lack of data on droughts and their impacts. Moreover, relatively little knowledge is available on the costs of indirect and longer-term drought impacts.

The costs of action against droughts are classified into three categories: preparedness costs, drought risk mitigation costs and drought relief costs. This paper reviews several methodologies for making economic drought impact assessments and describes the main obstacles and opportunities facing the transition from crisis management to risk management. It identifies drivers of ex ante and ex post action against drought and highlights actions that are associated with co-benefits beyond drought risk management.

1. Introduction

Droughts are major natural hazards and have wide-reaching economic, social and environmental impacts. Their complex, slow and creeping nature; the difficulty of determining their onsets and endings; their site-dependence; and the diffuse nature of their damage (Below et al. 2007) make the task of comprehensively and accurately determining the cost of droughts a highly challenging one. These difficulties are compounded by a lack of data on droughts and their impacts (Changnon 2003), especially in low-income countries.

Droughts are the most detrimental of all the natural disasters (Bruce 1994, Obasi 1994, Cook et al. 2007, Mishra and Singh 2010). Globally, about one-fifth of the damage caused by natural hazards can be attributed to droughts (Wilhite 2000), and the cost of droughts is estimated to be around USD 80 billion per year (Carolwicz 1996). In the USA – one of the few countries having relatively good data availability – the annual losses attributed to droughts were estimated to be around USD 6–8 billion in the early 1990s (Wilhite 2000, citing FEMA 1995). In the European Union, the damage caused by droughts is estimated to be around EUR 7.5 billion per year (CEC 2007, EC 2007). However, these estimates are likely to be quite conservative, since they often fail to take all the impacts into account. Indirect drought impacts in particular are seldom captured appropriately or systematically by drought monitoring and reporting systems. For example, in addition to affecting the quantity of water, droughts have negative effects on the quality of water systems. These effects include increased salinity, enhanced stratification leading to algal production and toxic cyanobacterial blooms, higher turbidity and deoxygenation (Webster et al. 1996, Mosley 2015). The costs of these water quality impacts are yet to be quantified adequately.

Importantly, droughts may also have far-reaching social and economic impacts; for example, by leading to conflict and civil unrest (von Uexkull 2014, Johnstone and Mazo 2011, Linke et al. 2015), migration (Gray and Mueller 2012), gender disparities (Fisher and Carr 2015), reduced hydro-energy generation (Shadman et al. 2016), food security and famine (IFRC 2006), poverty (Pandey et al. 2007), and negative short- and long-term health effects (Lohmann and Lechtenfeld 2015, Ebi and Bowen 2015, Hoddinot and Kinsey 2001). Conway (2008) indicates that between 1993 and 2003, drought-induced famines affected 11 million people in Africa. According to the World Meteorological Organization (WMO), droughts may have caused 280,000 human deaths between 1991 and 2000 globally (Logar and van den Bergh 2011). Other indirect impacts are mentioned in national post-disaster needs assessments supported by the Global Facility for Disaster Reduction and Recovery/World Bank and other technical and donor agencies, and extend to social (e.g. access to education) and environmental (e.g. loss of ecosystem services) issues (see for instance the reports from Kenya 2012, Djibouti 2011 and Uganda 2010–2011, available at https://www.gfdrr.org/post-disaster-needs-assessments). However, there is relatively little literature on the economic costs of such indirect impacts. Furthermore, indirect costs may increase to a greater extent than direct costs in the future due to increasing frequency and severity of droughts under climate change, and these will be particularly challenging to model (Jenkins 2011).

The difficulty of assessing the costs and impacts of droughts is complicated by the challenge of how to define drought. Drought is a temporary climatic feature, unlike aridity, which is a permanent characteristic of a climate (Wilhite 1992). Drought has numerous definitions, which may be mutually incompatible. Ideally, the definition should be set specifically for each location, taking into account the characteristics of that location.

Drought is a natural hazard, so its occurrence in any location and during a given time period could be evaluated by attaching probabilities depending on the biophysical and climatic characteristics of that location (Wilhite 2000). However, drought impacts are strongly modulated by the socio-economic characteristics of affected areas, such as their vulnerability and resilience to drought, as well as their level of drought preparedness. The role of socio-economic factors in determining drought impacts is complex and relations are not linear; for example, a higher level of socio-economic development and water services infrastructure can mitigate or exacerbate the impacts of drought.

In a risk-based approach to drought (described in this study as drought risk management), we refer to mitigation of the risk of incurring negative impacts from drought events, rather than reducing the probability of occurrence of drought events. In this sense, vulnerability to drought is the susceptibility to be negatively affected by drought (Adger 2006), with the opposite being resilience, i.e. the ability to cope successfully with drought and overcome its impacts. Vulnerability and resilience to drought are affected by actions taken to mitigate drought impacts and increase drought preparedness (Wilhite et al. 2014). These both reflect the degree of adaptive capacity of a community (Engle 2013). Drought preparedness involves actions undertaken before drought occurs and that will improve operational and institutional response to drought (Kampragou et al. 2011).

On the other hand, drought impact mitigation actions include a variety of activities carried out before drought occurs that will minimize the impacts of drought on people, the economy and the environment. Wilhite et al. (2005) classified actions for drought preparedness in a ten-step process. This has been further refined for national drought management policies by WMO and GWP (2014). Based on the High-Level Meeting on National Drought Policies (WMO, UNCCD and FAO 2013), the Integrated Drought Management Programme (IDMP) and its partners have adopted three pillars of drought management: i) drought monitoring and early warning systems; ii) vulnerability and impact assessments; and iii) drought preparedness, mitigation and response.

The difficulty of accurately assessing the costs of droughts presents substantial challenges for the analysis of the costs and benefits of investments made and policy actions taken against droughts. At the same time, droughts are not weather or climatic anomalies, but a recurrent and normal feature of almost any climate (Kogan 1997), even in comparatively water-rich countries (Kampragou et al. 2011). NCDC (2002) indicates that about 10% of the territory of the United States (US) is affected by drought at any given time. Between 2000 and 2006, 15% of the European Union's land area was affected by drought (Kampragou et al. 2011), more than double the annual average for 1976–1990 (EC 2007). Droughts have occurred in different locations across Vietnam in 40 out of the past 50 years (Lohmann and Lechtenfeld 2015). Gan et al. (2016) provides an extensive review of climate change and variability in drought-prone areas of Africa and predicts critical negative impacts on a wide variety of drought-related indicators. Given the scale of the issue and the likely drought trends under climate change, it is essential to have a well-defined strategy for mitigating the impacts of drought and enhancing drought preparedness.

However, the default course of action used by many countries is to respond to the impacts of droughts once they have occurred, through drought relief (i.e. crisis management), rather than proactively improving resilience through appropriate risk management strategies (Wilhite 1996). Crisis management approaches usually fail to reduce future vulnerability to drought. On the contrary, by providing drought relief to activities that are vulnerable to drought, they may in fact incentivize their perpetuation. As a result, continued vulnerability makes crisis management more costly to society than ex ante investments that mitigate drought risks by building resilience. Moreover, since we currently lack comprehensive assessments of the full social and environmental costs of droughts, the ultimate costs of continued vulnerability are likely to be higher than estimated at present. Furthermore, climate change is expected to increase the frequency and severity of droughts (Bates et al. 2008, Stahl and Demuth 1999, Andreadis and Lettenmaier 2006). The changing climate is also likely to expand the geographical extent of drought-prone areas (IPCC 2014, Mishra and Singh 2009), making crisis management approaches even less affordable than they are today. This begs the question: if proactive risk management is socially optimal compared with reactive crisis management, why is the shift from crisis management to risk management happening so slowly?

This review seeks to shed light on responses to this question by evaluating current relevant literature. More specifically, we seek to summarize the key literature on the costs and benefits, and pros and cons, of reactive public crisis management versus ex ante government policies for drought risk management directed towards investment in mitigation actions and drought preparedness that reduce the impacts of future droughts. We also identify the obstacles and opportunities facing the transition from crisis management to risk management, presenting country experiences from around the world. In this regard, the findings highlight that many drought risk management actions and investments have substantial co-benefits and positive social returns even without droughts. Hence, they can be promoted widely as low- or no-regret strategies for sustainable development and building resilience to a variety of environmental, economic and social shocks. Finally, this review discusses the major existing research and knowledge gaps in current drought-related literature and policy actions.

Selection of literature for this review was based on searches in Google Scholar and ScienceDirect platforms using the word 'drought' in combination with other key words such as 'vulnerability', 'resilience', 'early warning and monitoring', 'impacts', 'risk management' and 'crisis management'. IDMP partners and participants in the IDMP Expert Group Meeting on this topic (see acknowledgements) also provided key references. Moreover, citations in key documents were followed to identify additional relevant publications. This review did not cover every aspect of the drought literature in detail, but focused on publications of most relevance to the specific research question mentioned above. Although peer-reviewed papers, institutional publications and unpublished sources were included, we gave peer-reviewed papers a higher preference in shaping the conclusions of the review, while institutional publications served as valuable background material and sources of further reading.

2. Benefits of action versus costs of inaction: Concepts and methodologies

This review was developed and guided by the conceptual framework depicted in Figure 1. Drought events lead to numerous economic, social and environmental costs of a magnitude modulated by social and household vulnerability and resilience to drought. When a drought occurs, bearing its costs while taking no action could increase the overall cost of damage due to the drought, representing the cost of inaction, as compared to taking ex ante and ex post actions against drought. The costs of action against droughts can be classified into three categories: i) preparedness costs; ii) drought risk mitigation costs; and iii) drought relief costs. If drought relief costs make up the costs of crisis management, drought preparedness costs and the costs of proactive mitigation of drought risks make up the costs of risk management (Figure 2). Risk management also leads to the preparation of drought management plans, which identify a set of ex ante and ex post actions against drought and its impacts.

The assumption made in this review is that the costs of action are usually lower than the costs of inaction, and the returns from investing in ex ante risk management actions are higher than those of investing in ex post crisis management, as indicated in Figure 2. Actions involving drought preparedness and drought risk mitigation lower the eventual drought relief costs, in addition to helping to mitigate the costs of inaction. For example, the US Federal Emergency Management Agency (FEMA) estimated that the US would save at least USD 2 on future disaster costs from every USD 1 spent on drought risk mitigation (Logar and van den Bergh 2013). The facility to respond to drought events before and after they occur – amounting to "adaptive

Figure 1. Conceptual framework

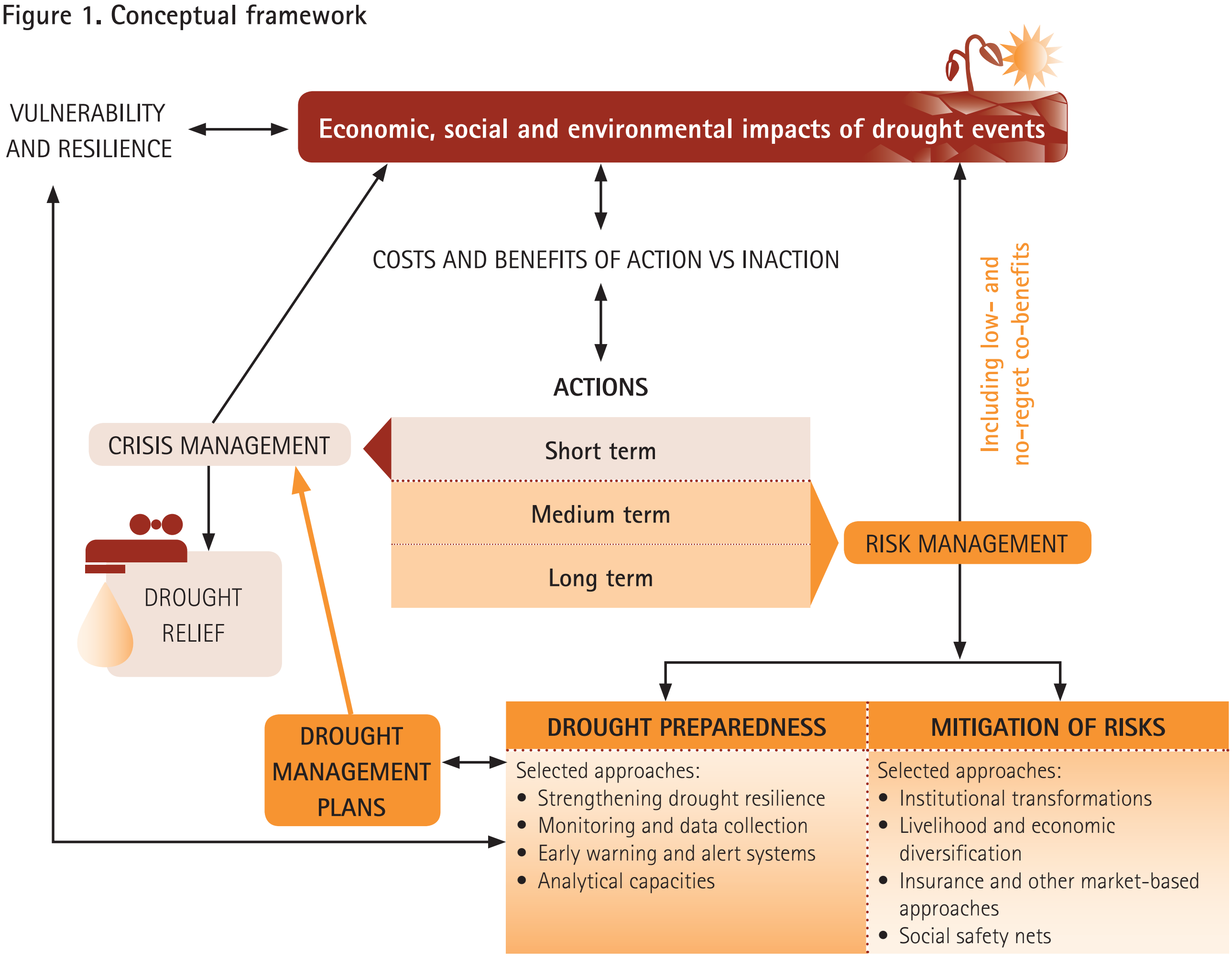
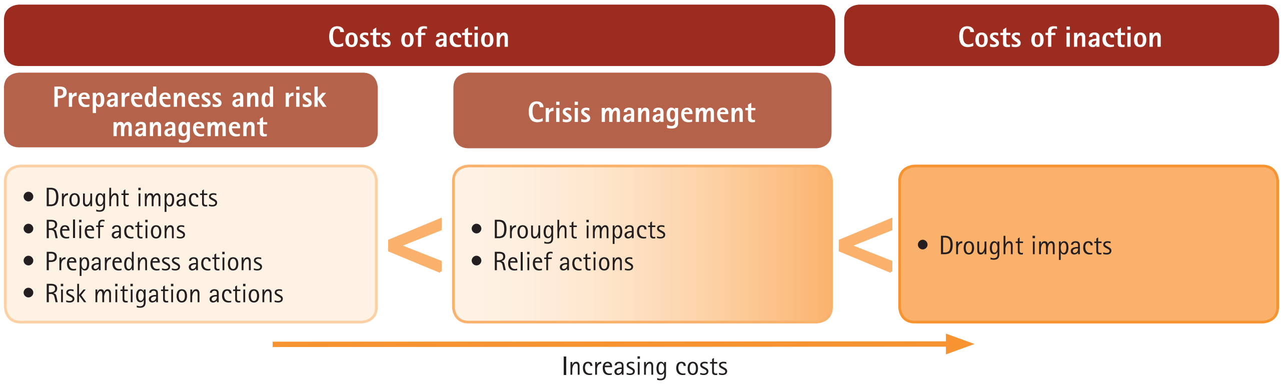


Figure 2. Summary of costs of drought under different action scenarios



Note: The figure suggests that the costs of droughts due to inaction are higher than the costs of addressing the impacts of droughts through crisis management approaches (using the inequality sign '<'). In their turn, the costs of actions against droughts using crisis management approaches are expected to be higher than those of using risk management approaches.

capacity", according to Engle (2013) – and reduce their economic and social costs depends on a number of factors, which are context-specific. Engle (2013) identifies a number of these factors for the US, among which he crucially lists "regulated flexibility", i.e. balancing the trade-offs between state regulations and structural preparedness, and the capacity for adaptive capacity at the local community level (notably for community water suppliers).

2.1 Methodologies for drought impact assessment

The site- and time-specific nature of droughts have led to multiple and diverging methods of assessing their impacts. Methodologies vary across scales (from intra-household or crop-specific to economy-wide impacts) and causal channels (direct or indirect, see Birthal et al. 2015). The choice begins with selection of drought indicators (Bachmair et al. 2016). Specifically, econometric models are used to estimate the impact of droughts on crop losses (e.g. Quiroga and Iglesias 2009, Birthal et al. 2015, Bastos 2016), and sometimes also economy-wide, regional-level or basin-level drought costs (Sadoff et al. 2015, Gil et al. 2013, Kirby et al. 2014).

On the other hand, partial equilibrium, computable general equilibrium and input–output models are used to evaluate the sectoral or economy-wide costs of droughts (Dono and Mazzapicchio 2010, Peck and Adams 2010, Booker et al. 2005, Perez y Perez and Barreiro-Hurle 2009, Horridge et al. 2005, Dudu and Chumi 2008, Berrittella et al. 2007, Pauw et al. 2011, Rose and Liao 2005) or of specific policy responses to drought, e.g. water restrictions (González 2011). All these papers offer great insights on the methodologies and their improvements in the application of models to assess the costs of droughts or water scarcity. Perez y Perez and Barreiro-Hurle (2009) estimated that the direct drought costs in agriculture amounted to EUR 482 million in the Ebro river basin in Spain during 2005. At the same time, indirect costs in the energy sector amounted to EUR 377 million, indicating the substantial scale of indirect costs. Gil et al. (2011) used a combination of econometric and modelling approaches for ex ante assessment of potential drought impacts in Spain. Jenkins (2013) used an input–output model to show the importance of indirect drought costs in projections to 2050. Finally, Santos et al. (2014) used a mixed approach of input–output analysis and event decision trees to evaluate three risk management strategies: reducing the level of water supply disruption; managing water consumption; and prioritizing water use.

Naturally, all these valuation techniques are associated with some difficulties in their implementation or drawbacks in their results. More crucially though, there is a need for mutually compatible methodologies that allow comparison of drought costs and impacts between sites and across time, or even across various types of natural hazard assessment (Meyer et al. 2013). This would help to target international and national drought mitigation investments or, more generally, investments in the mitigation of all natural hazards. It would also enable a more accurate understanding of vulnerabilities to droughts and impact pathways of droughts. At the same time, such methodologies should account adequately for intrinsic differences in the ways droughts occur in different biophysical settings.

The estimates of drought costs need to include both direct (e.g. reduced crop productivity) and indirect (e.g. increased food insecurity and poverty) impacts of droughts, immediate costs and long-term costs, and losses in both market-priced and non-marketed ecosystem services (Ding et al. 2011). Meyer at al. (2013) provides a complete review and classification of the costs of natural hazards, some of which overlap. Thus double counting, as in the case of assessing ecosystem services, must be avoided (Balmford et al. 2008). Indeed, Banerjee et al. (2013) claims that an ecosystem services approach for estimating the economic losses associated with droughts could be used for this purpose. Ecosystem services-based approaches could indeed be useful for assessing non-market impacts of droughts by applying the techniques of avoided and replacement costs methods, contingent valuation, benefit transfer and other ecosystem services valuation approaches (Nkonya et al. 2011). Using the ecosystem services approach, Banerjee et al. (2013) estimated the costs of the millennium drought of 1999–2011 in the South Australian Murray–Darling Basin to be about USD 810 million.

Building a pool of case studies that evaluate the costs of action versus inaction against droughts using consistent and mutually comparable methodological approaches could provide the basis for a more rigorous understanding of drought costs, impact pathways, vulnerabilities, costs and benefits of various crisis and risk management approaches against droughts. This would ultimately lead to better informed policy and institutional action (Ding et al. 2011, Wilhite et al. 2014). Without more accurate estimations of the costs of inaction, it is obviously difficult to compare these with the costs and benefits of action against droughts (Changnon 2003).

2.2 Global and local drought costs evaluations

Meanwhile, existing evaluations of drought costs, although highly valuable, remain partial and are often contradictory. Table 1 provides some wide-ranging quantifications of drought impacts from the literature. For agriculture, a critical factor affecting the costs of droughts is the possibility to substitute surface water with groundwater resources. Use of groundwater is associated with additional pumping costs, due partly to falling groundwater levels (Howitt et al. 2014, 2015), but the future costs of such groundwater substitution seem to be unknown. In another example, the severe drought occurring in Spain and Portugal in 2005 reduced total European cereal production by 10% (UNEP 2006). EEA (2010) indicates that the average annual costs of droughts in the European Union doubled between 1976–1990 and 1991–2006, reaching EUR 6.2 billion after 2006, although it is not clear if this doubling was due to increased frequency and severity of droughts or due to the increased area of the European Union caused by new countries joining.

Many countries in Africa, especially in the Sahel region, have long been prone to severe droughts causing massive socio-economic costs (Mishra and Singh 2010), but quantifications are generally more difficult to find for all developing

Table 1: Selected examples of the costs of droughts

Drought costs per annum (USD billion)	Period	Geographical unit	Source
0.75	1900–2004	Global	Below et al. (2007)
6.0–8.0	Early 1990s	USA	FEMA (1995)
40.0	1988	USA	Riebsame et al. (1991)
2.2	2014	California	Howitt et al. (2014)
2.7	2015	California	Howitt et al. (2015)
2.5	2006	Australia	Wong et al. (2009)
6.2	2001–2006	European Union	EEA (2010)

countries. Uganda lost on average USD 237 million annually to droughts during the last decade (Taylor et al. 2015). Sadoff et al. (2015) found that droughts were likely to reduce gross domestic product (GDP) in Malawi by 20% and in Brazil by 7%. According to Sadoff et al. (2015), the countries that are most vulnerable to GDP losses due to droughts are located in eastern and southern Africa, South America, and South and Southeast Asia. Indeed, the World Bank reports that the frequency of droughts has been increasing in India (World Bank 2003). The magnitude of drought costs also seems to be increasing over time in India (World Bank 2003) and Morocco (MADRPM 2000), due mainly to the increasing value of drought-vulnerable assets. Another issue with these assessments is that they do not really capture costs in the sense of drought costs due to inaction, but implicitly cover the mitigating effects of various measures of either relief or risk management. For comparability and consistency, all assessments of the costs of droughts should be clear about which categories of costs they cover – whether they are the broad categories described in Figure 2 or as described in Meyer et al. (2013).

Comprehensive evaluations of the costs of action versus inaction need to be informed by drought risk assessments. These would include analyses of drought hazards, vulnerability to drought and drought risk management plans (Hayes et al. 2004). Analyses of drought hazards are important because proper risk assessments are impossible without knowledge of historical drought patterns and evolving probabilities of drought occurrence and magnitudes under climate change (Mishra and Singh 2010). This requires weather and drought monitoring networks with sufficient coverage, as well as sufficient human capacity to analyse and transform this information into drought preparedness and risk mitigation action (Pozzi et al. 2013, Wu et al. 2015). However, the operational forecasting of drought onset, its severity and potential impacts several months in advance has not been broadly possible so far, especially in developing countries (Enenkel et al. 2015). Hallegatte (2012) indicates that the development of hydro-meteorological capacities and early warning systems in developing countries to levels similar to those in developed countries would yield annual benefits of between USD 4 and 36 billion, with benefit–cost ratios between 4 and 35 (Pulwarty and Sivakumar 2014).

Peck and Adams (2010), citing the case of the Vale Oregon Irrigation District in the USA, demonstrated that longer lead time weather forecasts are essential to enable appropriate responses to droughts. For example, if agricultural producers lack the knowledge that a second drought will shortly follow the first, they may mistakenly increase their future drought costs by expanding their earlier, vulnerable activities as a way to recoup their past losses. In this regard, in addition to physical meteorological infrastructures, wider innovative applications of available information and communication technologies, such as remotely sensed satellite data, have been instrumental in tracking vegetation cover change over long periods of time and with wide geographical coverage (Le et al., 2016). Similarly, mobile phone networks could help trace rainfall patterns with increased time and scale resolutions, especially in contexts where it could be time-consuming and costly to build physical weather monitoring infrastructure (Zinevich et al. 2008, Dinku et al. 2008, Hossein et al. 2008, Yin et al. 2008).

Although, as stated above, the literature on the impacts of droughts is fairly extensive, there is a lack of studies comparing the costs of inaction versus action. For example, Salami et al. (2009) traced the economy-wide effects of the 1999–2000 drought in Iran and found the total costs to be equal to 4.4% of the country's GDP. The same study also found that applying water-saving technologies to increase water-use productivity by 10% would reduce losses due to drought by 17.5% or USD 282 million. Furthermore, changing cropping patterns to suit the drought conditions allowed losses to be reduced by USD 597 million. Taylor et al. (2015) evaluated the viability of government drought risk mitigation strategies through increasing water-use efficiency, implementing integrated water resource management and improving water infrastructures in Uganda. The results indicated that the rate of return could be more than 10%. Harou et al. (2010) used the case of California to show that mitigation action such as water markets could substantially reduce the costs of drought impacts; while Wheeler et al. (2014) showed how such markets have worked for Australia's Murray River Basin. Most of these examples of drought costs are linked to agriculture, yet droughts also have impacts in urban areas (Box 1).

Box 1: Drought impacts and responses in urban areas

Although agriculture continues to be the major water user globally, the impacts and costs of droughts can be extensive in urban areas. In addition to specific industries (e.g. food and beverage), this also puts the service sector (e.g. tourism) at risk and could spark social tensions. The urban costs of droughts will continue to grow in the future due to climate change and expanding urbanization, and are magnified by relatively higher levels of returns from urban compared with agricultural water use. Therefore, drought preparedness and mitigation efforts in urban areas are important.

Several ways to increase urban drought resilience and drought-proof urban areas have been suggested. For example, reducing the overall costs of droughts may involve water transfers from low-value agricultural uses to higher-value urban uses during drought periods. Similarly, drought costs can be substantially reduced in the urban areas of northern California by purchasing water from lower-value agricultural uses.

Drought preparedness and mitigation plans in urban areas include increasing water conservation through appropriate policies and infrastructures. Water conservation measures could include non-market and market mechanisms. Non-market mechanisms usually involve water conservation education and explicit restrictions on specific water uses, while market-based mechanisms involve increasing water prices during droughts. Non-market mechanisms may be associated with significant transaction costs to enforce compliance, as well as loss of revenues to water utilities. Increasing the price of water during drought periods, on the other hand, may pose challenges in terms of social equity in water access. Beyond their immediate short-term impacts, droughts may also have longer-term indirect impacts on urban economies and livelihoods. For example, water conservation measures and higher water pricing may encourage a transition to more water-efficient home appliances (e.g. washing machines, dishwashers, showerheads and toilets).

Sources: Dixon et al. 1996, Guneralp et al. 2015, Harou et al. 2010, Michelsen and Young 1993, Moncur 1987, Rosegrant et al. 2009, Sauri 2013.

3. Action against drought: Risk management versus crisis management

Drought risk management includes the following elements: drought preparedness; mitigation of drought risks; and forecasting and early warning of droughts. Drought risk assessments serve as the basis for drought preparedness and drought risk mitigation (Hayes et al. 2004). These feed into drought management plans and identify specific ex ante and ex post actions (Alexander 2002).

Drought risk management activities concern reducing vulnerability to droughts and are conducted at various scales. The micro-level actions involving households, communities and individual businesses are often underappreciated but, arguably, are the most important elements of drought risk mitigation. For example:

- More secure land tenure and better access to electricity and agricultural extension were found to facilitate the adoption of drought risk mitigation practices among agricultural households in Bangladesh (Alam 2015). Similarly, Kusunose and Lybbert (2014) found that access to secure land tenure, markets and credit played a major role in helping farmers cope with droughts in Morocco.
- Holden and Shiferaw (2004) found that improved access to credit helped farming households in Ethiopia to cope better with drought impacts since they no longer needed to divest their productive assets. Moreover, since many rural households in Ethiopia tend to channel their savings into livestock, which may be wiped out during droughts, developing access to financial services and alternative savings mechanisms could also help to mitigate drought risk.
- Land use change and modification of cropping patterns are frequently cited as ways to build resilience against droughts (Lei et al. 2014 in China, Deressa et al. 2009 in Ethiopia, Huntjens et al. 2010 in Europe, Willaume et al. 2014 in France).
- Dono and Mazzapicchio (2010) showed that agricultural producers in Italy's Cuga hydrographic basin could minimize the impact of future droughts by tapping into groundwater resources.
- Another frequently used drought risk mitigation strategy is to diversify livelihoods by adopting off-farm activities (Sun and Yang 2012 in China, Kochar 1999 in India, Kinsey et al. 1998 in Zimbabwe), and divesting of

livestock assets (Kinsey et al. 1998 in Zimbabwe, Reardon and Taylor 1996 in Burkina Faso).

- Finally, UNDP (2014) found that a strong asset base and diversified risk management options were among the key characteristics of drought-resilient households in Kenya and Uganda. These aspects were due primarily to the households having better education and greater knowledge of coping actions against various hazards. This allowed them to diversify their income sources.

At the macro level, activities contributing to the mitigation of drought risks mostly involve institutional and policy measures. Booker et al. (2005) found that the establishment of interregional water markets could reduce drought costs by 20–30% in the US Rio Grande basin. Other examples include the development of an early warning system (Pulwarty and Sivakumar 2014), drought preparedness plans, increased water supply by investing in water infrastructure (Zilbermann et al. 2011), demand reduction, e.g. water conservation programmes (Taylor et al. 2015), and crop insurance.

Although drought insurance is an effective and proactive measure, the development of formal drought insurance mechanisms is hindered in many developing countries by a number of obstacles, including high transaction costs, asymmetric information and adverse selection (OECD 2016). At the same time, the covariate nature of droughts decreases the effectiveness of traditional community and social network-based informal risk sharing (Kusunose and Lybbert 2014). On the other hand, insurance can actually discourage ex ante drought mitigation behaviour. However, this depends on the type of insurance used. In general, two types of insurance are used to insure against drought damage in agriculture. Indemnity-based insurance protects against predefined losses, while index-based insurance protects against predefined risk events such as droughts (Barnett et al. 2008, GlobalAgRisk 2012).

Specifically, under indemnity-based insurance, crop producers are compensated for their drought-induced losses after a formal assessment of the extent, often compared with their pre-existing productivity levels (Meherette 2009). As a result, the transaction costs of indemnity-based insurance schemes are high and they are more suitable for large-scale farming operations.

Index-based insurance schemes use shortfalls in rainfall, temperature or soil moisture (without formal on-farm assessments of the extent of the damage) to trigger pay-outs to insured farmers. With significantly lower transaction costs, index-based insurance could be more suitable for smallholder farmers (Barnett et al. 2008, Meherette 2009). Index-based insurance, however, requires a well-functioning and relatively dense infrastructure of weather monitoring stations. Presently, the lack of such infrastructure presents a barrier to the wider rollout of index-based insurance schemes in many developing countries. Under index-based insurance, insurance pay-outs are not linked to actual damage, but to deviations in weather parameters. Insured farmers therefore would continue to have an incentive to take measures to limit the extent of their losses due to droughts. Moreover, index-based approaches allow for insurance against the indirect costs of droughts. For example, agro-processors could take out index-based insurance, while they may find traditional indemnity-based insurance is not applicable to them within the context of droughts (GlobalAgRisk 2012).

A limitation of index-based insurance lies in appropriate identification of risk event thresholds that trigger payments, i.e. minimizing the so-called basis risk, when the realized weather parameters in the area covered by the same index could be very heterogeneous (Barnett and Mahul 2007). If the threshold is too high, it may not cover some of the losses. If it is too low, the longer-term viability of the insurance scheme may be jeopardized. Identification of optimal payment trigger thresholds also requires the availability of sufficient past data to construct the index. Naturally, depending on the context, a blend of both index- and indemnity-based insurance approaches could be used.

Beyond local and national levels, international coordination of drought risk mitigation and drought responses are equally important in transboundary river basins (Cooley et al. 2009). Inadequate management of transboundary water systems during droughts could magnify both direct and indirect costs of droughts, especially in downstream countries. The existing transboundary agreements on water allocation may need to be reviewed for their flexibility to respond adequately to the increasing frequency of hydrological droughts under climate change (Fischhendler 2004). For example, whether the transboundary water allocation schemes are based on predefined minimum flow deliveries from upstream to downstream countries, or on percentage quotas could have substantially different impacts during droughts (Hamner and Wolf 1998). Regional drought risk mitigation efforts would include increasing the flexibility of transboundary water allocation regimes in response to droughts (McCaffrey 2003). This includes the operation of large-scale water reservoirs, which could have considerable impacts on upstream–downstream water flow regimes (Lopez-Moreno et al. 2009). Transboundary water management institutions could play a vital role in coordinating such responses to droughts (Cooley et al. 2009), and efforts are needed to promote the development of national and transboundary drought preparedness plans, assuring they are consistent in cases when they are interdependent.

As it is not possible nor economically efficient to eliminate drought vulnerability completely, droughts will continue to affect society to some extent. It is therefore important to identify more efficient drought responses. Crisis management measures may include impact assessments, response and reconstruction, involving such tools as drought relief funds, low-interest loans, transportation subsidies for livestock and livestock feed, provision of food, water transport, and drilling wells for irrigation and public water supplies (Wilhite 2000). Several studies identify ways to improve the efficiency of drought response measures. For example, pooling resources at the regional level in sub-Saharan Africa was found to be an effective strategy to hasten drought relief and reduce its costs (Clarke and Hill 2013), although this may not reduce future drought vulnerability. Experiences from Ethiopia showed that employment generation schemes could be effective in terms of immediate aid and strengthening local resilience against future droughts. These schemes paid drought-affected populations to work in drought mitigation activities (e.g. building terraces and check dams) rather than giving direct food relief (IFRC 2003).

Since it is difficult to evaluate the costs of droughts, it is even more challenging to compare the costs and benefits of proactive risk management versus reactive crisis management. Lack of comprehensive data on drought costs also makes it difficult to assess the effectiveness of mitigation investments (FEMA 1997). Moreover, due to the limited number of historical mitigation investments, any ex ante assessments of the rate of return from future mitigation actions will depend on modelling assumptions, which may not always prove to be consistent with the actual performance of the investments. However, once mitigation investments are made, governments and donors will want to know the returns from their investments. This should lead to additional impact assessments being conducted and will identify more efficient drought risk mitigation options (Changnon 2003). Most of the relevant past studies investigated the impact of adopting very specific drought mitigation options, where data were available and the uncertainty of assumptions could be reduced; for example, the impact of water-saving technologies (Ward 2014) or policies such as water trading (Booker et al. 2005, Ward et al. 2006). There is a need for additional such case studies. While it is plausible that drought risk management approaches are more efficient than crisis management measures, this review found a lack of rigorous empirical evidence to support this argument.

4. From crisis management to risk management: Obstacles and opportunities

4.1 Drivers of ex ante and ex post action against drought

Over the past few decades, we have experienced an increasing frequency and severity of droughts (Changnon et al. 2000) associated with rising economic and social costs (Downing and Bakker 2000). We have also seen an increased perception of the greater efficiency of risk management strategies (Wilhite 2005), and their lower burden on public budgets compared with frequent drought relief actions. These trends are leading to shifts from drought crisis management to risk management in many countries, including Australia, India, USA and the countries of the European Union (Birthal et al. 2015, EC 2008). Among these factors, the escalation of drought relief costs and the increasing burden on government budgets seem to have played a major role in promoting risk management strategies in the USA (Changnon 2003), Australia (Stone 2014) and probably additional countries embarking on this transition path. Box 2 illustrates that, even with the best dispositions towards risk management, governments are sometimes locked in crisis management strategies, especially during particularly long and acute drought episodes.

Nonetheless, path dependence and lack of information on the costs and benefits of risk management and crisis management actions are the leading causes of the persistence of crisis management approaches in many countries.

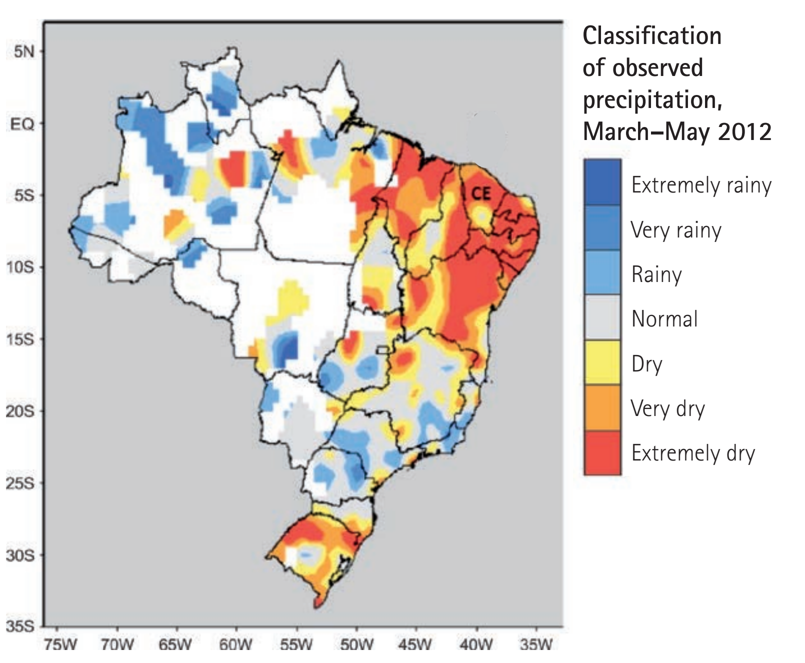
Box 2: Drought in Brazil: Impacts, costs and policy responses

Droughts in Brazil, especially in the northeast, are expected to increase in frequency and intensity as a result of global climate change. Drought and climate change combined with existing pressure on freshwater availability and quality are likely to lead to new and increased water management challenges. These have been recognized by the Brazilian water community, including resource managers and users, researchers and policymakers.

The country has several semi-arid regions, particularly in the northeast, where droughts are frequent events. Parts of this region experience high rainfall variability, with the rainy season in February to May accounting for about 70% of annual rainfall. The country in general and the region in particular thus have a long history of institutional drought management. This dates back to the first reservoir built in 1886 followed by the creation of agencies to address drought throughout the 20th century. Some of these are still in place in revised forms. The country also established a Water Code as early as 1930. According to the Brazilian Constitution, "water is a limited natural resource and an inalienable public good that belongs either to the Federal or state government".

Yet, the recent multiyear drought event of 2010–2013 has been particularly severe. As shown in the map below, precipitation during the rainy season of 2012 was classed as 'dry' to 'extremely dry' for most of the northeast, reaching only about 50% of the historical average for the season. The lack of water availability affected crops, livestock and industries, as well drinking water levels. Hence, despite its history of water management institutions, Brazil is struggling to cope with new, prolonged and extreme drought events.

In the wake of these events, Brazil has reverted to emergency relief and response actions. These are listed in Bastos (2016) and include various measures aimed at mitigating the negative impacts on communities and farmers as a direct consequence of the lack of water (water truck deliveries, cisterns) or as an indirect consequence of reduced agricultural production (emergency credit lines, debt negotiation – the costliest measure). Additionally, infrastructure development such as well drilling or new dams has been included under the Growth Development Plan. These measures have come with high costs; as of 2014, USD 4.5 billion had been allocated to emergency relief and infrastructure development. These costs are in addition to the estimated 13% loss in gross real value of agricultural output over the period 2010–2014.



Source: modified from Guttiérez et al. 2014

The magnitude of these costs demonstrates the difficulty of implementing pre-drought plans and actions to cope with the economic impacts of droughts. This is true in Brazil, a country with a history of drought management, infrastructure, available indicators and scientific knowledge and expertise in meteorological, climatological and hydrological monitoring and forecasting. The gaps and opportunities for drought preparedness and policy in Brazil, identified in Guttierez et al. (2014), can help to improve the situation in the country and in similar emerging economies. These point largely towards more and better integration between monitoring and forecasting communities, as well as with state and municipal decision-making bodies; the keeping of national archives to determine vulnerabilities to and impacts of drought (and other disasters); and vulnerability assessments conducted in the context of climate change. Many of these gaps are of an organizational nature, pointing to the need for documentation of droughts and their impacts. Others point to the need for analysis of vulnerability to drought. Together, such action should ensure faster and better mitigation and response to drought in the future.

Sources: World Bank 2013, Guttierez et al. 2014, Bastos 2016.

When there is a lack of information on the costs and benefits of mitigation actions, governments are often reluctant to make costly investments in mitigation (Ding et al. 2011). Moreover, under various uncertainties and with a shortage of empirical evidence on the greater efficiency of drought risk mitigation actions, it may be economically rational to respond to droughts only after shocks (Zilberman et al. 2011). Economic theory shows that under conditions of uncertainty, actors will delay irreversible investments until their net benefits exceed a positive critical value (McDonald and Siegel 1986). Meanwhile, Zilbermann et al. (2011) indicates that major changes in institutions and technological adoptions are likely to happen ex post as a response to droughts. For example, the drought of 1987–1991 in California led to wide adoption of water conservation technologies (sprinkler irrigation), fallowing of land, lining of canals for reducing water loss and the introduction of water trading, although these measures had been recommended for a long time before the occurrence of the drought (Zilbermann et al. 2011).

Jaffee and Russell (2013) suggest that ex ante actions are not always preferable to ex post actions when individuals attach varying subjective probabilities to drought hazards, which then shape their investment decisions. In such contexts, they suggest, to maximize social welfare it may be better to provide disaster relief rather than ex ante actions. Moreover, ex ante adjustments to droughts could increase resilience in the case of droughts, but could also simultaneously lead to choices that have lower returns during non-drought periods (Kusunose and Lybbert 2014). However, this analysis needs to compare ex ante and ex post interventions on farmers' production and investment decisions, and varying impacts of droughts on them (OECD 2016).

Drought preparedness plans need to include various trajectories of change that occur after they are implemented. For example, in the Segura river basin in Spain, drought preparedness plans imposing water supply restrictions from surface water led to the overexploitation of groundwater, which was not covered by the plan. This led to higher drought risks than would have occurred without the plan (Gomez and Perez-Blanco 2012). Therefore, drought preparedness plans, like other action plans, need to be evaluated and improved continuously to suit the evolving context and encompass learning from past mistakes (WMO and GWP 2014).

Although ex post actions seem to happen more often, there are economic reasons for ex ante actions. Drought is a business risk and agricultural producers will try to avoid its costs. Thus, while they have incentives to undertake mitigation actions, they face obstacles in the form of lack of knowledge about drought occurrences (early warning systems) and their impacts (extension and advisory services), and lack of funds (access to credit) (OECD 2016).

Similarly, numerous studies show that human and social systems evolve continuously to adapt to the changing environment. Biazin and Sterk (2013) showed that pastoral households in Ethiopia were shifting to more resilient mixed farming systems as a response to drought and that their earlier coping option involving migrating to alternative pastures was no longer feasible. Households in many drought-affected areas continuously apply risk management strategies as a normal part of their livelihood behaviour. Such risk management strategies are often applied in response to past drought shocks with a view to minimize the impacts of future drought events, i.e. households learn from their past experiences.

In the context of public goods, where experience plays a reduced role in fostering proactive behaviour, the lack of visibility of the impacts of drought risk management versus drought response measures is critical. However, risk management strategies could be more efficient and forward-looking if they were supported by scientific data on climate, drought and drought risk mitigation measures, with enabling ex ante government policies. Birthal et al. (2015) indicates that, although agricultural households carry out coping actions after droughts, which could serve as risk management strategies by reducing their vulnerability to future droughts, they may rarely be able to recover fully the loss of their productive assets due to the impact of the past drought. Indeed, drought relief in many developing countries is not as comprehensive as it might be in some developed countries, or is simply non-existent, so that affected households are left to their own means. On one hand, this may accelerate transitions to risk management approaches at the micro-economic level, but on the other, if governments do not need to save on drought relief costs (because they are small or none, or are borne by outside donors), there will be no urgency to make the transition at the macro level.

4.2 Co-benefits of drought risk management strategies

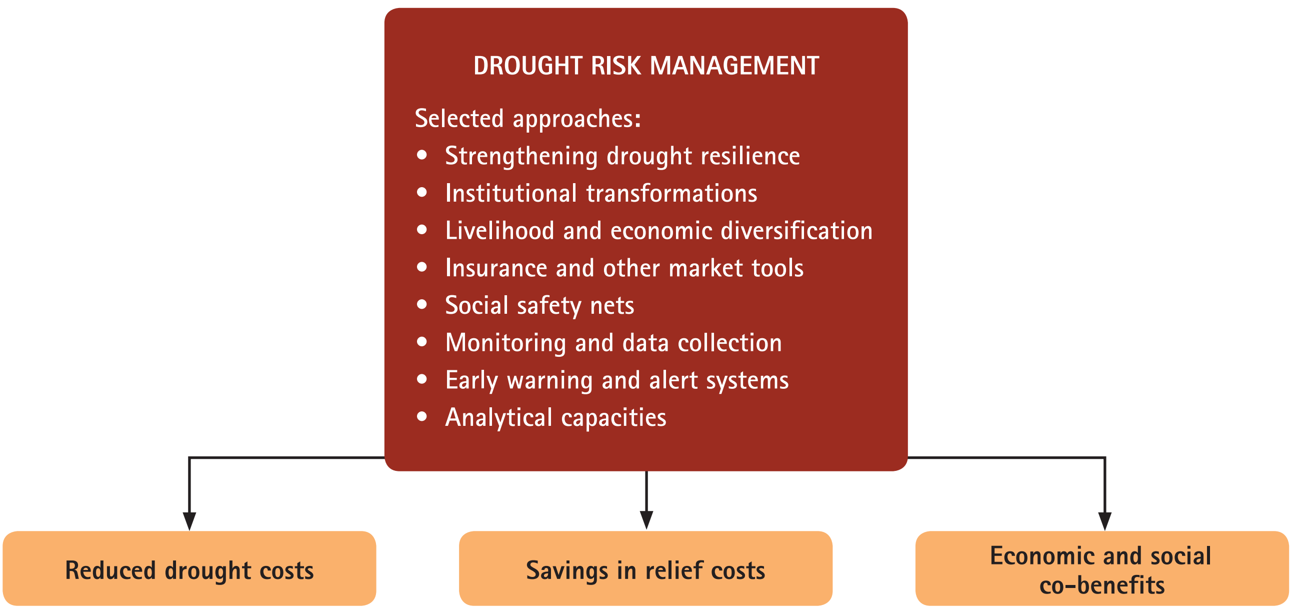
In addition to mitigating drought risks, risk management strategies have a major appealing characteristic in that they have substantial socio-economic co-benefits. Many drought risk management actions build resilience against droughts and additional socio-economic and environmental shocks. Thus a number of approaches to risk management against droughts are low- or no-regret options (Figure 3). Therefore, their application makes sense as a precautionary measure to prevent the negative impacts of many direct and, especially, indirect costs of droughts about which we have little knowledge. Figure 3 highlights that the benefits of adopting risk management approaches include reducing drought costs and lowering drought relief costs as well as having substantial socio-economic co-benefits.

For example, as elaborated earlier, more secure land tenure, better access to electricity and agricultural extension, access to credit, diverse livelihood options (including off-farm activities) and higher education levels were associated with stronger resilience against drought impacts (Holden and Shiferaw 2004, Sun and Yang 2012, UNDP 2014, WMO and GWP 2014, Alam 2015). At the same time, these factors substantially increase adaptive capacities against climate change (Deressa et al. 2009), help address land degradation (Nkonya et al. 2016), facilitate poverty reduction (Khandker 1998), improve household food security (Babatunde and Qaim 2010), and promote broader sustainable development.

Another example – the adoption of improved irrigation techniques or alternative water sources (Hettiarachchi and Ardakanian 2016) – could have positive impacts on agricultural income and sustainable water and land use during normal conditions as well as during times of drought. For example, the adoption of conservation agriculture practices in Kazakhstan, which included zero tillage and mulching, had the effect of reducing soil erosion and fuel use for land preparation as well as helping people cope better with the effects of the 2010 drought (Kienzler et al. 2012). This was because conservation agriculture practices allowed better retention of available soil moisture, thus reducing losses in crop productivity compared with previous droughts. While the adoption of conservation agriculture was driven primarily by the desire to save on fuel costs, it eventually served as a drought risk management strategy (Kienzler et al. 2012).

As a result, investments in drought risk management strategies and actions that have significant co-benefits can serve as 'low-hanging fruit' in drought risk mitigation; i.e. they are the easiest to implement initially. Although literature exists on the links between poverty reduction/food

Figure 3. Approaches to drought risk management and benefits



security and such factors as income diversification, land tenure security, and access to extension and credit, there is a need for more studies incorporating the co-benefits of promoting these and other similar drought risk mitigation factors as part of drought risk management approaches. Ideally, such studies would include quantification of the contributions of these factors to reducing drought costs and the extent of their co-benefits.

It should be noted that drought risk management strategies, such as household options for proactive increases in resilience to drought events, are not without trade-offs and that their impact can be highly case-specific. For instance, UNDP (2014) provides a number of examples where such strategies can have negative effects economically and socially at the level of the household and beyond. Examples include early marriages to boost the asset base through dowries, or disinvestment in education in favour of immediate employment in low-skill jobs. In specific agro-climatic systems, income specialization in livestock activities can prove to be a more drought-resilient strategy than income diversification. Similarly, gender- and age-differentiated impact assessments might lead to interesting insights on the distributional impacts of drought events and drought risk management strategies. This could ultimately point to different cost–benefit ratios and recommendations for action tailored to population target groups.

5. Conclusions and next steps

This review shows that although significant progress has been made over the past decade in understanding droughts and their impacts, as well as the merits of risk management approaches compared with traditional crisis management approaches, important research and policy gaps remain. There is a need for mutually compatible methodologies to comprehensively assess drought costs and impacts. Presently, many available estimates of drought costs are partial and difficult to compare. The problem is compounded by the lack of data on droughts and their impacts. Moreover, there is relatively little knowledge available on the costs of indirect and longer-term drought impacts.

Potential next steps include the following:

- Building up case studies evaluating the costs of action versus inaction against droughts using consistent and mutually comparable methodological approaches. This should allow better understanding of the drought costs, impact pathways, vulnerabilities, costs and benefits of various crisis and risk management approaches against droughts and the co-benefits of risk management approaches, which will ultimately lead to better informed policy and institutional actions on droughts.
- Comprehensive evaluations of the costs of action versus inaction against droughts need to be informed by drought risk assessments. They require weather and drought monitoring networks with sufficient coverage, as well as adequate human capacity to analyse and transform this information into drought preparedness and mitigation actions.
- When the previous two points are fulfilled, a clearer picture of the cost–benefit ratio of actions before drought (drought preparedness) versus the cost–benefit ratio of reactive actions (crisis management) can emerge. This is required to guide policy and investments for building drought resilience.
- Since it is not possible nor economically efficient to eliminate vulnerability to droughts, they will continue to affect society to some extent. Therefore, more efficient drought responses also need to be identified.
- To have impact, research and development partners need to demonstrate to governments that it will be unaffordable to continue with drought relief in the future. It is already putting a huge burden on budgets, thus requiring a shift to risk management approaches in both the discourse and through specific funded actions. A 'low-hanging fruit' in this regard would be to choose mitigating actions that have immediate co-benefits beyond drought risk management and that would be beneficial with or without droughts. There is a need for more research to identify such socio-economic co-benefits of drought risk management strategies and approaches and for more evidence-based advocacy on this issue.

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For more information, please contact:

Integrated Drought Management Programme Technical Support Unit
World Meteorological Organization and Global Water Partnership
7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland
Tel: +41 (0) 22 730 83 05, Fax: +41 (0) 22 730 80 42
Email: idmp@wmo.int

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Green Ink (www.greenink.co.uk)