DROUGHT RISK REDUCTION IN INTEGRATED WATER RESOURCES MANAGEMENT

Cap-Net

Global Water Partnership

IDMP
Integrated Drought Management Programme

WORLD METEOROLOGICAL ORGANIZATION

Cover photo: Andrés Callizaya Barrientos – Second place at Cap-Net photo & art contest 2020 edition

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Revised by the Integrated Drought Management Programme (IDMP)

Contents

3

4

5

Foreword

Drought risk is a growing threat to many people and economies in both developing and developed countries, although the characteristics may differ considerably across the world. Irrespective of the location of occurrences, droughts are considered the most far-reaching of all natural disasters, causing short- and long-term social, economic and ecological losses as well as significant secondary and tertiary impacts. Drought by itself does not trigger an emergency but rather, whether it becomes an emergency depends on its impact on local people. And that, in turn, depends on their vulnerability to such a 'shock'.

Disasters impede human development and can be life-threatening. Gains in development are inextricably linked to the level of exposure to disaster risk within any given community. In the same light, the level of disaster risk prevalent in a community is linked to the developmental choices exerted by that community. The magnitude of drought and number of people affected are increasing, with extreme effects on poor countries and poor communities. Ironically, the most affected countries lack sufficient capacity to reduce risk to a desired level.

To reduce societal vulnerability to droughts, a paradigm shift of drought management approaches is required to overcome the prevailing structures of reactive, post-hazard management and move towards proactive, risk-based approaches of disaster management. Risk-based drought management is, however, multifaceted and requires the involvement of a variety of stakeholders, and, from a drought management policy perspective, capacities in diverse ministries and national institutions are needed.

The issue of people's vulnerability and capacity in the context of drought hazards is very important in understanding the potential impact and making choices about management and development interventions. Vulnerability results from people's *exposure* to hazards and their *susceptibility* to hazard impacts. It reflects social, economic, political, psychological and environmental variables, shaped by dynamic pressures (such as urbanisation, land use planning) that are linked to the national and political economy. The converse of vulnerability is *capacity* to *anticipate*, *cope* with, *resist* and *recover* from hazard impacts. These capacities may be realised through collective action within a favourable institutional framework.

Drought risk management (DRM) therefore is the concept and practice to avoid, lessen or transfer the adverse effects of drought hazards and the potential impacts of drought disaster through activities and measures for prevention, mitigation and preparedness. It is a systematic process of using administrative directives, organizations and operational skills and capacities to implement strategies, and policies and improve coping capacities. Action to reduce risks from drought must be at the centre of development policy, and that includes water resources management and development.

In recognition of the multiplicity of drought challenges in the context of water resources management, Cap-Net UNDP and its affiliated networks are focusing on capacity development for resilience and mitigating immediate risks and impacts of drought to water resources. Integrated approaches to water resources management offer some opportunities for managing the risk of drought by reducing exposure and vulnerability to droughts by replacing old uncoordinated sectoral regulation of water and a heavy dependence on technology to supply water and alter the water system for the benefit of humankind.

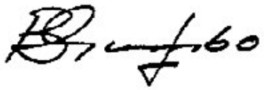
Cap-Net has for a number of years engaged in capacity development and knowledge-sharing practices through regional and national networks, supported by global knowledge partners. Cap-Net's years of experience in capacity development suggest that knowledge and innovation may be the key to designing sustainable developmental initiatives, and that include drought resilience. Understanding drought phenomena and communities; their ability to play with the variable and changing climate conditions; their changing needs and the like requires continuous learning and sharing at all levels in the development space.

This manual is primarily for learners, trainers and facilitators, practitioners, and water and natural resources managers, and is aimed at strengthening the capacity to anticipate and reduce the impact of drought by enhancing knowledge and skills for drought risk reduction practices as an integral part of the development process at community, national, sub-regional and regional levels. More specifically to:

i. Create greater awareness about effective drought risk management and responses
ii. Provide comprehensive knowledge on drought disaster preparedness, mitigation and rehabilitation
iii. Enable learners to carry out risk assessment and vulnerability analysis
iv. Generate awareness of the institutional mechanism, mobilization and participation in drought disaster management.

The approach emphasizes an improved understanding of both the natural hazard and human exposure to this climatic extreme. The different elements of drought risk management enjoy attention, and how these different elements contribute to understanding and better management of drought risk is explained.

When using this manual, considerable attention to practical examples, situation and realities on the ground is advisable in order to successfully link and illustrate terms, concepts and processes.



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Cover photo: Andrés Callizaya Barrientos, Second Best Picture - Cap-Net Photo Competition “Visualising water knowledge” 2020.

Glossary

Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014).
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, take advantage of opportunities or respond to consequences (IPCC, 2014).
Aquifer	Underground, interconnected layers of permeable rock, sediment or soil filled with water where it either stored or flows through them. The two major types of aquifers are confined and unconfined (GWP, 2017).
Aridity	Characteristic of a climate relating to insufficiency or inadequacy of precipitation to maintain vegetation. Aridity is measured by comparing long-term average water supply (precipitation) to long-term average water demand (evapotranspiration). If demand is greater than supply, on average, then the climate is 'arid' (NOAA NCEI, 2019; WMO, 1992).
Available groundwater resource	Volume of water stored in an aquifer that is available for extraction and use (WMO-UNESCO). It is calculated as the difference between the long-term annual average rate of groundwater recharge and the long-term annual rate of flow required to maintain the ecological quality of surface waters recharged by groundwater (EC, 2000; WMO and UNESCO, 2012).
Basin (catchment or watershed)	An area with a common outlet for its surface runoff (WMO and UNESCO, 2012).
Climate change	A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).
Crop failure	Abnormal reductions in crop yield such that it is insufficient to meet the nutritional or economic needs of the community (EM-DAT, 2017).
Desalination	Water desalination: removal of salt from sea or brackish water. It is achieved by various methods, such as distillation, reverse osmosis, hyperfiltration, electrodialysis, ion exchange and solar evaporation followed by condensation of water vapour. Soil desalination: removal of salt from soil by artificial means, usually leaching (FAO, 2017).
Desertification	Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 2019).
Disaster	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts (UNISDR, 2017).

Disaster risk	The potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (UNISDR 2017).
Disaster risk management (DRM)	Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (UNISDR, 2017).
Disaster risk reduction (DRR)	Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience, and therefore, to the achievement of sustainable development (UNISDR, 2017).
Drainage	Removal of surface water or groundwater from a given area by natural or artificial means (WMO and UNESCO, 2012).
Drought	(1) Prolonged absence or marked deficiency of precipitation. (2) Period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance (WMO, 1992).
Drought assessment	Assessment that reviews drought conditions and indicates potential impacts for various economic sectors, such as agriculture and forestry (NOAA NWS, 2017).
Drought forecast	The statistical estimate of the probability of occurrence of a future drought event (GWP CEE, 2015).
Drought impact	A specific effect of drought on the economy, society and/or environment, which is a symptom of vulnerability (GWP CEE, 2015).
Drought impact assessment	The process of assessing the magnitude and distribution of the effects of a drought (GWP CEE, 2015).
Drought index	Computed numerical representations of drought severity assessed using climatic or hydro-meteorological inputs, including precipitation, temperature, streamflow, groundwater and reservoir levels, soil moisture and snowpack. They aim to measure the qualitative status of drought on the landscape for a given time period. Indices are also technically indicators (WMO and GWP, 2016).
Drought indicator	Variables or parameters used to describe drought conditions. Examples include precipitation, temperature, streamflow, groundwater and reservoir levels, soil moisture and snowpack (WMO and GWP, 2016).
Drought management plan	A planning tool that can be applied to basin or other scales. It aims to define mechanisms and a methodology for detecting and predicting droughts, establish thresholds for different stages of drought as it intensifies and recedes, define measures to achieve specific objectives in each drought stage, and ensure transparency and public participation in the development of drought strategies. The main objective of drought management plans are to minimize the adverse impacts of drought on the economy, social life and environment (GWP CEE, 2015).

Drought vulnerability assessment	A drought vulnerability quantification and description that identifies the relevant factors influencing drought from the point of view of exposure, sensitivity and adaptive capacity. The final aim of a drought vulnerability assessment is to identify the underlying sources of drought impact (Urquijo et al., 2015).
Dry spell	Period of abnormally dry weather. Use of the term should be confined to conditions less severe than those of a drought (WMO, 1992).
Early warning (EW)	The provision of timely and effective information through identified institutions that allows stakeholders at risk of a disaster to take action to avoid or reduce their risk and prepare for effective response (GWP CEE, 2015).
Early warning system (EWS)	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss (IPCC, 2014).
El Niño	The large-scale ocean-atmosphere climate phenomenon linked to a periodic warming in sea surface temperatures across the central and east-central equatorial Pacific (between approximately the date line and 120W). El Niño represents the warm phase of the El Niño/Southern Oscillation (ENSO) cycle, and is sometimes referred to as a Pacific warm episode. El Niño originally referred to an annual warming of sea surface temperatures along the west coast of tropical South America (CPC NWS, 2018).
El Niño Southern Oscillation (ENSO)	The coherent and sometimes very strong year-to-year variations in sea surface temperatures, convective rainfall, surface air pressure and atmospheric circulation that occur across the equatorial Pacific Ocean. El Niño and La Niña represent opposite extremes in the ENSO cycle (CPC NWS, 2018).
Erosion	Wearing away and transport of soil and rock by running water, glaciers, wind or waves (WMO and UNESCO, 2012).
Evapotranspiration (eT)	The combined processes by which water is transferred from the Earth's surface to the atmosphere by evaporation from the land and ocean surfaces as well as by transpiration from vegetation (WMO, 1992).
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (UNISDR, 2017).
Famine	Famine exists in areas where at least one in five households has an extreme lack of food and other basic needs. Extreme hunger and destitution is evident. Significant mortality, directly attributable to outright starvation or to the interaction of malnutrition and disease, is occurring (IPC, 2016).
Food security	People are considered food secure when they always have availability and adequate access to sufficient, safe, nutritious food to maintain a healthy and active life. It is comprised of three main elements: food availability, food access and food utilization (FAO, 2009).

Groundwater	Water within the earth that supplies wells and springs; water in the zone of saturation where all openings in rocks and soil are filled, the upper surface of which forms the water table (NOAA NWS, 2017).
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic or 'human-induced' hazards, are induced entirely or predominantly by human activities and choices. Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability (UNISDR, 2017).
Integrated water resources management (IWRM)	A process that promotes the coordinated development and management of water, land and related resources to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000).
Land degradation	Reduction or loss in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation (UNCCD, 2019).
Land use	Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term 'land use' is also used in the sense of the social and economic purposes for which land is managed (e.g. grazing, timber extraction and conservation) (IPCC, 2014).
La Niña	La Niña refers to the periodic cooling of sea surface temperatures in the central and east-central equatorial Pacific that occurs every three to five years or so. La Niña represents the cool phase of the El Niño/Southern Oscillation (ENSO) cycle, and it is sometimes referred to as a Pacific cold episode. La Niña originally referred to an annual cooling of ocean waters off the west coast of Peru and Ecuador (CPC NWS, 2018).
Mitigation	Mitigation (of disaster risk and disaster): The lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure and vulnerability (IPCC, 2012). Mitigation (of climate change): A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2012).
Monsoon	Seasonal change of wind direction, from sea to land or vice versa, associated with widespread changes in temperature and rainfall in subtropical regions (WMO and UNESCO, 2012).
Preparedness	The knowledge and capacities developed by governments, response and recovery organisations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters (UNISDR, 2017).

Prevention	Activities and measures to avoid existing and new disaster risks. Prevention (i.e. disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts of hazardous events. While certain disaster risks cannot be eliminated, prevention aims at reducing vulnerability and exposure in such contexts where the risk of disaster is removed as a result (UNISDR, 2017).
Proactive approach to drought management	A proactive approach to drought risk management includes appropriate measures being designed in advance, with related planning tools and stakeholder participation. The proactive approach is based on both short-term and long-term measures and includes monitoring systems for a timely warning of drought conditions, the identification of the most vulnerable in a population and tailored measures to mitigate drought risk and improve preparedness. The proactive approach entails the planning of necessary measures to prevent or minimize drought impacts in advance. This approach is reflected in the three pillars of integrated drought management (Vogt et al., 2018).
Reactive approach to drought management	A reactive approach to drought management is based on crisis management; it includes measures and actions after a drought event has started and is perceived. This is the approach taken in emergency situations and often results in inefficient technical and economic solution because actions are taken with little time to evaluate best options and stakeholder participation is very limited. This approach has often been uncoordinated and untimely. In addition, crisis management places little attention on trying to reduce drought impacts caused by future drought events (Vogt et al., 2018).
Recovery	The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and 'build back better' to avoid or reduce future disaster risk (UNISDR, 2017).
Reservoir	Body of water, either natural or human-made, used for storage, regulation and control of water resources (WMO and UNESCO, 2012).
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).
Response	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Disaster response is predominantly focused on immediate and short-term needs and is sometimes called 'disaster relief' (UNISDR, 2017).
Runoff	The part of precipitation that flows towards a river on the ground surface (surface runoff) or within the soil (subsurface runoff or interflow) (WMO and UNESCO, 2012).
Soil degradation	The decline in soil quality caused by natural processes, or more commonly, improper use by humans, resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries (FAO, 2017).

Soil moisture	Moisture contained in the portion of soil that lies above the water table, including water vapour contained in the soil pores. Sometimes it refers strictly to the humidity contained in the root zone of the plants (WMO, 1992).
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (UNFCCC, 2019).
Water consumption	Water abstracted that is no longer available for use because it has evaporated, transpired, been incorporated into products and crops, consumed by humans or livestock, ejected directly into sea, or otherwise removed from freshwater resources. Water losses during transport of water between points of abstractions or use are excluded (EEA, 2017).
Water demand	Quantities of water scheduled for delivery to consumers during specified periods for identified uses at given prices (WMO and UNESCO, 2012).
Water governance	The political, administrative, economic and social systems that exist to manage water resources and services. They are essential for sustainable water resource management and providing access to water services for domestic or productive purposes (GWP, 2017).
Water scarcity	An imbalance between supply and demand of freshwater in a specified domain (country, region, catchment, river basin, etc.) as a result of a high rate of demand compared with available supply under prevailing institutional arrangements (including price) and infrastructural conditions (FAO, 2012).
Water security	The availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies (GWP, 2017).
Water shortage	(1) A shortage of water supply of an acceptable quality. (2) Low levels of water supply, at a given place and a given time, relative to design supply levels. The shortage may arise from climatic factors, or other causes of insufficient water resources, a lack of or poorly maintained infrastructure, or a range of other hydrological or hydro-geological factors (FAO, 2012).
Water stress	The symptoms of water scarcity or shortage, such as widespread, frequent and serious restrictions on use, growing conflict between users and competition for water, declining standards of reliability and service, harvest failures and food insecurity (FAO, 2012).
Water supply	The share of water abstraction that is supplied to users (excluding losses in storage, conveyance and distribution) (GWP, 2017).
Water withdrawal	Extraction of water from a surface reservoir or an aquifer (WMO and UNESCO, 2012).
Weather	State of the atmosphere at a particular time, as defined by the various meteorological elements (WMO, 1992).

1 Introduction to integrated drought management

1.1 An introduction to droughts

Drought is often referred to as the most complex and severe weather-related natural hazard due to its intrinsic nature and wide-ranging and cascading impacts. While drought impacts result in severe economic losses, environmental damage and human suffering, they are generally less visible than the impacts of other natural hazards (e.g. floods and storms) due to their non-structural nature. Drought affects a wide range of sectors, such as agricultural production, public water supply, energy production, transportation, tourism, human health, biodiversity, natural ecosystems, etc., and a single drought can last from a few weeks to several years. Drought-related impacts develop slowly, are often indirect and can linger long after the end of the drought. Therefore, drought risk is often miscalculated and remains a 'hidden' hazard (UNDRR, 2019).

Droughts have become more frequent and intense in many regions of the world since the 1970s, and projections show that drought is likely to become regionally more frequent and severe in the 21 Century (IPCC, 2018). It is now more important than ever to better understand the physical processes leading to drought, drought propagation, the societal and environmental vulnerability to drought and drought impacts. Hence, in order to reduce the risk of disastrous drought effects, it is imperative to adopt proactive risk management strategies (WMO and GWP, 2014).

1.1.1 Drought impacts

Droughts are one of the costliest natural hazards (robust evidence, high agreement) (IPCC, 2019).[1] On average, major droughts reduce per capita gross domestic product (GDP) growth by half a percentage point, and in vulnerable economies, a 50 percent reduction in drought effects could lead to a 20 percent increase in per capita GDP over 30 years (Garrick *et al.*, 2015). Drought also ranks, in monetary terms, as the most destructive disaster affecting agriculture. Drought losses in the agricultural sector of developing countries alone were estimated to equal USD29 billion between 2005 and 2015 (Fig. 1.1) (FAO, 2018). From 1960 to 2013, some 612 recorded drought events affected 2.14 billion people and resulted in 2.19 million deaths (Sena *et al.*, 2014) (Fig. 1.2).

Regional examples of economic impacts of droughts

Here are some examples where drought has economically impacted areas around the world:

- In the **Horn of Africa** region, the 2015–2018 drought event forced more than 15 million people to seek urgent food assistance by early 2018. This food security crisis prompted financial commitments by the European Commission of more than EUR300 million for humanitarian aid (Reliefweb, 2018).
- Between 2011 and 2016, a drought event in **California** triggered economic losses of more than USD5.5 billion in the agriculture sector alone (Howitt *et al.*, 2014; Medellín-Azuara *et al.*, 2016).
- In **Asia and the Pacific**, droughts affecting 1.62 billion people between 1970 and 2014 have been associated with USD53 billion in economic losses (Ebi and Bowen, 2016).

Usually, these estimates are methodically restricted to capture only direct and on-site costs of droughts and, therefore, account for only some of the drought impacts. However, droughts also have wide-ranging

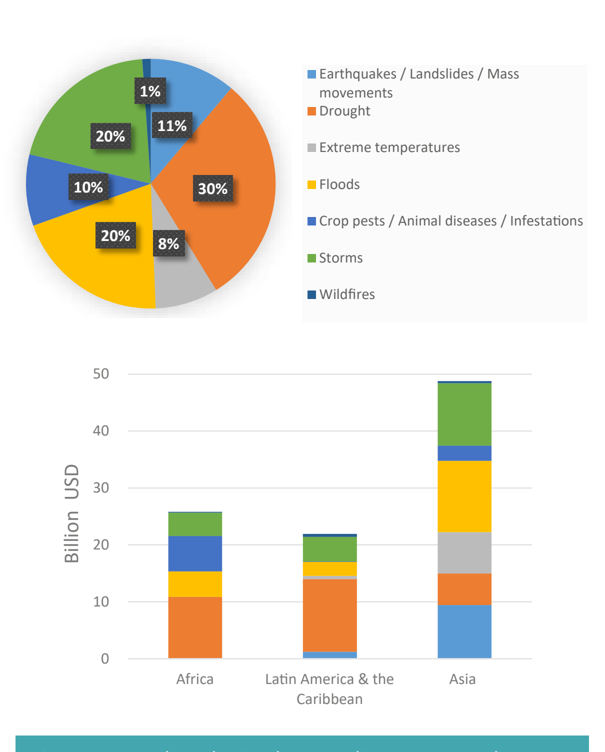

Figure 1.1. Total production loss per disaster type and production loss by region and per disaster in USD billion, 2005–2015. Source: FAO (2018).

secondary and off-site impacts, which are rarely quantified. These indirect impacts are both biophysical and socio-economic, with poor households and communities being particularly impacted (Winsemius *et al.*, 2018). Indirect socio-economic impacts of droughts are related to food insecurity, poverty, lowered health and displacement (FAO, 2018; IPCC, 2019). In addition to water quantity, droughts impact water quality, as the intensified use of scarce water sources during drought periods increases the likelihood of contamination (FAO, 2018).

1 Guidance on IPCC terminology used to describe uncertainty is provided in Mastrandrea et al. (2010).

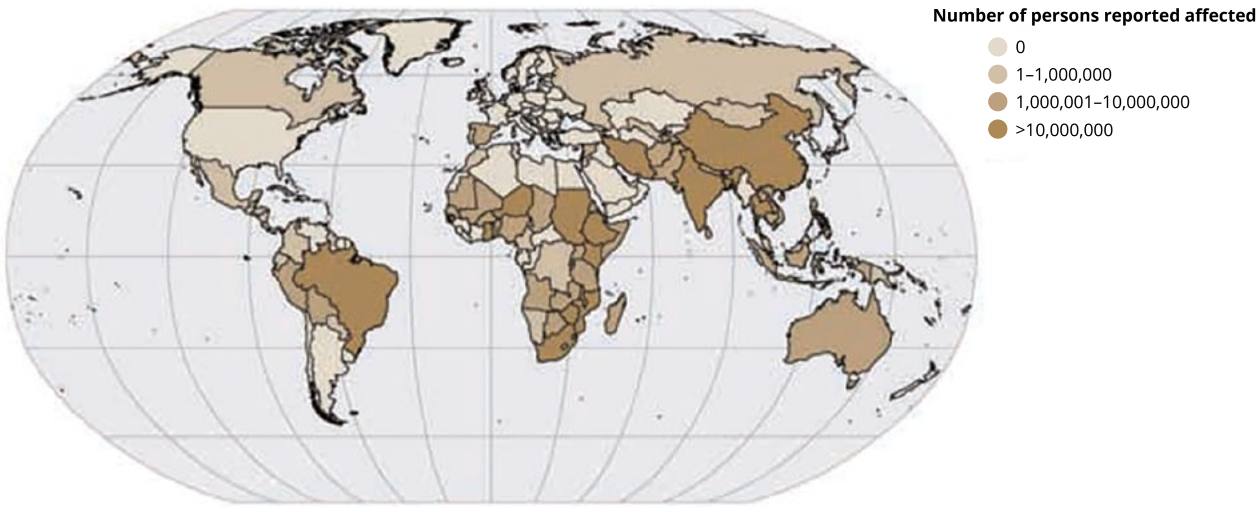

Figure 1.2. Number of people affected by droughts globally, 1970–2008. Source: UNISDR (2009).

1.1.2 Drought – definition and characteristics

Drought is a natural hazard that is highly dependent on the climatological context of a region. Therefore, it is often referred to as a complex phenomenon, rendering a clear definition of drought a challenge. Drought can be defined as (1) a prolonged absence or marked deficiency of precipitation and (2) a period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance (WMO, 1992). Another commonly used definition for drought is, "A deficiency of precipitation from expected or 'normal' over a season or longer period of time that results in insufficient water to meet the demands of human activities and the environment" (Wilhite *et al.*, 2014).

Droughts are a recurring, normal part of climatological conditions and are defined with respect to the long-term average climate of a given region. They should be distinguished from **aridity**, which relates to insufficiency or inadequacy of precipitation to maintain vegetation (WMO, 1992). Aridity is measured by comparing long-term average water supply (precipitation) to long-term average water demand (evapotranspiration). If, on average, demand is greater than supply, then the climate is considered arid (NOAA NCEI, 2019). Drought must also be distinguished from **water scarcity**, which is an imbalance between supply and demand of freshwater in a specified domain (country, region, catchment, river basin, etc.) caused by a high rate of demand versus available supply under prevailing institutional arrangements (including price) and infrastructural conditions (FAO, 2012). **Desertification** must also be distinguished from drought, as land degradation in arid, semi-arid and dry sub-humid areas results from various factors, including climatic variations and human activities (Fig. 1.3).

So-called 'flash droughts' are short periods (less than three months) of high temperatures and concurring anomalously low and rapidly decreasing soil moisture that can lead to major impacts (Mo and Lettenmaier, 2016).

There are four essential characteristics of any drought: **severity, location, duration** and **timing** (WMO and GWP, 2016). Monitoring and forecasting these

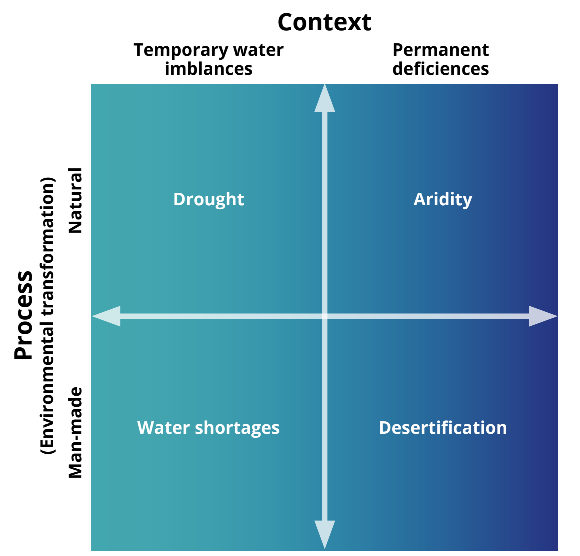

Figure 1.3. Schematic representation of different types of water shortage as defined by the temporal context and the driving force (process). Source: UNCCD (2019); Vlachos (1982).

characteristics, as well as arising impacts, is an integral part of proactive drought management. The impacts of droughts can be as varied as their causes, ranging from agriculture and food security to hydropower generation and industry, human and animal health, livelihood and personal security and access to education. Drought severity can be determined using climatological drought indices, which compare current conditions to the long-term average. The timing of a drought may be as significant as its severity. For example, during the critical moisture-sensitive period of a crop cycle, a short and relatively low-severity drought may have a higher impact on crop yield than a high-severity drought out of growing season. The type of impacts relevant to a particular drought monitoring and early warning context is often a crucial consideration in determining the selection of drought indicators. This formulation is much broader, flexible and less confusing than strictly defining different types of drought (i.e. meteorological, agricultural, hydrological, etc.) (WMO and GWP, 2016). Drought characteristics are described by one or multiple indices or indicators, which are used in the monitoring and identification of droughts and should be used to trigger action in managing drought risk (see chapter 2).

A drought creates a complex series of impacts that often follow long after the event itself has abated. Hence, a proactive approach to drought management is reliant on a more granular understanding of all stages of a drought event – a drought lifecycle – in order to put suitable measures in place. Such a holistic approach raises the need to delineate the **onset and termination of a drought**. For example, how long does precipitation deficiency have to persist to generate a drought? In humid areas, this may be a matter of days, whereas in arid and semi-arid regions, this could be several weeks due to the adaptation of the ecosystem and humans to dry conditions. In some cases, monsoon seasons can be delayed, and while the overall seasonal rainfall total may not indicate a drought, agricultural operations can be disrupted. The same issues arise when looking at the termination of drought conditions or the separation of subsequent drought events. In order to elucidate the concepts of a 'drought event', 'drought onset' and 'drought demise', Mo (2011) developed a drought lifecycle approach using monthly soil potential index and soil moisture values. Mo (2011) described a drought event as the period of time when the index falls below the drought threshold for a specified duration, which in this case is more than three months. Drought onset commences in the month when the index falls below the drought threshold, and the drought demise begins the month when the index first rises above the threshold. A schematic of a drought life cycle (Fig. 1.4) illustrates the concept (Howard *et al.*, in preparation).

Ultimately, the efforts to characterize a 'drought life cycle' are essential for increasing the temporal understanding of the hazard and to improve the linkage between drought stages and politically driven preparedness, mitigation and response actions (see chapter 2 for monitoring and early warning and chapter 4 for mitigation, preparedness and response actions).

1.1.3 Meteorological causes for droughts

Because of the importance of precipitation in defining droughts and their characteristics, it is important to describe the conditions that result in periods of reduced precipitation. While precipitation occurs where there are moist, low pressure air systems, the opposite occurs with dry, high pressure systems. Reduced precipitation (in relation to a defined average) occurs when anomalies in the global oceanic-atmospheric circulation system coincide with high atmospheric pressure systems and inhibit cloud formation. This interannual variability of circulation is controlled particularly through **remote sea surface temperature (SST) forcings**, such as the Inter-decadal Pacific Oscillation, the Atlantic Multi-decadal Oscillation, El Niño/Southern Oscillation (ENSO) and Indian Ocean Dipole, that cause drought as a result of reduced rainfall (IPCC, 2019).

The ENSO is arguably the weather phenomenon with the strongest fluctuations associated with global climate disasters, including droughts. The 'Southern Oscillation' refers to (1) the variation in the SSTs in the tropical eastern Pacific Ocean, with warming referred to as El Niño and cooling La Niña, and (2) variation in air surface pressure in the tropical western Pacific. High surface pressure with warming in the western Pacific leads to El Niño conditions, while cold conditions under low surface pressure in the western Pacific causes La Niña conditions. Surface air temperature anomalies affect the weather in many parts of the world (Fig. 1.5). For example, drought can occur virtually anywhere during an ENSO event, and strong correlations were found between ENSO and intense drought in Australia, India, Indonesia, the Philippines, Brazil, parts of east and southern Africa, the western Pacific basin islands (including Hawaii), Central America and various parts of the USA (Ropelewski and Halpert, 1987).

In many regions of the world, however, large-scale SST modes do not fully explain the severity of drought.

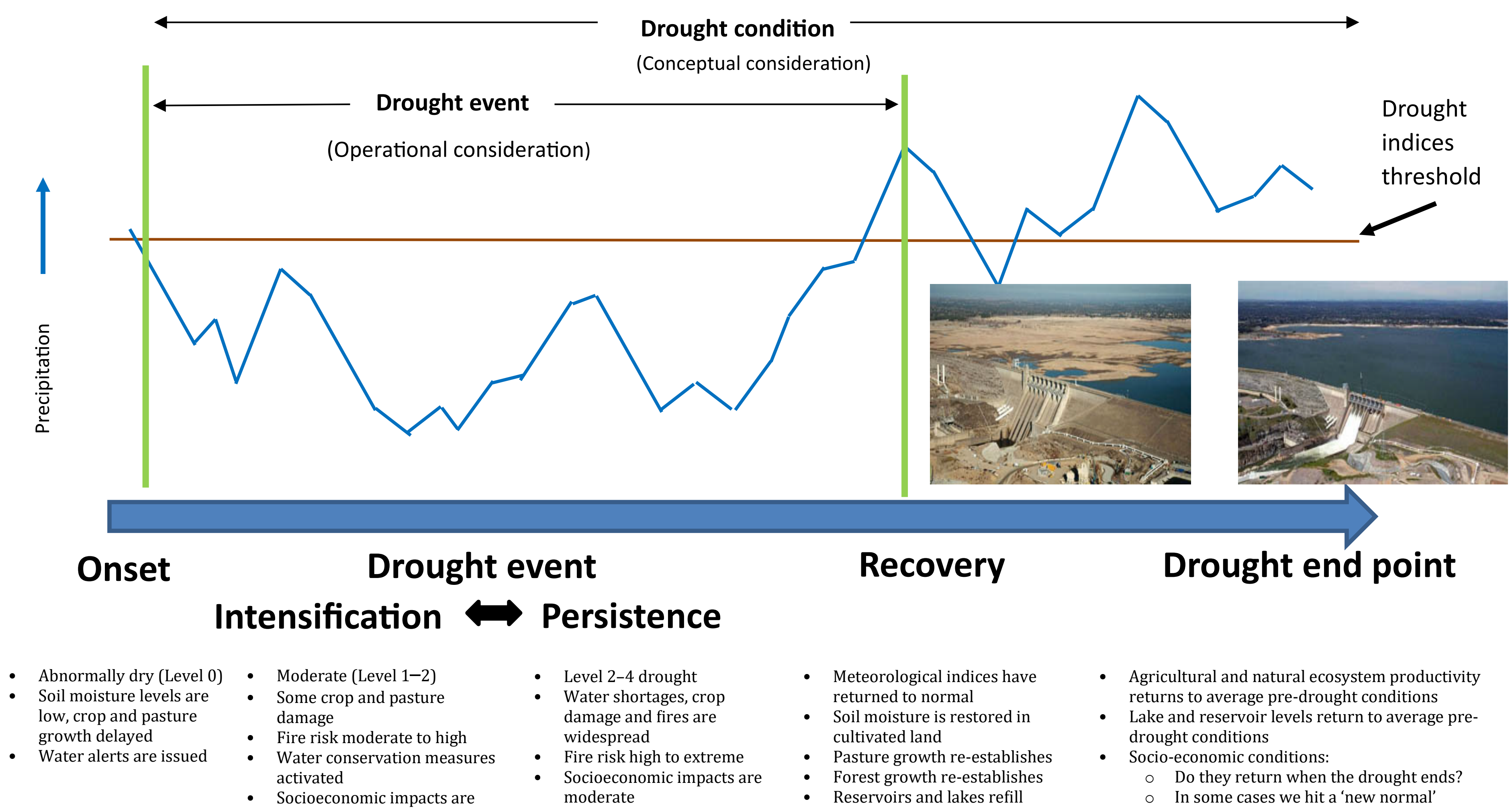

Figure 1.4. Schematic illustration of a drought lifecycle. Source: Howard *et al.* (in preparation).

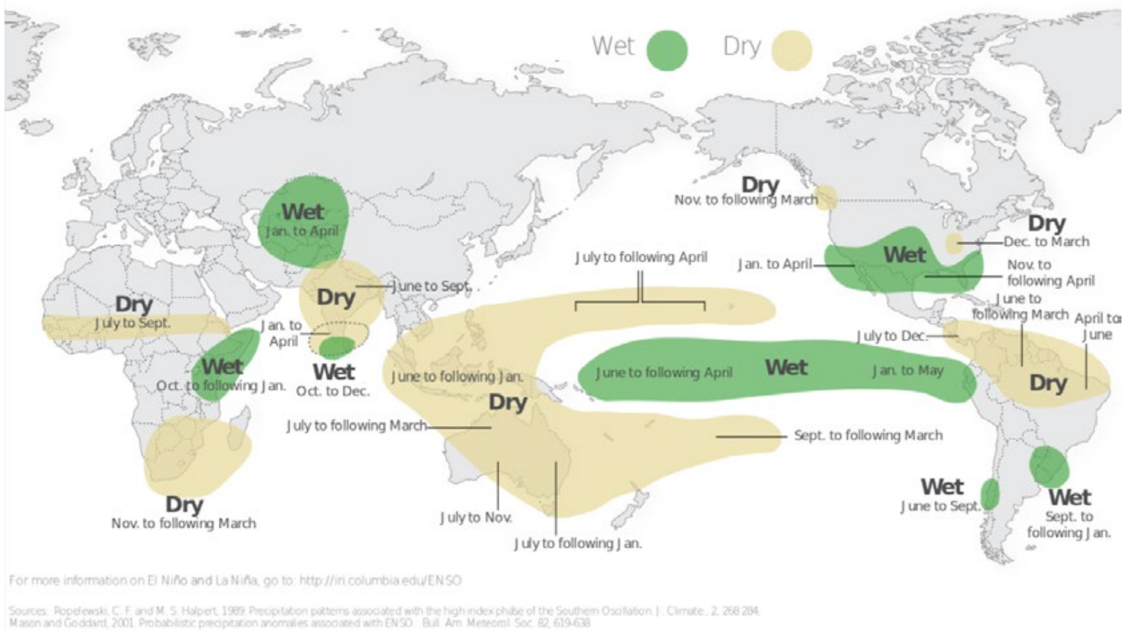

Figure 1.5. Commonly observed shifts in rainfall patterns caused by El Niño conditions in the southern Pacific. Source: https://www.climate.gov/sites/default/files/IRI_ENSOimpactsmap_lrg.png (accessed 14 October 2019).

Recently, a number of event attribution studies have identified a climate change fingerprint in several regional droughts, e.g. the western Amazon, southern and northern Africa, southern Europe and the Mediterranean, parts of North America, Russia, India and Australia (IPCC, 2019).

1.1.4 Impacts of drought and climate change

Droughts are predicted to worsen and occur at higher frequencies thanks to human-induced climate change. This means that drought preparedness will have to consider not only earlier observed severity but also increased aggravation of the drought conditions and be flexible to adaption.

To provide policy makers with regular scientific assessments on the current state of knowledge on climate change, the Intergovernmental Panel on Climate Change (IPCC) was created in 1988 as a body of the United Nations. Several assessment reports and special reports feature observations and projections for drought occurrence and have advanced the knowledge base on how climate change impacts ecosystems and society (https://www.ipcc.ch/).

Observed and attributed changes

The general consensus from the IPCC *Fifth Assessment Report* (AR5) is that drought frequency has increased in many parts of the world since the 1970s, partly as a result of increasing global temperatures (IPCC, 2014).

Regional trends in frequency and intensity of drought are evident in several parts of the world, particularly in low latitude land areas, such as the Mediterranean, North Africa and the Middle East, many regions of sub-Saharan Africa, Central China, the southern Amazon, India, east and south Asia, parts of North America and eastern Australia (IPCC, 2014). A recent study in which 4,500 meteorological droughts globally were analysed found increased drought frequency over the US East Coast, Amazonia and north-eastern Brazil, Patagonia, the Mediterranean region, most of Africa and north-eastern China, with decreased drought frequency over northern Argentina, Uruguay and northern Europe (Spinoni *et al.*, 2019). The database of drought events has specific entries for each macro-region and country. In the same study, drought intensity was found to have become more severe over north-western USA, parts of Patagonia and southern Chile, the Sahel, the Congo River basin, southern Europe, north-eastern China and south-eastern Australia, whereas eastern USA, south-eastern Brazil, northern Europe and central-northern Australia experienced less severe droughts.

While the AR5 and post-AR5 studies observed regional trends for drought events (increases in the Mediterranean and West Africa and decreases in central North America and north-west Australia), the IPCC *Special Report on Global Warming of 1.5°C* attributed an increase in droughts in the Mediterranean to human-induced climate change with medium confidence (IPCC, 2018)[2].

2 Guidance on IPCC terminology used to describe uncertainty is provided in Mastrandrea et al. (2010).

In addition, the IPCC *Special Report on Climate Change and Land* further observed, with medium confidence, that an increased frequency and intensity of drought will occur in Amazonia and north-eastern Brazil, Patagonia, most of Africa and north-eastern China (IPCC, 2019).

Projected changes in drought

Projections show medium confidence in increased frequency of droughts during the 21 Century in the Mediterranean, southern Africa and Central America (Fig. 1.6) (IPCC, 2014, 2018; Orlowsky and Seneviratne, 2013). Globally, however, there is overall low confidence in drought trends because of insufficient agreement on projections of drought changes, which are dependent on both a model and a dryness index (IPCC, 2018).

Projected precipitation changes show that precipitation is likely to decrease in subtropical latitudes, particularly the Mediterranean, while other regions will receive higher amounts of precipitation, and global mean precipitation changes show an increase in precipitation with continued global warming. It is important to note, however, that these changes become statistically significant with a global temperature rise of 1.5°C, and model projections of rainfall (an indicator for drought) vary widely, rendering a distinction from recent natural variability difficult (Vogt *et al.*, 2018). There is medium confidence in predictions that monsoon-related interannual rainfall variability will increase in the future. A future increase in precipitation extremes related to the monsoon is likely under low mitigation (IPCC, 2014).

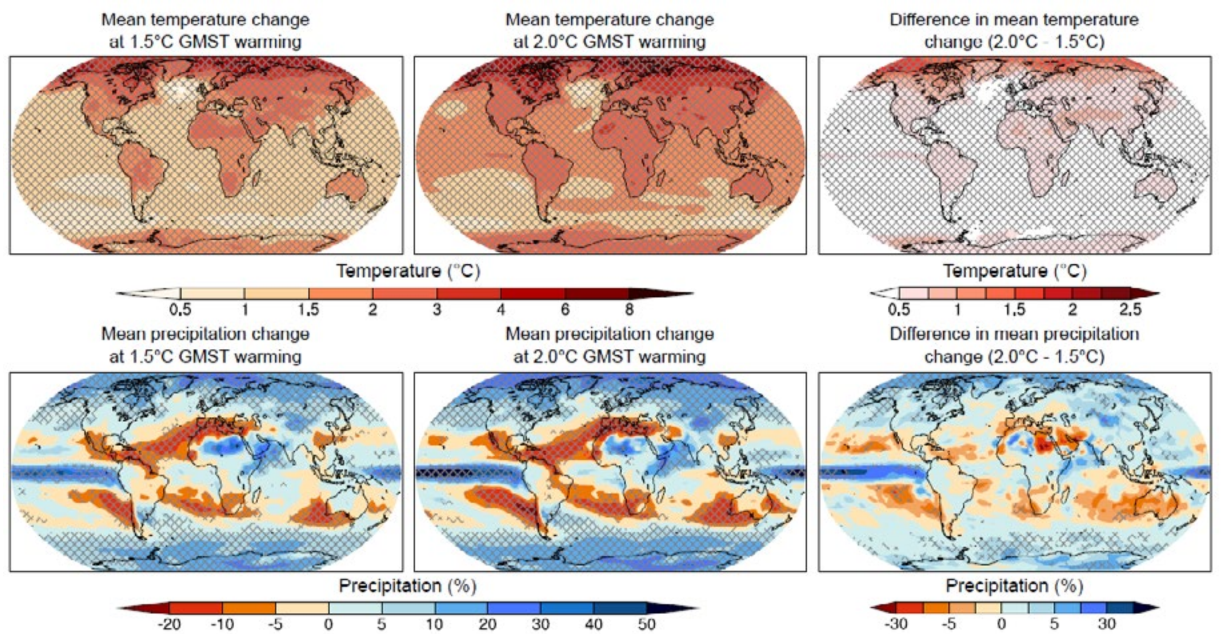

Figure 1.6. Projected changes in mean temperature (top) and mean precipitation (bottom) associated with a rise in surface temperatures of 1.5°C (left) and 2°C (middle), compared to the pre-industrial period (1861–1880), and the difference between the two scenarios (right). Cross-hatching highlights areas where at least two thirds of the models agree on the sign of change as a measure of robustness (18 or more out of 26). Values were assessed from the transient response over a 10-year period at a given warming level, based on Representative Concentration Pathway (RCP) 8.5 Coupled Model Intercomparison Project Phase 5 (CMIP5) model simulations based on Seneviratne *et al.* (2016) and Wartenburger *et al.* (2017) (IPCC, 2018). GMST = global mean surface temperatures.

Since climate change is increasing the likelihood of more drought events, the traditional view of drought as an episodic and rare event where future frequency and intensity is informed by historical variability may no longer apply in some regions. In some areas, climate change will foster the transition from experiencing droughts to undergoing encroaching aridity.

1.1.5 Drought risk reduction

The risk equation

Risk entails the combination of the probability of an event and its negative consequences (UNDP, 2011). Drought (disaster) risk refers to the potential loss of life, injury or destroyed or damaged assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (UNISDR, 2017). The level of drought disaster risk is defined as a function of the natural hazard, the exposed assets and the inherent vulnerability of the exposed social or natural system (Fig. 1.7):

Risk = f (hazard, exposure, vulnerability)

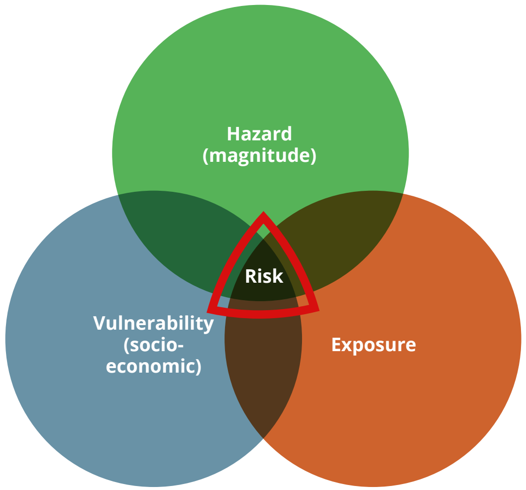

Figure 1.7. The risk equation

Considering that communities have little control over the occurrence of hazards (although they can be monitored and forecasted to a certain level [see chapter 2]) or exposure to hazards, the focus of development actors in drought risk reduction should be directed to finding ways to reduce the degree of vulnerability and increase the level of resilience.

Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, community, assets or systems to the impacts of hazards (UNISDR, 2017). Vulnerability is an encompassing composite term. It illustrates, for example, the capacity and nature of the resource base to continue to provide ecosystem goods and services during a period of severe rainfall deficit or the degree to which people are directly dependent on the provision of water and other resources necessary for their well-being.

According to this principle, many people exposed to a moderate drought hazard could be considered at the same risk level as a smaller number of people who live within a region of higher frequency and/or severity of drought hazards. It is difficult to set a standard procedure to examine risk levels because of the slow onset and creeping nature of drought.

Disaster risk reduction is only valuable when we understand the contexts in which people live, the changing environment in which they find themselves and the impact of this environment on their ability to support their livelihoods and absorb the impacts of occurrences such as droughts (see chapter 3).

It is important to note that people living outside the hazard location can still be affected. When a disaster causes large migrations, electric power failure and shortage of medicine, the effects of drought grow larger than its footprint. This should be captured in the vulnerability assessment.

Adaptive capacity

Whether a community is vulnerable or resilient to drought is largely a function of its coping or adaptive capacity. This is generally defined as the ability of people, organisations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity of the community to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks (UNISDR, 2017).

Resilience

It is impossible to circumvent the natural processes of drought hazards or the disruptions or anomalies in the global circulation pattern of the atmosphere. However, it is still possible to prevent drought disasters, mitigate drought impacts and reduce drought risks to human lives and livelihoods by increasing the degree of resilience.

Resilience is generally defined as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017). Proactive drought management approaches aim at increasing resilience to drought effects.

1.2 Water and drought management approaches

1.2.1 Integrated water resources management

A commonly accepted definition of integrated water resources management (IWRM) was coined by the Global Water Partnership (GWP) in 2000 as a process that promotes the coordinated development and management of water, land and related resources to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000).

Integrated approaches to water resources management offer some opportunities for managing the risk of drought by reducing exposure and vulnerability to droughts. Some results from the Consultative Group on International Agricultural Research Challenge Programme on Water for Food (Ncube *et al.*, 2010), for example, illustrate how IWRM reduces risk of crop failure during dry spells because it is a systematic approach to water management based on the principle of managing the full water cycle, including management of blue and green water.[3] Applying the principles of IWRM is expected to lead to better drought risk management.

Integrated approaches to water management have become dominant, replacing old uncoordinated sectoral regulation of water and a heavy dependence on technology to supply water with water systems that benefit humankind.

Four aspects of water management need to be integrated when an IWRM approach is used:

- Integration of water resource management in the broader **development context**
- **Sectoral integration** that considers both different uses of water (including the environment) and water-using sectors
- Integration of the (biophysical) **resource base,** including rain, surface and groundwater as well as green and blue water. An important part of integrating a biophysical water resource is the recognition that water is finite, and thus, improvements in water services and use must come not only from resource development and capture but also from efficiency gains
- **Spatial integration** that incorporates upstream and downstream interlinkages.

Ultimately, the success of water management is evaluated based on whether it sustainably contributes to the societal goals of economic viability, social equity and environmental sustainability.

For further reading, you may refer to other Cap-Net training materials on this topic at: http://www.cap-net.org/training-material.

Many common drought risk management measures are also good water management measures implied in the IWRM. These include:

- water pricing, cost recovery, investment

Table 1.1. Example of integrated river basin management using the IWRM approach during drought conditions

Water is a finite and vulnerable resource	Using participatory evaluation of water allocation regimes under different water availability conditions and putting in place conditional water use licences that depend on water availability can dampen the conflict around water uses during times of stress.
Participatory approach	This calls for the involvement of key stakeholders in the planning cycle, implying engagements of organisations tasked with drought planning and management. Institutions key to drought risk management, such as disaster teams or agencies and others, should be involved in risk preparedness and mitigation.
Role of women	Since the impacts of drought differ between genders, the inclusion of women in capacity-building and water management would lead to more relevant planning and actions. There are many parts of the world where women have direct responsibility for household water security and food security (see also chapter 3)
Social and economic value of water	This principle accepts that water has an economic value and should be priced and allocated as such. In times of drought, appropriate pricing that reflects its short supply can drive behaviour change that reduces wastage by domestic users, agriculture and industry. It also incentivizes the development and adoption of water use efficient technology in the home, in agricultural fields and in industry. However, the same principle states that water is a social good and implies that access to a basic amount of water should be promoted for good health and dignity. This is an important principle to be applied to emergency situations, as it places the burden on the government to protect its citizens.

3 Green water is the water stored in soil that is potentially available for uptake by plants, whereas blue water either runs off into streams and rivers as discharge or percolates below the rooting zone into a groundwater body.

- seasonal water rationing, re-allocation, managing water use
- drought risk mapping, infrastructure, scenario development
- increase capture and storage of surface run off
- reuse and recycle, better regulation, pressure for improved sanitation
- groundwater usage
- rainwater harvesting, warning systems
- improving drainage systems and water treatment
- better monitoring.

1.2.2 Proactive approach to drought management

Despite ongoing efforts and undeniable long-term benefits of a proactive approach to drought management, it is still not a reality in many countries. A recent publication by the World Bank, World Meteorological Organization (WMO) and GWP in the framework of the Integrated Drought Management Programme (IDMP) has analysed the reasons why reactive crisis management is still the most common response to drought and proposed a framework to guide the paradigm shift to forward-looking risk management by highlighting the benefits of action versus the costs of inaction (Venton *et al.*, 2019).

The proactive approach to drought management includes appropriate measures being designed in advance, together with related planning tools and stakeholder participation. The proactive approach is based on both short-term and long-term measures and includes monitoring systems for timely warning of drought conditions, identification of the most vulnerable part of the population and tailored measures to mitigate drought risk and improve preparedness. It involves the planning of necessary measures to prevent or minimize drought impacts in advance. This approach is reflected in the three pillars of integrated drought management (IDM) (see section 1.2.3) (Vogt *et al.*, 2018). It is also reflected in the disaster management cycle, which includes prevention and mitigation, preparedness, response and recovery (Fig. 1.8).

One causational factor for staying in a reactive disaster response mode is the great complexity of the drought phenomenon, its impacts and vulnerability. Understanding drought impacts is an entry point for planning drought risk management. However, many approaches fall short in recognizing the complexity of drought impacts, which can be direct and indirect as well as short- and long-term and affect societies and natural resources as well as the causes of

Box 1.1. The role of biodiversity in drought management, adapted from UNW-DPC (2015)

The key role of biodiversity in drought management is manifested in the ecosystem services (benefits for people) it supports. These play an important role in regulating the water cycle and include how vegetation in the landscape regulates the infiltration of water into soils, stabilizes soils (reducing erosion) and contributes to local climates (including precipitation) through evapotranspiration. For example, agricultural production depends on well-functioning ecosystems and the services they provide, such as the provision of healthy and fertile soils, water, pollination, climate regulation, natural pest management as well as extreme event buffering. Nearly 70 percent of the estimated 1.1 billion people living in poverty in rural areas depend directly on the productivity of ecosystems for their livelihoods (FAO, 2019). Soil biodiversity is particularly important in maintaining soil health, including its ability to maintain soil moisture, without which crops become vulnerable and water is lost from the landscape. Ecosystem degradation, which reduces water-related ecosystem services, is a major contributor to reduced drought resistance, and in many cases, it can trigger drought events (examples include how deforestation or other vegetation loss exacerbates drought and desertification or soil degradation undermines crop water and nutrient availability). Hence, in addition to the co-benefits that biodiversity provides, evidence shows that more biologically diverse landscapes are also more resilient to drought.

Ecosystems are being increasingly considered as 'green' or 'natural' water infrastructures to be managed either as an alternative to, but more usually in conjunction with, built (physical) infrastructure (Coates and Smith, 2012). Ecosystem conservation and restoration have a major role to play in reducing drought vulnerability and risks as well as mitigating impacts of drought. Ecosystem-based adaptation approaches and disaster risk reduction should, therefore, feature prominently in any proactive approach to reducing drought vulnerability and risk, including as a key element of land and water management strategies (CBD, 2019).

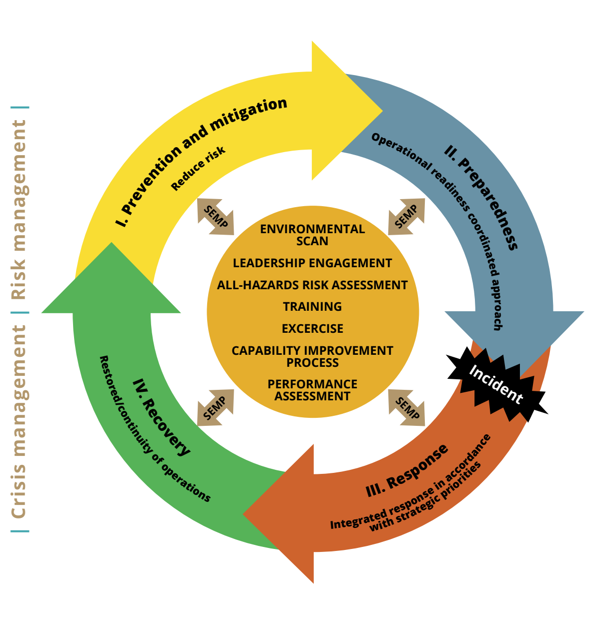

Figure 1.8. Disaster management cycle
SEMP = Strategic Emergency Management Plan.

vulnerability. Second, weaknesses in knowledge, institutions, capacity and political will are hampering the shift to a more proactive approach to disaster risk management. Improvement of monitoring networks to make meteorological data and forecasts more accessible has not always improved drought preparedness, as a lack of preparedness results from the inability of institutions to establish and enact drought preparedness plans and policies at the national and subnational level (Pulwarty and Sivakumar, 2014). Governments are often faced with a political economy that creates weak incentives for a risk management approach, and economic analysis has largely been insufficient to drive a paradigm shift to a risk management approach and greater investment in preventive actions. Therefore, recent research efforts have focused on revealing the benefits of action versus the cost of inaction (Venton *et al.*, 2019).

To move from a reactive, crisis management mode to a risk management approach requires clear policy and institutional capacity. Institutional capacity should be able to provide (Wilhite and Pulwarty, 2018):

- effective monitoring and early warning systems to deliver timely information to decision makers
- effective impact assessment procedures
- proactive risk management measures
- preparedness plans aimed at increasing coping capacity
- effective emergency response programmes directed at reducing the impacts of drought.

1.2.3 Integrated drought management and the three pillars

Historically, drought responses by governments and other organisations have been generally reactive: poorly coordinated, ineffective and untimely. This 'crisis management approach' is associated with the provision of drought relief or assistance in response to a drought event to those most affected. Without a coordinated national drought policy that includes comprehensive monitoring, early warning and information delivery systems, vulnerability and impact assessments, and the identification and adoption of appropriate local-level mitigation and response measures for risk reduction, nations will continue to respond to drought in a reactive, crisis management mode. It is imperative that nations adopt a new paradigm for drought risk management (WMO and GWP, 2014).

As illustrated in Fig. 1.9, to create a successful drought policy aimed at risk reduction, it is vital for policy to emphasize the three pillars of a comprehensive monitoring and early warning system, vulnerability and impact assessment, and mitigation and response. The three-pillar approach requires an emphasis on each pillar, with appropriate linkages and interactions between each one. This manual is structured around the three-pillar approach: monitoring and early warning (chapter 2), vulnerability and impact assessment (chapter 3) and preparedness, mitigation and response (chapter 4). In chapter 5, these pillars of drought management will be synthesized in the context of successful establishment of national drought policies.

Figure 1.9. The interconnected three pillars of effective integrated drought management.

1.3 Overview of relevant international processes

1.3.1 High-Level Meeting on National Drought Policies

A key element of IDM is the development of a national/ regional drought policy. These policies include an effective plan that is intrinsically linked to the development and implementation of preparedness and mitigation plans for the vulnerable population. Having noticed the necessity for concerted action to reduce drought risks on the national level, the WMO, the Secretariat of the United Nations Convention to Combat Desertification (UNCCD) and the Food and Agriculture Organization of the United Nations (FAO), in collaboration with several United Nations agencies, international and regional organisations and key national agencies, organized the High-Level Meeting on National Drought Policy (HMNDP) in Geneva, Switzerland in March 2013. The outcome of the HMNDP was the HMNDP *Policy Document: National Drought Management Policy* (UNCCD *et al.*, 2013). In this document, the goals for a national drought policy were identified as follows:

- Proactive mitigation and planning measures, risk management, public outreach and resource stewardship as key elements of effective national drought policy
- Greater collaboration to enhance the national/ regional/global observation network and information delivery systems to improve public understanding of, and preparedness for, drought
- Incorporation of comprehensive governmental and private insurance and financial strategies into drought preparedness plans
- Recognition of a safety net of emergency relief based on sound stewardship of natural resources and self-help at diverse governance levels
- Coordination of drought programmes and response in an effective, efficient and customer-orientated manner.

1.3.2 Integrated Drought Management Programme

One major outcome of the HMNDP was the establishment of the IDMP by WMO and GWP. With the objective of supporting stakeholders at all levels by providing policy and management guidance, and by sharing scientific information, knowledge, and best practices for an integrated approach to drought management, the IDMP aims to (Pischke and Stefanski, 2016):

- shift the focus from reactive (crisis management) to proactive measures through drought mitigation, vulnerability reduction and preparedness
- integrate the vertical planning and decision-making processes at regional, national and community levels into a multi-stakeholder approach including key sectors, especially agriculture and energy
- promote the evolution of the drought knowledge base and establish a mechanism for sharing knowledge and providing services to stakeholders across sectors at all levelsbuild capacity of various stakeholders at different levels.

Based on the HMNDP and subsequent work with IDMP partners, three pillars of drought management have been adopted: (1) drought monitoring and early warning systems; (2) vulnerability and impact assessment; and (3) drought preparedness, mitigation and response (www.droughtmanagement.info).

To date, more than 35 organisations are IDMP partners, and they have agreed to support and provide input to the goals of the IDMP. The IDMP also uses the network of the National Meteorological and Hydrological Services, which are members of WMO, the United Nations specialized agency for weather, climate and water. Also, the IDMP involves regional and country water GWP partnerships as the multi-stakeholder platform to bring together actors from government, civil society, the private sector and academia working on water resources management, agriculture and energy. There are three IDMP regional projects that are supported by GWP: central and eastern Europe, West Africa and East Africa. In addition, the IDMP liaises with related initiatives that are not formally part of IDMP but contribute to WMO and the GWP.

1.3.3 Sustainable Development Goals

In September 2015, a United Nations summit adopted the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, which officially came into force in January 2016. The SDGs are built on the success of the Millennium Development Goals and aim to go further on many issues. The SDGs are unique, since they call for action by all countries, poor, rich and middle-income, to promote prosperity while protecting the planet. They recognize that ending poverty must be addressed with strategies that build economic growth and focus on a range of social needs, including education, health, social protection and job opportunities, while tackling climate change and environmental protection (UN, 2015).

The cross-cutting nature of water management in the context of disaster risk reduction is also reflected in the SDGs, where an integrated approach to addressing climatic extremes is featured throughout but particularly in the targets under the goals of ending poverty, achieving food security, water management, human settlements, climate change and land degradation. The SDGs cover a wide scope of issues, and there are about eight SDGs (1, 2, 6, 9, 11, 13, 15 and 17; Fig. 1.10) that are relevant to drought issues.

1.3.4 The United Nations Framework Convention on Climate Change and the Paris Agreement on climate change

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force on 21 March 1994. Currently, there are 197 countries that have ratified the convention. At the UNFCCC 21st Conference of the Parties (COP21) in Paris on 12 December 2015, parties of the UNFCCC reached a landmark agreement to combat climate change and accelerate and intensify the actions and investments needed for a sustainable, low-carbon future. The aim of the Paris Agreement is to limit global temperature increase during this century to well below 2˚C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5˚C. The Paris Agreement also aims to increase the ability of countries to address the impacts of climate change through adaptation. The Nationally Determined Contributions (NDCs), which are country commitments on mitigation and voluntarily adaptation, were established as a formal mechanism of the international climate action architecture for the ratification of the Paris Agreement.

In 2010, the UNFCCC established the process for countries to develop National Adaptation Plans (NAPs) as a means of identifying adaptation needs and developing and implementing strategies and programmes to address those needs. The objectives of NAPs, as defined by the COP17 to the UNFCCC (UNFCCC, 2012), are to:

- reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience
- facilitate the integration of climate change adaptation into relevant new and existing policies, programmes and activities, particularly in development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

Figure 1.10. All 17 SDGs, with those highlighted relevant to drought issues.

It is worth noting that drought and higher temperatures are among the key climate hazards identified by the UNFCCC parties as part of their NDCs (Fig. 1.11), as they often occur together. In addition, the most vulnerable sectors referred to by the parties were water, agriculture, biodiversity and health.

1.3.5 Sendai Framework for Disaster Risk Reduction

The *Sendai Framework for Disaster Risk Reduction 2015–2030* is the successor instrument to the *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations*

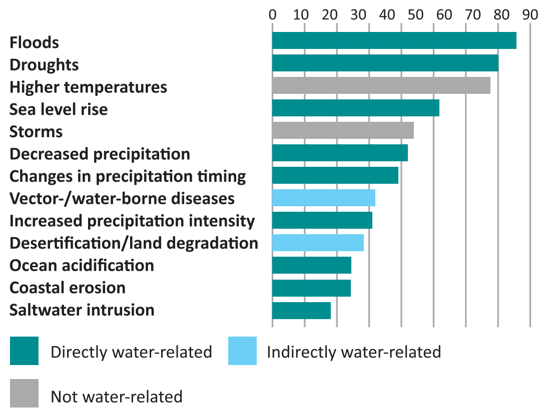

Figure 1.11. Key climate hazards identified in the adaption components of NDCs. Source: UNFCCC (2016).

and Communities to Disasters. The Sendai Framework is a voluntary, non-binding agreement that recognizes that country governments are primarily responsible for reducing disaster risk but that responsibility should be shared with local governments, the private sector and other stakeholders.

Under the Sendai Framework, four priorities actions were identified to reduce disaster-risk:

- Understanding disaster risk
- Strengthening disaster risk governance to manage disaster risk
- Investing in disaster risk reduction for resilience
- Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction.

An overview of the Sendai Framework is available at https://www.unisdr.org/we/inform/publications/44983.

Exercise: Describe how each of the four priority areas of the Sendai Framework for Disaster Risk Reduction relate to an integrated approach to drought management

1.3.6 The United Nations Convention to Combat Desertification

The UNCCD was established in 1994 and is the sole legally binding international agreement linking environment and development to sustainable land management. The full title of the convention as ratified is the *United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa.*

The UNCCD specifically addresses the arid, semi-arid and dry sub-humid areas, known as 'the drylands', where some of the most vulnerable ecosystems and peoples can be found. The UNCCD's 197 parties are committed to working together to improve the living conditions for people in the drylands, to maintain and restore land and soil productivity and to mitigate the effects of drought (UN, 1994). In 2017, at the UNCCD COP13, the parties agreed to implement the Drought Initiative, which acted on drought preparedness systems, regional efforts to reduce drought vulnerability and risk, and a toolbox to boost the resilience of people and ecosystems to drought. It also agreed to support countries in developing and implementing national drought management policies (UNCCD, 2017).

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2

Monitoring and early warning (Pillar 1)

2.1 Introduction to drought monitoring and early warning systems

Droughts are a normal part of the climate, meaning that they are a recurrent deficiency of precipitation from the long-term average. Other factors, such as temperature, low humidity and wind, can also contribute to the severity and duration of a drought episode. Thus, droughts can occur in any climate regime around the world, even deserts and rainforests. Droughts are one of the costlier natural hazards on a year-to-year basis; their impacts are significant and widespread, affecting many economic sectors and people at any one time.

The geographical and societal impacts of droughts are typically larger than those for other hazards, which are usually constrained to floodplains, coastal regions, storm tracks or fault zones. The slow onset of droughts allows time to observe changes in precipitation, temperature and the overall status of surface water and groundwater supplies in a region, therefore facilitating drought monitoring. Drought indicators or indices are often used to help identify and/or depict drought conditions, and these tools vary depending on the region and the season.

The type of impacts relevant to a particular drought monitoring and early warning context is often a crucial consideration in determining the selection of drought indicators. Droughts can adversely affect a variety of sectors, such as agriculture and food security, hydropower generation and industry, human and animal health and livelihood security. Such impacts depend on the socio-economic contexts in which droughts occur, in terms of who or what is exposed to the droughts and the specific vulnerabilities of the exposed entities. Therefore, effective drought monitoring and early warning must integrate precipitation and other climatic parameters with water information, such as stream flow, snowpack, groundwater levels, reservoir and lake levels and soil moisture, into a comprehensive assessment of current and future drought and water supply conditions. In addition, monitoring the impacts (i.e. social indicators) that are occurring on the ground as a drought develops helps to calibrate assessments of severity for local areas. This assessment can then trigger appropriate mitigation and response actions that have been identified previously (see chapter 3 on vulnerability assessment and chapter 4 on mitigation and response).

Early warning is defined as the provision of timely and effective information, through identified institutions, that allows stakeholders at risk of a disaster to take action to avoid or reduce their risk and prepare for effective response (GWP CEE, 2015). Effective 'end-to-end' and people-centred early warning systems (EWSs) may include four interrelated key elements (Fig. 2.1):

- Disaster risk knowledge based on the systematic collection of data and disaster risk assessments
- Detection, monitoring, analysis and forecasting of the hazards and possible consequences
- Dissemination and communication of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact by an official source
- Preparedness at all levels to respond to the warnings received.

These four interrelated components need to be coordinated within and across sectors and multiple levels and include a feedback mechanism for continuous improvement for the system to work effectively. Failure in one component or a lack of coordination across them could lead to the failure of the whole system (WMO, 2018).

One of the goals of the *Sendai Framework for Disaster Risk Reduction 2015–2030* is to substantially increase the availability of, and access to, multi-hazard EWS and disaster risk information and assessments to people by 2030 (UNISDR, 2015). However, because of the slow onset and non-structural, indirect and often geographically widespread impacts of drought, early warning and emergency measures are required on timescales that vary largely from those of other natural hazards, such as floods, storms and earthquakes. The integration of drought into multi-hazard EWSs has not widely been performed. However, the concurrency and interlinkages, as well as cascading effects, between droughts and heatwaves, wild fires and floods still need to be explored (UNDRR, 2019). In the case of floods, for example, dry soils from drought conditions may show significantly reduced instant infiltration capacities, thereby rendering more severe (flash) flooding following heavy precipitation, as in the case of the Afghanistan flash flood event in 2019 (IFRC, 2019).

2.2 Understanding and measuring hydrological and climatological parameters

2.2.1 Hydrological cycle

Drought is a problem caused by multiple variables, and it varies in both space and time. To characterize drought requires looking at all the components of the hydrological cycle, not just one part. The hydrological cycle is illustrated in Fig. 2.2.

Figure 2.1. Four elements of end-to-end, people-centred early warning systems. Source: WMO (2018).

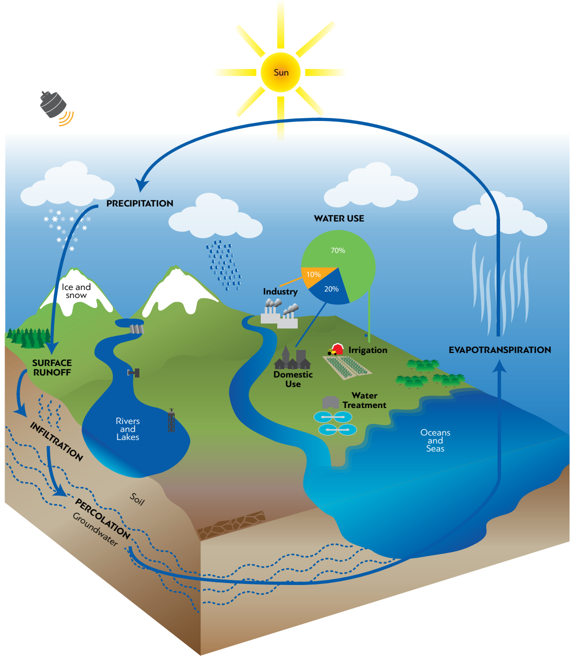

Figure 2.2. Components of the global hydrological cycle.

The sun is the driving force behind the hydrological cycle, as it heats water in the oceans. This causes evaporation of surface water into the atmosphere as vapour. In addition, the land surface loses water to the atmosphere in the form of evapotranspiration (eT), which combines plant transpiration and soil evaporation. Warm air and water vapour rise into the atmosphere until they reach cooler temperatures and condense to form clouds.

Air currents move clouds around the globe, and cloud particles collide, grow and eventually fall as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers. Most precipitation falls back into the oceans or onto land, where, due to gravity, it flows over the ground as surface runoff. A portion of runoff enters rivers in valleys, with streamflow moving water towards the oceans. Runoff and groundwater seepage accumulates and is stored as freshwater in lakes.

Not all runoff flows into rivers; much of it soaks into the ground as infiltration where it may replenish aquifers (saturated subsurface rock). Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge, and some groundwater finds openings in the land surface and emerges as freshwater springs. Yet more groundwater is absorbed by plant roots to end up as eT from the leaves. Over time though, all of this water keeps moving, and some will re-enter the ocean.

In drought monitoring, it is superfluous to investigate the complete hydrological cycle over the whole Earth when the area of interest is much smaller. Instead, a local hydrological cycle can be developed so that all the components within an area are covered (Syed *et al.*, 2008). Inflow can be assumed to be the runoff from the neighbouring catchments/pixels. Regional drought can thus be investigated using the local values of each of these hydrological cycle components. Diverse types of drought exist due to the different temporal variations present in each hydrological cycle component. Note that inflow into a catchment/pixel can be considered as the runoff/outflow from a neighbouring catchment/pixel. Hence, they are treated as the same variable. It becomes clear that a more detailed look at the hydrological cycle components is needed in order to understand drought and its impact.

Precipitation
Precipitation is the dominant source of freshwater in most areas. Precipitation comes from water vapour in the air and is mostly dependent on the evaporation of the sea (and the sea surface temperature), even though eT from the land surface also plays a significant role.

As water continually moves between the oceans, atmosphere, cryosphere and land, clouds play an important role in the hydrological cycle. The properties and movement of coherent cloud features are primarily determined by large-scale atmospheric circulations, which are pertinent manifestations of weather systems. The amount of water moved through the hydrological cycle every year is equivalent to the amount of water uniformly distributed over the Earth's surface to a depth of one metre. This annual amount of water enters the atmosphere through evaporation and returns to the surface as precipitation. In this cycle, clouds are the medium through which the transport of water vapour takes place.

Soil moisture
Soil moisture is the water stored within the soil, which is defined as the uppermost layer of the Earth's crust that is the natural medium for the growth of plants and is influenced by living organisms. Primarily, soil moisture is a function of rates of evaporation and precipitation, although the type of soil and vegetation cover also influences the rates at which water filters through the soil and runs off the surface. Both the amount of soil moisture and the water-holding capacity of the soil are important. The water-holding capacity of soil, which differs according to soil type, affects possible changes in soil moisture deficits: the lower the water-holding capacity, the greater the sensitivity to prolonged absence of precipitation.

Evapotranspiration
Evapotranspiration is the largest sink of the hydrological cycle (Kite and Droogers, 2000; Thornthwaite and Mather, 1951). It represents the combination of water loss to the atmosphere through evaporation of water bodies and soil moisture and the transpiration of water content by vegetation. While transpiration of the soil is a purely physical process dependent only on the energy available at the leaf level and the meteorological conditions, transpiration from vegetation is a combined biological and physical, or 'biophysical' process (Cammalleri *et al.*, 2012; Shenbin *et al.*, 2006). Therefore, the combined process of eT is dependent not only on the meteorological parameters but also on processes within the vegetation canopy, such as carbon assimilation and growth patterns.

A difference must be made between actual eT and potential eT (Allen *et al.*, 2005). Potential eT is the hypothetical maximum amount of water lost from soil/vegetation for specific meteorological conditions, while actual eT is the real water loss calculated for those same conditions. The combination of these two estimations is incredibly important for determining the water stress level, and consequently, drought (Allen *et al.*, 1998).

Groundwater flow, runoff and river discharge
Groundwater flow and runoff can be considered as the leftover parts of the hydrological cycle. They are very difficult to determine, as they depend on the water available for precipitation, the amount of water lost through infiltration, the amount of water that is stored as soil moisture and the roughness of the land surface. Runoff is defined as the precipitation that flows towards a river on the ground surface (surface runoff) or within the soil (subsurface runoff or interflow) (WMO and UNESCO, 2012).

River discharge is defined as the volume of water flowing through a river (or channel) cross-section per unit of time (WMO and UNESCO, 2012).

2.2.2 Methods for hydro-meteorological data collection

Ground-based measurements
There are a large variety of ground-based measurements that can be used to calculate the different components of the hydrological cycle.

Precipitation
Estimations of precipitation rely primarily on tipping bucket rain gauges and radar estimations. While tipping buckets are accurate instruments, rain

events are often widely distributed, so many tipping buckets are required to fully capture the precipitation of a specific region. Using radar measurements, the coverage of precipitation estimation is greatly improved. However, the measurement still needs to be interpreted to obtain the actual rainfall amount. In addition, the measurements only cover regional, not large-scale, areas and are very costly to maintain.

Evapotranspiration

Conventional methods of eT estimation are based on ground measurements. Some examples of conventional eT estimation methods are the Bowen ratio, eddy covariance, lysimeter, scintillometer and sap flow. Although such conventional methods have proven relatively accurate for measuring eT for a homogenous area, their uses become limited for larger heterogeneous areas, and more instruments are required (Kite and Droogers, 2000).

Soil moisture

Methods for measuring soil moisture include theta probes, ground radar and gravimetric measurements. For the first two methods, additional information, such as the soil conductivity, is necessary to estimate soil moisture. However, these additional measurements are not required for the gravimetric method, in which a sample of the soil is taken to the lab, weighed, dried and then weighed again. For all measurements, however, multiple locations need to be investigated, and the number of soil moisture networks is limited.

Runoff ('surface runoff' and 'subsurface runoff')

Runoff is difficult to measure and is generally not operationally quantified by field measurements. However, many models have been developed to estimate water movement, such as the Hydrologiska Byråns Vattenbalansavdelning (HBV) hydrology model, which has been applied to numerous catchments on most continents (Lindström *et al.*, 1997). Using this HBV model, precipitation is divided into surface runoff and infiltration. Surface runoff occurs if the simulated soil moisture storage exceeds the maximum storage capacity. The remaining precipitation infiltrates the soil moisture reservoir and seeps through the soil layer to the quick runoff reservoir. From the quick runoff reservoir, the water is either removed through quick runoff or percolates down to the base flow or groundwater reservoir (Fig. 2.3).

Runoff must be distinguished from river discharge (also river runoff). The measurement of **river discharge** in the field is generally carried out using current meters and calibrated or rated channel cross-sections, flumes or standardized weirs, together with water level readings (often by automatic recorders), to give a continuous height record that can be correlated to flow (FAO, 1995).

Groundwater level (change)

Common methods of measuring groundwater include boreholes, soil moisture stations and lake level measurements. Such methods have good accuracy but are too costly for monitoring a large area with an adequate network of measuring stations. Accurate measurement of groundwater at large scales is challenging due to the limited number of groundwater monitoring stations.

While quantitative estimation of these components, with high spatial and temporal resolution, is vital

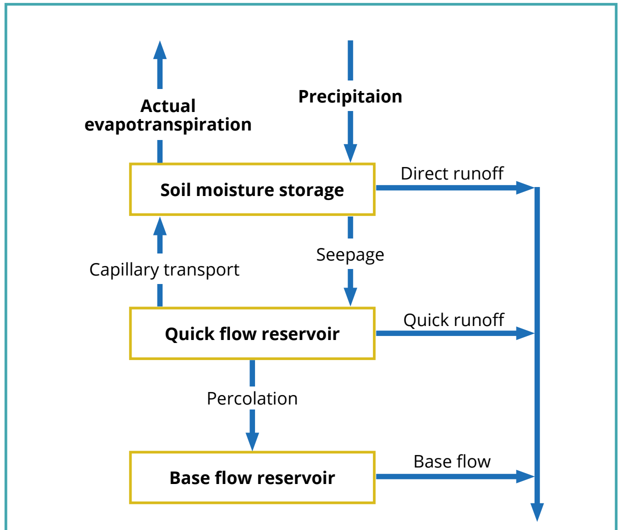

Figure 2.3. Schematic representation of the infiltration process for runoff estimation using the HBV hydrology model. Source: Lindström *et al.* (1997).

in water management, the number of operational networks for such data is low. Although a high number of measurement mechanisms exists in Europe and North America, vast areas of land are still unrepresented because it is costly to establish a single, fully fledged hydro-meteorological station and associated infrastructure. In addition, hydro-meteorological equipment is unique in design, expensive and prone to periodic breakdown due to the environmental effects. Therefore, remote sensing is needed to cover larger areas.

Remote sensing techniques

Satellite remote sensing has become a vital technique in water management. Satellite sensors allow observation of large areas with a single sensor. In addition, these observations are made several times per week, with data available within two or three days after the satellite image has been taken. In the past, drought-related remote sensing observables were limited to air temperature but now include precipitation and soil moisture. Using advanced algorithms, it is even possible to estimate land surface processes, such as eT.

Remote sensing uses observations of radiation to determine the state of the atmosphere, ocean or land surface. Hence, only land surface parameters that have a significant impact on the reflection or emission of radiation can be detected by remote sensing. Remote sensing sensors can be active or passive: active sensors emit radiation and measure the return signal, while passive remote sensors only observe radiation. In addition, a distinction is made between optical and microwave measurements.

Optical remote sensing
Optical remote sensing observes solar radiation reflected from the Earth's surface and thermal radiation emitted from the Earth's surface. The wavelength of this radiation is between 15 and 400 nm and needs to be initially corrected for the absorption/reflection of the atmosphere. Emitted radiation is directly measured from the temperature of the cloud/land surface, while the reflected radiation provides information about the size of land surface.

Microwave remote sensing
This technique measures satellite-emitted radiation refracted back by the atmosphere/Earth's surface or radiation emitted by the Earth's surface. The wavelength of this radiation is between 0.1 and 10 cm, and therefore, is unimpeded by cloud cover during the day or night. As such, the amount of radiation received by the sensor cannot be identified as a reflection from a specific object, but instead it is a measure of the dielectric constant of the soil/atmosphere.

Open data sources
In recent years, advancements have been made in the creation of open datasets on precipitation and soil moisture using satellite or combined satellite and ground measurement data. Most datasets were created with a specific temporal and spatial resolution. A non-exhaustive list of products is given below.

Soil moisture data and products:
- https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-soil-moisture?tab=overview
- https://smap.jpl.nasa.gov/data/
- https://ismn.geo.tuwien.ac.at/en/ and https://www.esa-soilmoisture-cci.org/

Precipitation data:
- https://pmm.nasa.gov/data-access
- ftp://ftp.cpc.ncep.noaa.gov/
- https://www.chc.ucsb.edu/data/chirps
- https://climatedataguide.ucar.edu/climate-data/gpcc-global-precipitation-climatology-centre
- https://opendata.dwd.de/climate_environment/GPCC/html/fulldata_v7_doi_download.html

eT:
- https://landsaf.ipma.pt/en/products/evapotranspiration-energy-flxs/

Historical climate data:
- https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn

For more information on measurement techniques, please refer also to the CapNet Manual on IWRM and Earth Observation (https://cap-net.org/wp-content/uploads/2020/04/EO-manual-2017-LR.pdf).

2.3 Drought indicators and indices

Drought indicators are defined as variables or parameters used to describe drought conditions (WMO and GWP, 2016). Examples include precipitation, temperature, streamflow, groundwater and reservoir levels, soil moisture and snowpack. Drought indices are tools used to identify the characteristics of drought, such as severity, location, timing and duration. They assess the qualitative state of droughts on the landscape for a given period using climatic or hydro-meteorological input, such as the indicators mentioned above. Drought indices provide a basis for drought assessment.

A single indicator or index was used in the past by decision makers and scientists, as this was the only measurement available to them or they had only limited time to acquire data and compute derivative indices or other deliverables. During the past few decades, however, driven by the global necessity to improve characterization of drought conditions, new indices have been developed based on various indicators that are suitable for different applications and scales, both spatial and temporal. These new tools have given decision makers and policymakers more choices, and the growing computing capacities, including the use of geographic information systems, are being increasingly used to overlay, map and compare indices and synthesize results into a simple message that can be conveyed to the public. A more detailed discussion on mapping drought indices and indicators is presented in chapter 9 of the *Standardized Precipitation Index User Guide* (WMO, 2012).

Given the large number of available drought indicators and indices, it is often challenging to choose the most suitable indicator or index, especially when they are linked to a drought plan as triggers for drought management actions. It takes time and a system of trial and error to determine the best fit for any given location, area, basin or region. Experience has shown that drought severity is best evaluated using a suite of multiple indicators. Therefore, composite (sometimes referred to as 'hybrid') indicators have been developed to merge different indicators and indices, either weighted or not, or in a modelled fashion. The idea is to use the strengths of a variety of inputs while maintaining a single, simple source of information for decision makers, policymakers or the public (WMO and GWP, 2016).

A comprehensive compilation and review of the most commonly used drought indices has been published by WMO in its *Handbook of Drought Indicators and Indices* (WMO and GWP, 2016). An overview of the indices mentioned in this review is presented in Table 2.1, along with a legend depicting the colour coding of the ease of use. This selection of indicators and indices is also available at http://www.droughtmanagement.info/indices/.

Table 2.1. Indicators and indices listed in the Handbook of Drought Indicators and Indices (WMO and GWP, 2016)

Meteorology	Page	Ease of use	Input parameters	Additional information
Aridity Anomaly Index (AAI)	11	Green	P, T, PET, ET	Operationally available for India
Deciles	11	Green	P	Easy to calculate; examples from Australia are useful
Keetch–Byram Drought Index (KBDI)	12	Green	P, T	Calculations are based upon the climate of the area of interest
Percentage of normal precipitation	12	Green	P	Simple calculations
Standardised Precipitation Index (SPI)	13	Green	P	Highlighted by WMO as a starting point for meteorological drought monitoring
Weighted Anomaly Standardised Precipitation (WASP)	15	Green	P, T	Uses gridded data for monitoring drought in tropical regions
Aridity Index (AI)	15	Yellow	P, T	Can also be used in climate classifications
China Z Index (CZI)	16	Yellow	P	Intended to improve upon SPI data
Crop Moisture Index (CMI)	16	Yellow	P, T	Weekly values are required
Drought Area Index (DAI)	17	Yellow	P	Gives an indication of monsoon season performance
Drought Reconnaissance Index (DRI)	17	Yellow	P, T	Monthly temperature and precipitation are required
Effective Drought Index (EDI)	18	Yellow	P	Program available through direct contact with originator
Hydro-thermal Coefficient of Selyaninov (HTC)	19	Yellow	P, T	Easy calculations and several examples in the Russian Federation

Table 2.1. Indicators and indices listed in the Handbook of Drought Indicators and Indices (continued)

Meteorology	Page	Ease of use	Input parameters	Additional information
NOAA Drought Index (NDI)	19	Yellow	P	Best used in agricultural applications
Palmer Drought Severity Index (PDSI)	20	Yellow	P, T, AWC	Not green due to complexity of calculations and the need for serially complete data
Palmer Z Index	20	Yellow	P, T, AWC	One of the many outputs of PDSI calculations
Rainfall Anomaly Index (RAI)	21	Yellow	P	Serially complete data required
Self-Calibrated Palmer Drought Severity Index (sc-PDSI)	22	Yellow	P, T, AWC	Not green due to complexity of calculations and serially complete data required
Soil Moisture Anomaly (SMA)	25	Yellow	P, T, AWC	Intended to improve upon the water balance of PDSI
Standardised Anomaly Index (SAI)	22	Yellow	P	Point data used to describe regional conditions
Standardised Precipitation Evapotranspiration Index (SPEI)	23	Yellow	P, T	Serially complete data required; output similar to SPI but with a temperature component
Agricultural Reference Index for Drought (ARID)	23	Red	P, T, Mod	Produced in south-eastern USA and not tested widely outside that region
Crop-specific Drought Index (CSDI)	24	Red	P, T, Td, W, Rad, AWC, Mod, CD	Quality data of many variables needed, making it challenging to use
Reclamation Drought Index (RDI)	25	Red	P, T, S, RD, SF	Similar to Surface Water Supply Index, but with a temperature component
Evapotranspiration Deficit Index (ETDI)	26	Red	Mod	Complex calculations with multiple inputs required
Soil Moisture Deficit Index (SMDI)	26	Red	Mod	Weekly calculations at different soil depths; complicated to calculate
Soil Water Storage (SWS)	27	Red	AWC, RD, ST, SWD	Owing to variations in both soil and crop types, interpolation over large areas is challenging

Table 2.1. Indicators and indices listed in the Handbook of Drought Indicators and Indices (continued)

Hydrology	Page	Ease of use	Input parameters	Additional information
Palmer Hydrological Drought Severity Index (PHDI)	27	Yellow	P, T, AWC	Serially complete data required
Standardised Reservoir Supply Index (SRSI)	28	Yellow	RD	Similar calculations to SPI using reservoir data
Standardised Streamflow Index (SSFI)	29	Yellow	SF	Uses the SPI program along with streamflow data
Standardised Water-level Index (SWI)	29	Yellow	GW	Similar calculations to SPI, but using groundwater or well-level data instead of precipitation
Streamflow Drought Index (SDI)	30	Yellow	SF	Similar calculations to SPI, but using streamflow data instead of precipitation
Surface Water Supply Index (SWSI)	30	Yellow	P, RD, SF, S	Many methodologies and derivative products are available, but comparisons between basins are subject to the method chosen
Aggregate Dryness Index (ADI)	31	Red	P, ET, SF, RD, AWC, S	No code, but mathematics explained in the literature
Standardised Snowmelt and Rain Index (SMRI)	32	Red	P, T, SF, Mod	Can be used with or without snowpack information

Remote sensing	Page	Ease of use	Input parameters	Additional information
Enhanced Vegetation Index (EVI)	32	Green	Sat	Does not separate drought stress from other stresses
Evaporative Stress Index (ESI)	33	Green	Sat, PET	Does not have a long history as an operational product
Normalised Difference Vegetation Index (NDVI)	33	Green	Sat	Calculated for most locations
Temperature Condition Index (TCI)	34	Green	Sat	Usually found along with NDVI calculations
Vegetation Condition Index (VCI)	34	Green	Sat	Usually found along with NDVI calculations
Vegetation Drought Response Index (VegDRI)	35	Green	Sat, P, T, AWC, LC, ER	Takes into account many variables to separate drought stress from other vegetation stresses

Table 2.1. Indicators and indices listed in the Handbook of Drought Indicators and Indices (continued)

Remote sensing	Page	Ease of use	Input parameters	Additional information
Vegetation Health Index (VHI)	35	Green	Sat	One of the first attempts to monitor drought using remotely sensed data
Water Requirement Satisfaction Index (WRSI and Geo-spatial WRSI)	36	Green	Sat, Mod, CC	Operational for many locations
Normalised Difference Water Index (NDWI) and Land Surface Water Index (LSWI)	37	Green	Sat	Produced operationally using Moderate Resolution Imaging Spectroradiometer data
Soil Adjusted Vegetation Index (SAVI)	37	Red	Sat	Not produced operationally

Composite or modelled	Page	Ease of use	Input parameters	Additional information
Combined Drought Indicator (CDI)	38	Green	Mod, P, Sat	Uses both surface and remotely sensed data
Global Integrated Drought Monitoring and Prediction System (GIDMaPS)	38	Green	Multiple, Mod	An operational product with global output for three drought indices: Standardised Soil Moisture Index, SPI and Multivariate Standardised Drought Index
Global Land Data Assimilation System (GLDAS)	39	Green	Multiple, Mod, Sat	Useful in data-poor regions due to global extent
Multivariate Standardised Drought Index (MSDI)	40	Green	Multiple, Mod	Available but interpretation is needed
United States Drought Monitor (USDM)	41	Green	Multiple	Available but interpretation is needed

Note: Indicators and indices are sorted by 'ease of use' and then alphabetically within each 'ease of use' category.

Key to variables:
AWC = available water content
CC = crop coefficient
CD = crop data
ER = ecoregion
ET = evapotranspiration
GW = groundwater
LC = land cover
Mod = modelled
Multiple = multiple indicators used
P = precipitation
PET = potential evapotranspiration
Rad = solar radiation
RD = reservoir
S = snowpack
Sat = satellite
SF = streamflow
ST= soil type
SWD = soil water deficit
T = temperature
Td = dewpoint temperature
W = wind data.

Green : Indices are considered to be green if one or more of the following criteria apply:

- A code or program to run the index is readily and freely available
- Daily data are not required
- Missing data are allowed for
- Output of the index is already being produced operationally and is available online.

Note: While a green 'ease of use' classification may imply that the indicator/index may be the easiest to obtain or use, it does not mean it is the best for any given region or locality. The decision as to which indicators/indices to use has to be determined by the user and depends on the given application(s).

Yellow : Indices are considered to be yellow if one or more of the following criteria apply:

- Multiple variables or inputs are needed for calculations
- A code or program to run the index is not available in the public domain
- Only a single input or variable may be needed, but no code is available
- The complexity of the calculations needed to produce the index is minimal.

Red : Indices are considered to be red if one or more of the following criteria apply:

- A code would need to be developed to calculate the index based upon a methodology given in the literature
- The index or derivative products are not readily available
- The index is obscure and not widely used, but may be applicable
- The index contains modelled input or is part of the calculations.

Source: WMO and GWP (2016).

Some of the most commonly applied indices are presented in more detail below.

2.3.1 Standardized Precipitation Index

The Standardized Precipitation Index (SPI) uses precipitation data from a minimum of 30 years (the longer the period of record, the better the index output). The long-term precipitation record is normalized using a probability distribution so that the mean SPI for a location and desired period is zero. The SPI is computed for different time scales ranging from 1, 3, 6, 12, 24 and 48 months. The SPI is helpful for early warning of droughts and in assessing drought severity. The only disadvantage of using SPI is that the values based on preliminary data may change. It also does not involve important parameters such as temperature and eT.

The SPI is based on the same principle as the precipitation anomaly: it uses only precipitation data. However, this value is then divided by the standard deviation in the specific area. This creates a standardized value, which provides similar results for different study areas. As a result, droughts over different study areas can be compared. The SPI is calculated using the following formula:

$$SPI = \frac{(P_i - \bar{P})}{\sigma}$$

Where P_i is the monthly precipitation observation, $\bar{P}$ is the mean monthly precipitation, and σ is the standard deviation of this mean. Negative SPI values indicate dryness, and positive values indicate wetness, as categorized in Table 2.2.

Table 2.2. SPI values and probability of recurrence

SPI	Category	Number of times in 100 years	Severity of event
0 to –0.99	Mild dryness	33	1 in 3 years
–1.00 to –1.49	Moderate dryness	10	1 in 10 years
–1.5 to –1.99	Severe dryness	5	1 in 20 years
< –2.0	Extreme dryness	2	1 in 50 years

Source: WMO (2012).

While a meteorological drought can still be predicted with a short-term absence of precipitation, this method does not consider the state of the land surface. Therefore, it is insufficient to use the precipitation anomaly or the SPI to monitor and predict more intense drought conditions that affect agriculture and/or other sectors. One way to include land information is to use soil moisture (in parallel with SPI).

2.3.2 Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) was developed in the 1960s as one of the first attempts to identify droughts using more than just precipitation data. Palmer was tasked with developing a method to incorporate temperature and precipitation data with hydrological cycle information to identify droughts in crop-producing regions of the USA. For many years, the PDSI was the only operational drought index, and it is still very popular around the world. Calculated using monthly temperature and precipitation data along with information on the water-holding capacity of soils, it considers moisture received (precipitation) as well as moisture stored in the soil, accounting for the potential loss of moisture due to temperature influences.

A global dataset of the PDSI and potential evaporation at 1.0 degree, monthly resolution is available here: http://hydrology.princeton.edu/data.pdsi.php (Sheffield *et al.*, 2012; Sheffield *et al.*, 2006).

This PDSI has been further developed through self-calibration. The self-calibrated PDSI accounts for all the constants contained in the PDSI and includes a methodology in which the constants are calculated dynamically based on the characteristics present at each station location (Wells *et al.*, 2004). A common critique of the PDSI is that the behavior of the index at various locations is inconsistent, making spatial comparisons of PDSI values difficult, if not meaningless. A serially complete record of temperature and precipitation data is required for this index. Information on the water-holding capacity of soils can be used, but defaults are also available. The source code for calculation of this index is available here: https://cran.r-project.org/web/packages/scPDSI/index.html.

2.3.3 Soil Moisture Deficit Index

In the development of the Soil Moisture Deficit Index (SMDI) and the Evapotranspiration Deficit Index, the following demands were set (Narasimhan and Srinivasan, 2005). The index should:

- respond to agricultural drought
- be able to respond to all seasons (summer or winter)
- be spatially comparable irrespective of climatic zones.

$$SMDI_j = 0.5 \cdot SMDI_{j-1} + \frac{SD_j}{50}$$

where $SMDI_{j-1}$ represents the SMDI for the previous period, and SD is the soil moisture deficit:

$$SD_{i,j} = \frac{(SWS_j - MSW_{i,j})}{(MSW_j - minSW_j)} \cdot 100 \text{ if } (SW_{i,j} \leq MSW_j)$$

$$SD_{i,j} = \frac{(SW_j - MSW_{i,j})}{(maxSW_j - MSW_j)} \cdot 100 \text{ if } (SW_{i,j} > MSW_j)$$

where MSW_j is the long-term median available soil water in the soil profile (mm), $maxWS_j$ is the long-term maximum soil water, and $maxWS_j$ is the long-term minimum soil water. On average, the monthly soil deficit index value ranges from -100 to +100, indicating very dry to very wet conditions, respectively. As soil moisture depends on the depth of the measurements, and its impact on the plant depends on the rootzone, several SMDIs are defined: SMDI-2, SMDI-4 and SMDI-6 for a depth of 2, 4 and 6 feet, respectively. As some plants do not take their water from the first 15 cm, an additional hydrological parameter should be investigated, namely eT.

Therefore, the SMDI is defined as a weighted average between the previous SMDI value and the current soil moisture deficit at different soil depths (entire soil column, 0.61, 1.23 and 1.83 m). In Narasimhan and Srinivasan (2005), calculations are provided and explained thoroughly. Modelled data from a hydrologic model, together with the Soil and Water Assessment Tool (SWAT) model, are used initially to compute soil water in the root zone on a weekly basis. Information on the SWAT model can be found at http://swat.tamu.edu/software/swat-executables/.

2.3.4 Water Requirement Satisfaction Index

The Water Requirement Satisfaction Index (WRSI) is an operational monitoring measure which indicates the performance of a crop based on the availability of water during a growing season (Allen *et al.*, 1998). It relies partially on remote sensing data and is calculated as the ratio of seasonal actual crop eT (*AET*) to the crop water requirement (WR).

$$WRSI = \frac{AET}{WR} \cdot 100$$

Where *WRSI* is the crop WRSI (%), *AET* is the seasonal actual crop eT (mm d^{-1}), and *WR* is the seasonal water requirement (mm d^{-1}). The *WR* is the same as the potential crop eT estimated after the FAO's reference eT has been adjusted with the appropriate crop coefficient (*KC*) value, which is the water use pattern of a crop: *WR* = *PeT* * *KC*.

To define the spatial variation during the growing season for each modelling grid-cell, the WRSI model requires a start-of-season (SOS) and end-of-season time. The threshold used to determine SOS is based on the amount and distribution of rainfall received in three consecutive decades, and SOS starts when there is at least 25 mm of rainfall in one decade followed by rainfall records of at least 20 mm in the next two consecutive decades. End-of-season time can be estimated by adding the length of a growing period and SOS. The calculated WRSI value of a given pixel can represent the seasonal integrated conditions from the start of the growing season until the time of the modelling period (Brown, 2008).

The GeoWRSI is a stand-alone installable software for calculating the WRSI, as it is implemented by the United States Geological Survey Famine Early Warning Systems Network (FeWSNet) activity. The software and datasets can be downloaded here: https://www.chc.ucsb.edu/tools/geowrsi.

Questions about specific drought indicators and indices can be posted in the comment section on http://www.droughtmanagement.info/indices/ or submitted to the IDMP helpdesk (http://www.droughtmanagement.info/ask/ask-form/).

2.4 Drought monitoring and forecasting products

Monitoring and forecasting drought assists in building resilience towards drought events and contributes to lower drought risk. The adverse effects of drought are mitigated by warning the risk holders in time. However, for the effective and timely delivery of information on drought characteristics, a drought monitoring tool or product faces several challenges. Most indices compare the current status of meteorological parameters with a long-term average. Therefore, observational data collected from networks must be able to support adequate resolution of prevailing meteorological conditions, and data records on climate and water supply must be sufficient enough to produce significant and meaningful results. The integration of multiple indicators, such as precipitation, temperature, surface water and soil moisture, leads to a more robust characterization of the drought status. However, observational networks are often maintained by several different national government agencies and research institutions. Coordination and cost sharing of data sources, therefore, needs to be addressed on a national level. Finally, drought monitoring products face the challenge of making the results of data integration available to the general public and decision makers, meaning that the results of a complex and highly technical process need to be simplified, often through visualization, and translated into potential impact (WMO, 2006). A well-functioning monitoring system is the cornerstone of an early warning system, providing timely climatological information to initiate preparedness, mitigation and response actions based on a sound vulnerability assessment.

In recent years, many products on drought monitoring have been developed and are now operational. Since drought is a slow-onset hazard, current information is of great importance to decision makers. Drought forecasting would be the ideal product for providing stakeholders with the time needed to implement drought risk reduction measures, but it has not yet been widely implemented due to the great uncertainty of long-term weather forecasts (WMO, 2006). The USA monthly and seasonal drought outlook is one of the few operational products for drought forecasting (see https://www.drought.gov/drought/data-gallery/us-seasonal-drought-outlook and https://www.drought.gov/drought/data-gallery/us-monthly-drought-outlook).

2.4.1 Example: United States Drought Monitor

The production of the United States Drought Monitor (USDM) (Fig. 2.4) has been a team effort since its inception in 1999 and is produced jointly by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the National Oceanic and Atmospheric Administration and the US Department of Agriculture (USDA) (Svoboda *et al.*, 2002). It is not a statistical model, despite the incorporation of a number of numeric inputs: the PDSI, SPI and other climatological inputs, including satellite-based assessments of vegetation health, various indicators of soil moisture, and hydrologic data, particularly in the west, such as the Surface Water Supply Index and snowpack.

The USDM relies on experts to synthesize the best available data from available sources and work with local observers to interpret the information. The USDM also incorporates ground truthing and

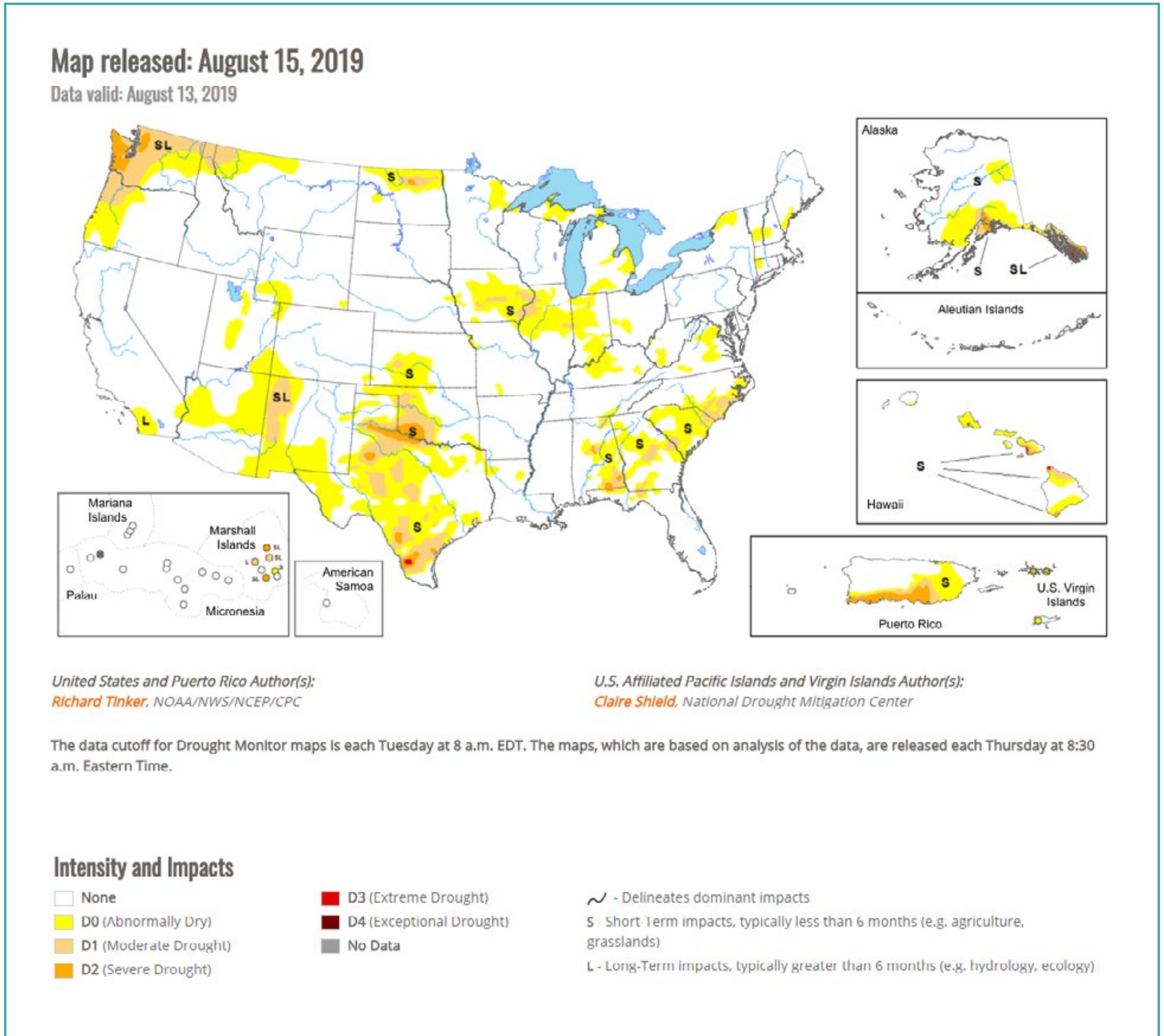

Figure 2.4. The United States Drought Monitor user interface. Source: https://droughtmonitor.unl.edu/.

information about how drought is affecting people via a network of more than 450 observers from across the country, including state climatologists, USDA field office personnel, National Weather Service field staff, extension agents and hydrologists. The result is a weekly assessment of drought conditions, based on how much precipitation was registered, up to the Tuesday morning before the map comes out on the Thursday morning. Therefore, the USDM itself, as presented in Fig. 2.4, is a 'now-cast' for precipitation. Drought outlooks or forecasts are provided by the Climate Prediction Center of the National Weather Service (https://www.cpc.ncep.noaa.gov/index.php).

2.4.2 Example: DriDanube DroughtWatch

The DroughtWatch drought monitor (https://droughtwatch.eu/) is one of the outcomes of the DriDanube project (2017–2019), which aimed to increase the capacity of the Danube region (a large part of south-eastern Europe) to manage drought-related risks. The DroughtWatch user interface features different data products from a range of operational remote sensing satellites, data from meteorological stations and drought impact reports, which can be mapped and overlaid in a map viewer to create ready-to-use drought information for the general public (Fig. 2.5). Indicator datasets are included, such as temperature and precipitation as well as indices (Soil Water Index, Normalized Difference Vegetation Index, Surface Water Balance and Vegetation Condition Index). As part of the DriDanube project, national reporting networks were developed, which consist of farmers and other agricultural experts who evaluate their precipitation observations weekly throughout the year. The resulting information is compiled to assess how drought influences crop yield or forest

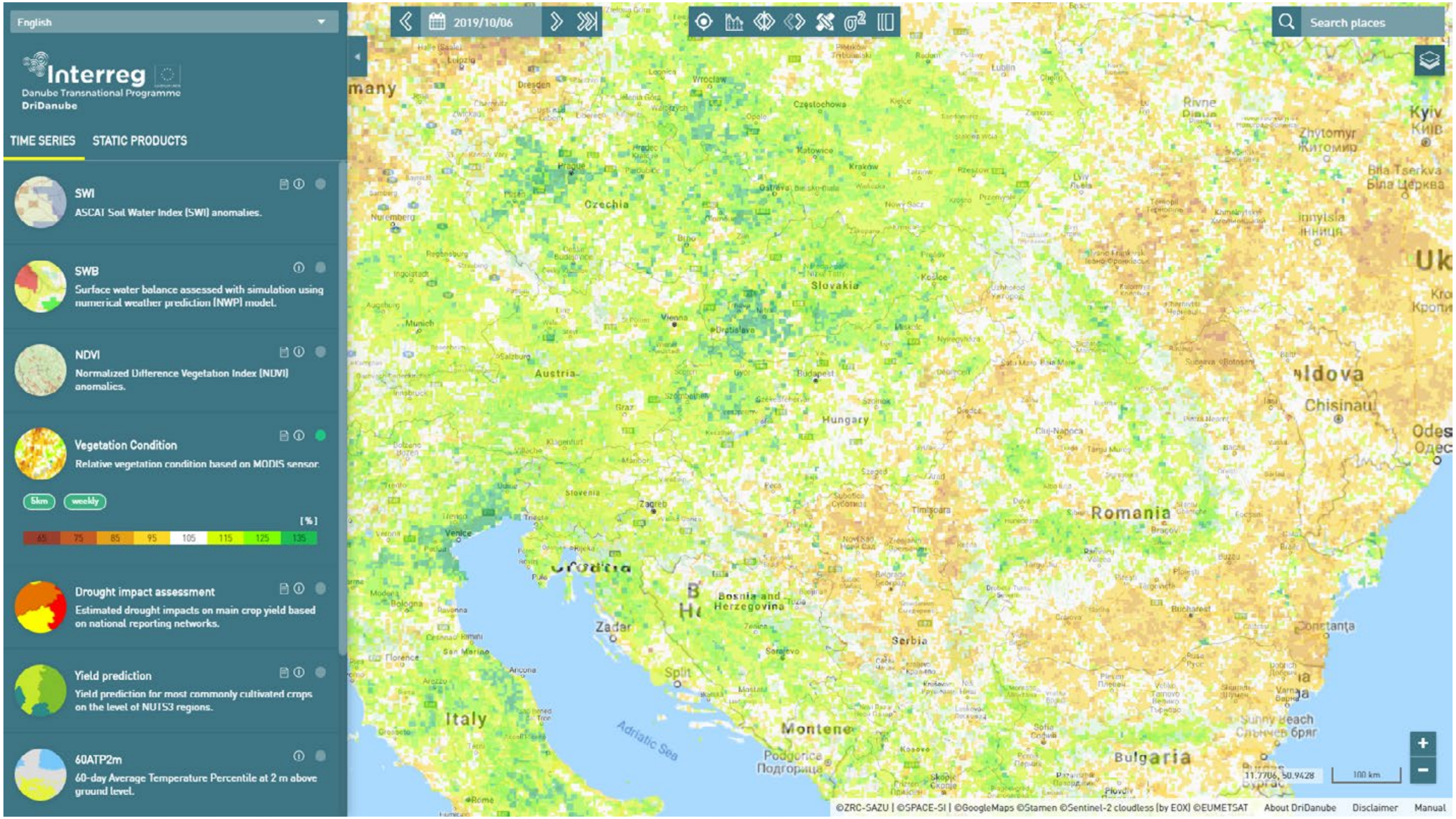

Figure 2.5. DroughtWatch user interface of the drought monitoring product developed by the DriDanube project. Source: www.droughtwatch.eu.

growth at a specific location and is visualised in a 'drought impact assessment' layer. Static products include the duration of rainless periods and a layer visualizing overall drought risk. Functionalities of the drought monitoring product are explained in a tutorial video here: https://www.youtube.com/watch?v=2MC5goO17H8&feature=youtu.be.

2.4.3 Example: North-east Brazil Drought Monitor

The Brazilian Drought Monitor (http://monitordesecas.ana.gov.br/) covers the drought-prone north-eastern part of Brazil and is continuing to increase its spatial coverage. The user interface includes a monthly map displaying the spatial extent and severity of drought conditions using the SPI (Fig. 2.6) as well as an explanation of regional conditions (Table 2.3). The process for generating the map of current drought conditions (Fig. 2.6) is detailed in the 'Frequently asked questions' section of the monitoring website.

Other examples of drought monitoring products include:

- European Drought Observatory
- North American Drought Monitor

Please refer to http://www.droughtmanagement.info/pillars/monitoring-early-warning/ for a larger list of drought monitoring products.

2.5 Drought early warning systems

A drought early warning system (DEWS) is the foundation of integrated drought management. An EWS is defined as the set of capacities needed to generate and disseminate timely and meaningful

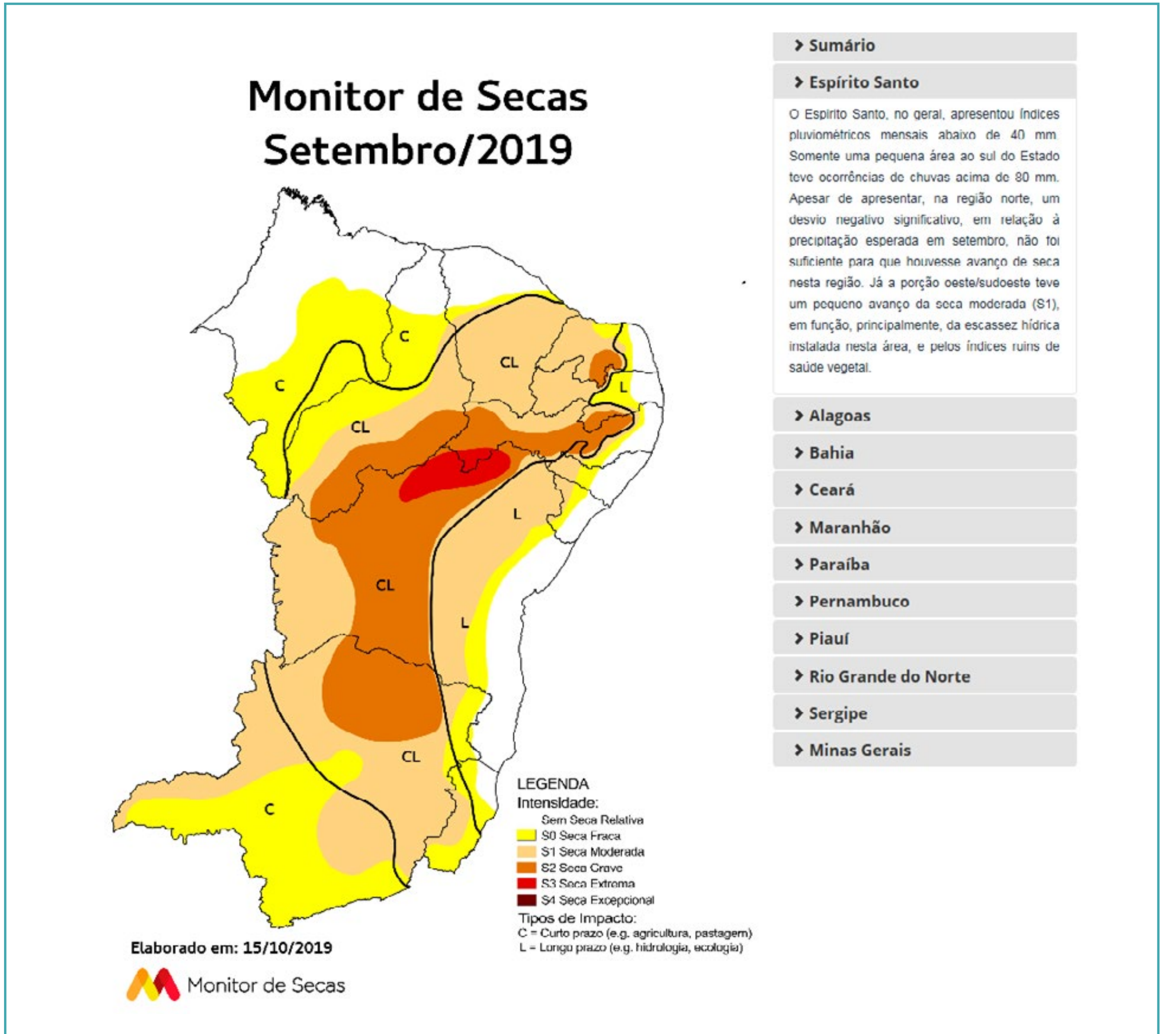

Figure 2.6. Brazilian Drought Monitor map. Source: http://monitordesecas.ana.gov.br/.

Table 2.3. Extended legend of the Brazilian Drought Monitor map

Map description summary

S0-S4: The Drought Monitor has a legend that identifies the drought areas classified by intensity, ranging from S1 (less intense drought) to S4 (the most intense). S0 indicates that they are areas with abnormally low humidity conditions and are drying out and may possibly become areas of drought.
C and L: These letters indicate how drought and moisture deficits have social, environmental or economic impacts over time:

> *C = Short-term drought, usually acting for 4 months or less (eg agriculture)*
> *L = Long-term drought, usually acting for more than 12 months (eg hydrological and ecological)*

Drought Severity Rating

Category	Percentile	description	Possible Impacts
S0	30% useful	Weak Drought	Going into drought: short-term summer decreasing planting, crop growth or pasture. Coming out of drought: some prolonged water deficits, pastures or crops not completely recovered.
S1	20% useful	Moderate Drought	Some damage to crops, pastures; streams, reservoirs or wells with low levels, some water shortages in development or imminent; voluntary water use restrictions requested.
S2	10% useful	Severe Drought	Crop losses or probable pastures; common water shortages; water restrictions imposed.
S3	5% useful	Extreme Drought	Large crop / pasture losses; widespread water shortages or restrictions
S4	2% useful	Exceptional Drought	Exceptional and widespread crop / pasture losses; scarcity of water in reservoirs, streams and water wells, creating emergency situations.

Drought stages, or categories, which define the intensity of drought on the Monitor map.
Source: Adapted from the National Drought Mitigation Center, Lincoln, Nebraska, US. https://drought.unl.edu/

warning information to enable individuals, communities and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss (IPCC, 2014). Hence, EWSs aim to reduce vulnerability and improve response capacities of people at risk. Governments maintain DEWSs to warn their citizens and themselves about impending drought conditions. A DEWS is ultimately concerned with drought impacts; however, drought impact assessment is a large gap in many DEWSs currently used around the globe. The assessment of drought impacts is complicated by the observation that socio-economic factors, besides the physical nature of droughts, influence the levels and types of impacts related to drought exposure and vulnerability (WMO and GWP, 2016).

The drought monitoring component of a DEWS identifies climatic, hydrologic and water supply conditions and trends and detects the emergence or probability of occurrence and the likely severity of drought and its impacts. Therefore, a DEWS ideally has both a monitoring (including impacts) and a forecasting component. Additionally, a DEWS contains mechanisms on how this information must be communicated in a timely manner to water and land managers, policy makers and the public through appropriate communication channels (Fig. 2.7). The objective is to provide timely information in advance of, or during, the early onset of drought to prompt action (via threshold triggers) within a risk management plan to reduce drought impacts.

Therefore, EWSs are more than scientific and technical instruments for forecasting hazards and issuing alerts. They should be designed as sources of scientifically credible, authoritative and accessible knowledge. EWS integrate information about and from areas of risk that facilitate decision-making (formal and informal) in a way that empowers vulnerable sectors and social groups to mitigate potential losses and damage from approaching hazard events. Ideally, early warning represents a proactive social process whereby networks of institions, agencies and organisations conduct collaborative analyses and coordination (Pulwarty and Verdin, 2013). In this context, indicators are used to identify when and where policy interventions are most needed. Historical and institutional analyses, on the other hand, help to identify the processes and entry points that need to be understood if vulnerability is to be reduced. Taking local knowledge and practices into account promotes mutual trust, acceptability, common understanding, community sense of ownership and self-confidence (Dekens, 2007).

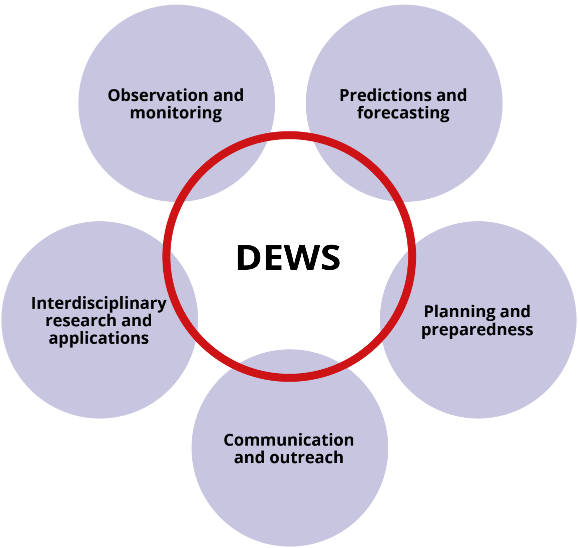

Figure 2.7. Schematic representation of the parts of the Intermountain West Regional Drought Early Warning System (DEWS) put forward by the National Oceanographic and Atmospheric Administration's National Drought Information System. Source: https://www.drought.gov/drought/intermountain-west-drought-early-warning-system-strategic-plan.

It is one thing to be aware of an impending drought event, and a different thing to trigger the right actions in response, and this includes the power to make decisions and allocate resources. Drought triggers should be designed and promoted to stimulate response action by the respective implementing agencies. A drought management plan defines communication paths, responsibilities and measures to be taken at different levels of drought risk. Guidance on how to approach the establishment of such a plan is given in chapter 5.

Triggers are the key linkages that connect drought monitoring with informed action in a DEWS. Therefore, it is vital that the triggers deployed in an EWS are carefully chosen to account for different types of response. For example, at an early stage, the trigger might be for advocacy, but as the situation deteriorates, it might be for a livelihood, and subsequent food/ nutrition, response.

2.5.1 Famine Early Warning Systems Network

The FeWSNeT (https://fews.net/) is an initiative funded by the United States Agency for International Development since its creation in 1985. It is a tool used to assist mitigation and preparedness in 17 countries in Africa. It analyses a variety of data and information, such as market prices, precipitation and crop failures, to predict if, when and where food insecurity will occur and issues alerts on predicted crises for early decision-making. FeWSNeT offers periodical reporting products, such as monthly *Food Security Updates, Monthly Weather Hazards Impact Assessments and Rain Watches*, and one-page reports issued every 10 days that present the current rain season and its implications for food security in a specified area.

More information on drought monitoring and early warning tools and products can be found here: http://www.droughtmanagement.info/pillars/monitoring-early-warning/.

Tailored assistance on drought-related topics can be requested here: http://www.droughtmanagement.info/ask/.

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3 Drought vulnerability and impact assessment (Pillar 2)

3.1 Introduction to drought vulnerability and impact assessment

3.1.1 Drought risk – linking hazard, exposure and vulnerability

Hazards in themselves do not constitute disasters. The magnitude of a disaster is usually described in terms of the adverse effects a hazard has on lives, property, infrastructure, and the environment, and the costs attached to post-disaster recovery and rehabilitation. In other words, there is a direct link between the capacity of those affected to withstand, cope with and recover from the adverse effects of a hazard using only their own resources and what constitutes disaster risk. Put simply, disaster risk is the product of the combination of three elements: vulnerability, exposure and hazard (Figs. 1 and 2):

Risk = hazard x exposure x vulnerability

A hazard is defined as a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena (e.g. droughts as a result of precipitation deficiency) (UNISDR, 2017). Exposure means the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (UNISDR, 2017).

Drought is a hazard, and exposure to drought can be analysed to identify areas prone to drought risk, and its occurrence can be monitored and forecasted (see chapter 2). However, the occurrence of drought cannot be managed. Studies show that drought risk is only partly a result of deficiencies in rainfall. Other drivers include poverty, structural vulnerability, increasing water demand from urbanization, industrialization, poor water quality, poor soil management, weak or ineffective governance and climate variability.

The only way to manage drought risk is to manage and mitigate the impacts of drought by reducing vulnerabilities.

3.1.2 Drought impacts

Droughts have significant impacts with regards to the social fabric of nations and communities, economic systems, agricultural, and livestock losses, loss of labour opportunities, health status of individuals and communities and societal impacts, among others. According to the United Nations International Strategy for Disaster Reduction (UNISDR), a disaster impact is the total effect of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being. A slow-onset disaster, such as drought, is defined as one that emerges gradually over time (UNISDR, 2017).

Impacts associated with drought are often temporally and geographically widespread but are generally **non-structural**, and thus, the impacts are less visible, more difficult to assess (e.g. reductions in crop yield) and do not require reconstruction as part of the recovery process.

The impacts of drought can be **direct and indirect,** while some have a ripple effect. Agriculture is often the first economic sector to be hit with the direct impact of reduced yield. Secondary or tertiary impacts that may follow are loss of income and farm closures. Additionally, drought-related damages can further be classified as **tangible** (market related) and **intangible** (non-market related). This distinction is particularly important in the case of drought, since many impacts, such as ecosystem degradation, are intangible and difficult to quantify. It is due to these intangible components, but also prolonged drought duration and delayed and spatially dislocated occurrence of cascading effects, that a comprehensive estimation of drought impacts is rendered extremely difficult (Vogt *et al.*, 2018). The impacts of droughts can be grouped as economic, environmental and social. A description of the main sectors affected by drought is given in Table 3.1. Table 3.2 shows an example of the huge economic losses a country can suffer due to drought. This is particularly critical in developing countries, such as Kenya.

When drought impacts are discussed, there is often an implicit consensus to focus on negative impacts. However, in the same way as the definition of 'disaster impacts' put forward by UNISDR, drought includes both **positive** and **negative** impacts (UNISDR, 2017). Favourable impacts of drought may arise through the strengthening of social connections in a society when drought or water management systems are managed and improved (UNCCD *et al.*, 2019).

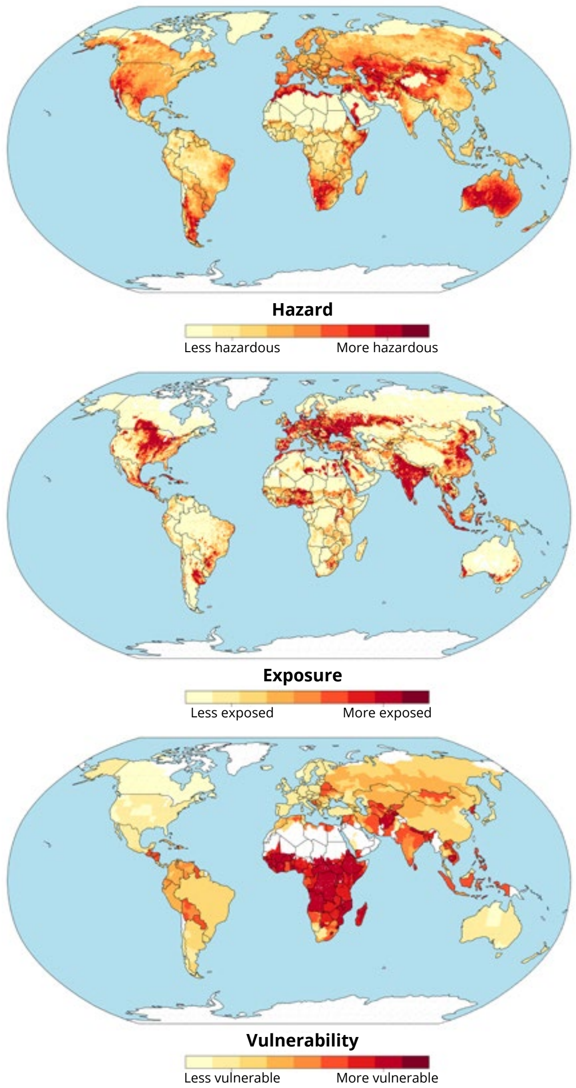

Figure 3.1. Global drought hazard according to the Weighted Anomaly of Standardized Precipitation Index (see also chapter 2), exposure and vulnerability. Source: Vogt *et al.* (2018).

Table 3.1. Description of the main sectors affected by droughts

Sector	Description
Economic impacts	A water deficit induced by drought affects production, sales and business in a variety of sectors.
Socio-economic impacts	Welfare changes experienced by human beings should be accounted for in the measures of the socio-economic impacts of drought. The social impacts of drought can affect people's health and safety, cause conflicts between people when water restrictions are required, and may result in changes in lifestyle.
Impacts on environment, forestry, wildfires and biodiversity	Drought affects the environment in many different ways. Plants and animals depend on water, and, under drought conditions, their food supply can shrink and their habitats can be damaged. Sometimes the damage is only temporary and their habitat and food supply return to normal when the drought is over. But sometimes drought impacts on the environment can last a long time or may lead to permanent land and ecosystem degradation.
Impacts on farming and livestock	Farmers might be adversely affected if a drought damages their crops. They may spend more money due to increasing irrigation costs, drilling new wells or feeding and providing water to their animals. Industries linked with farming activities, such as companies that make tractors and food, may lose business when drought damages crops or livestock.
Impacts on public water supply	Drought conditions impact water supplies by decreasing supply and increasing demand for various uses (industrial, agricultural or residential).
Impacts on surface and groundwater	Direct impacts of droughts on surface waters include reduced river flows and reservoir levels. Significant decreases in aquifer levels are the main impact of droughts on groundwater.
Impacts on power generation: hydropower, thermal and nuclear	Hydroelectricity production is related to the amount of water stored in the upper reservoirs; the production level can be lower during a drought. Peak demands for electricity then need to be satisfied by other means in the short term (e.g. gas turbines). The amount of losses depends on hydroelectricity infrastructures and drought severity. Reduced availability of cooling water can force the reduction of power generation and even shutdown of thermal and nuclear power plants during droughts.
Impacts on commercial shipping	During low-flow conditions, barges and ships may have difficulty in navigating streams, rivers and canals because of low water levels, affecting businesses that depend on water transportation for receiving or delivering goods and materials. People might have to pay more for food or fuel as a result.
Impacts on tourism and recreation	Since many activities in the tourism sector are water related, droughts can bring critical losses. Droughts have impacts on both summer and winter activities.

Source: Vogt *et al.* (2018).

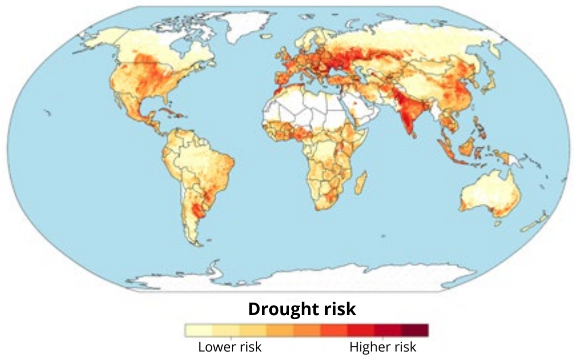

Figure 3.2. Drought risk based on the risk components shown in Fig. 3.1. Source: Vogt *et al.* (2018).

3.1.3 Understanding drought vulnerability

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity, as depicted in Fig. 3.3 (GIZ, 2014; UNFCCC, 2019). In other words, vulnerability is comprised of the physical, socio-economic and/or political factors that adversely affect the ability of communities to respond to events. It is an aggregate measure of exposure to risk and the resulting consequences. The term 'vulnerable' is used to describe socio-economic groups at risk as well as those with insecure livelihoods on the margins of society.

Vulnerability is related to the economic consequences of high susceptibility to drought. Although many developed countries face similar hazards to developing countries, their greater resource base renders them more resilient, and therefore, less vulnerable.

Table 3.2. Sectoral economic impacts associated with the 1998–2000 El Niño/Southern Oscillation-induced drought in Kenya

Effects	Associated costs	USD (millions)
Loss of crops	Crop loss	241
Loss of livestock	Livestock mortality	73
	Veterinary expenses	1
	Reduced livestock production	64
	Conflict management	<1
Forest fires	Forest destruction and damage	<1
Damage to fisheries	Reduced aquaculture production	<1
Reduced hydropower generation	Decreased income from generation	632
	Cost of import substitutes	10
Reduced industrial production	Loss of production	1,400
Water supply	Increased collection time	119
Total		2,540

Source: Cap-Net UNDP (2015).

The factors that define vulnerability in relation to drought – for example, the number of people exposed, per capita water availability, water use trends, technology, policies etc. – change over time, and therefore, vulnerability also changes. As a result, subsequent droughts in the same region will have different effects, even if they are identical in intensity, duration and spatial coverage, because societal characteristics change over time.

Instead of focusing on what has been going wrong in the past and the effects of hazards, vulnerability gives us the opportunity to focus on getting things right for

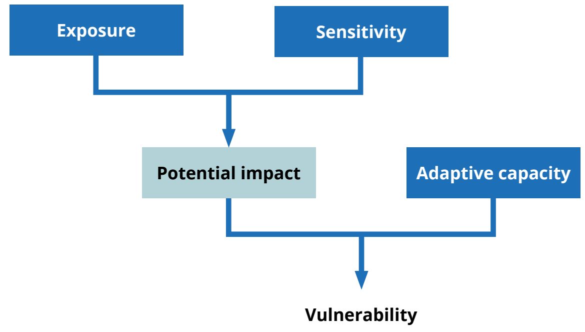

Figure 3.3. Schematic representation of the constituents of vulnerability. Source: GIZ (2014).

the future. As a future-focused concept, vulnerability is a way of using strengths and strategically improving weaknesses. Therefore, the promotion of resilient and adaptive societies requires an equally strong focus on both natural hazards and extreme weather events as well as the identification, assessment and ranking of vulnerability. Ultimately, understanding vulnerability is a prerequisite for understanding risk and the development of risk reduction and adaptation strategies to extreme events also in the light of climate change (IPCC, 2012).

Box 3.1. Vulnerability | Drought in Moldova

In Moldova, hail storms, frosts, droughts and floods have become more prevalent in recent years, with the most severe impacts felt by the rural populations who depend on agriculture for their livelihoods. During a severe drought in 2012, the Food and Agriculture Organization of the United Nations (FAO) supported the Moldova Ministry of Agriculture and Food Industry to evaluate the impact of natural hazards on standing crops, losses to main summer standing crops (maize and sunflower) and natural resources for livestock production, such as pastures and meadows. The findings of this comprehensive assessment were expanded to include recommendations to reduce the impact on small farmers. The resulting Programme of Disaster Risk Reduction identifies five technical aspects as critical bottlenecks that worsened the impact of the 2012 drought on small-scale farmers:

1. lack of fodder conservation
2. inappropriate seed varieties
3. absence of climate-smart agronomic techniques
4. poor pasture management
5. weak irrigation infrastructure for small farmers.

The implementation of disaster risk reduction initiatives is the next, crucial step to ensuring that small-scale farmers will be better prepared for the next instance of drought, by increasing their capacities, resilience and preparedness.

Source: FAO (n.d.).

Factors of vulnerability

There is common consensus on the factors that compound or alleviate vulnerability. These will be discussed below. Recent advancements have been made regarding the visualization of vulnerability on the global scale, where composite indices are used to assess vulnerability factors (Fig. 3.4).

Political factors

Vulnerability is directly linked to the political commitment to developmental and human welfare concerns. Vulnerability is as much about exposure to a given hazard as the decision-making linked to development that will address conditions of vulnerability.

Together, a set of deep-rooted, socio-economic elements, including denial of human rights, denial of access to power structures, access to quality education, employment opportunities, land tenure, availability of and access to resources, access to infrastructure, basic services and information, can create and maintain extreme levels of vulnerability. Political action is fundamental for disaster risk reduction.

Physical factors

Physical vulnerability refers to the susceptibility of individuals, households and communities to loss due to the physical environment in which they live (UNISDR, 2002). Physical vulnerability may be determined by aspects such as population density levels, remoteness of a settlement, or inadequate critical infrastructure for access to services, infrastructure and information.

Poor physical planning increases the susceptibility of individuals, households and communities to loss due to unsustainable land practices.

Economic factors

Poverty is likely the single most important factor for vulnerability; therefore, eradication of poverty is crucial to vulnerability reduction. The economic status of a population relates not only to the degree of losses in terms of lives, property and infrastructure, but also to the capacity to cope with, and recover from, adverse effects. In virtually all disasters, the

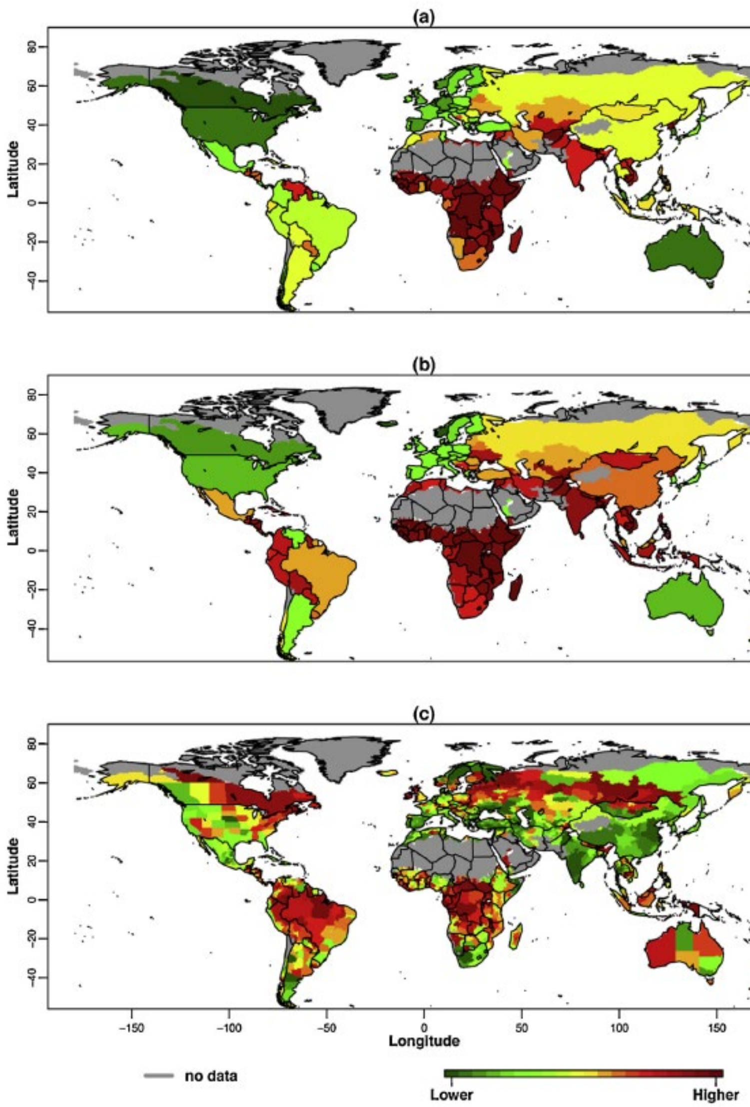

Figure 3.4. Example of global mapping of drought vulnerability factors: (a) social; (b) economic; (c) infrastructural. Source: Carrão *et al.* (2016).

wealthiest members of the population either do not suffer any adverse effects from a hazard or are able to recover quickly (due mostly to the presence of insurance, savings, investments or some other financial fallback), and often famine is the result of a lack of purchasing power to buy food, rather than the absence of food.

Social factors

The level of social well-being of individuals, households and communities directly impacts their level of vulnerability to hazards. Levels of education; literacy and training; safety and security; access to basic human rights; social equity; information and awareness; strong cultural beliefs and traditional values; morality; good governance and a well-organized, cohesive civil society, all contribute to social well-being, with physical, mental and psychological health being critical aspects. Figure 3.5 illustrates the multiple dimensions of vulnerability rooted in the dimensions of inequality and how they impact on a population's vulnerability to risk (Field *et al.*, 2014).

Vulnerability is not equally distributed. Minority groups, elderly people, orphans, persons with disabilities, and nursing mothers and their children are more vulnerable than others. The issue of gender, particularly the role of women, requires special consideration.

A lack of awareness and access to information can also result in increased levels of vulnerability. Drought risks increase because vulnerable people simply do not know what will happen and/or how to heed early warnings. Such ignorance may not necessarily be a function of poverty but a lack of effective dissemination and response procedures.

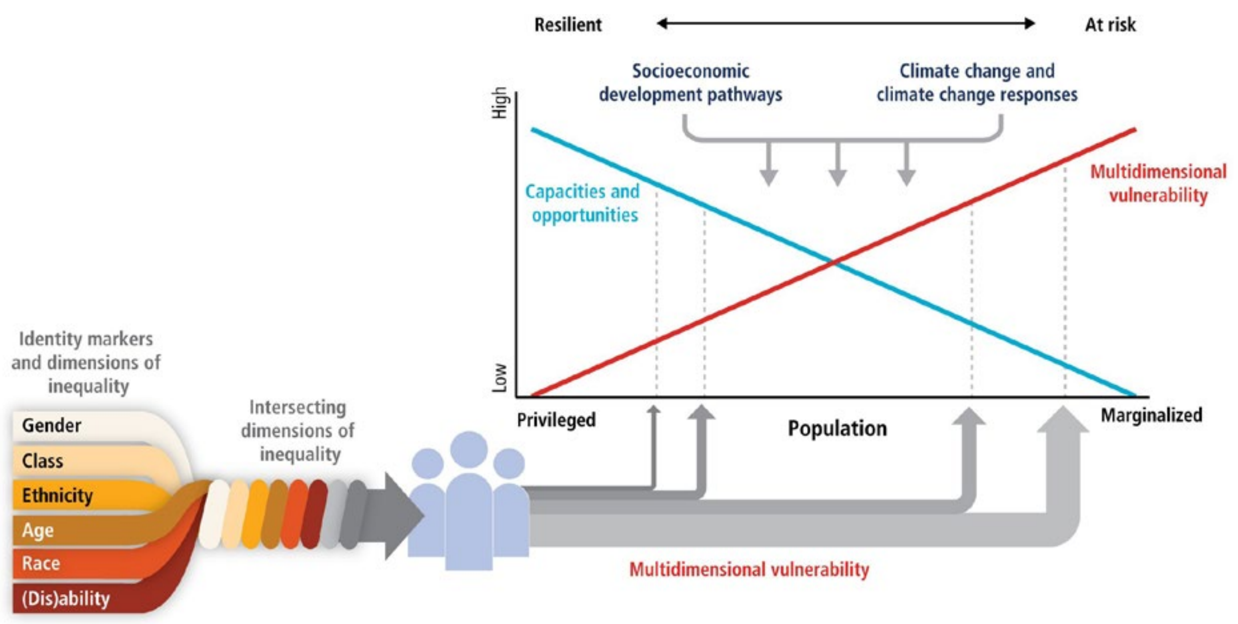

Figure 3.5. Multidimensional vulnerability driven by intersecting dimensions of inequality. Vulnerability increases when people's capacities and opportunities to adapt and adjust to climate change responses are diminished. Source: Field *et al.* (2014).

Environmental factors

Environmental aspects of vulnerability cover a very broad range of issues at the intersection of social, economic and ecological aspects of sustainable development relating to disaster risk reduction. The key aspects of environmental vulnerability can be summarized using the following five distinctions:

- The extent of natural resource depletion
- The state of resource degradation
- Loss of resilience of the ecological systems
- Loss of biodiversity
- Exposure to pollution, especially water pollution that reduces freshwater water availability during drought.

Many disasters are either caused or exacerbated by environmental degradation. The creation of drought conditions and their severity and length are mainly caused by natural phenomena. Drought conditions may be exacerbated by:

- poor cropping patterns
- overgrazing
- topsoil stripping
- poor conservation techniques
- depletion of both the surface and subsurface water supply
- unchecked urbanization.

Progression of vulnerability

Factors contributing to vulnerability are subject to change over time. The disaster Pressure and Release (PAR) model has become the internationally accepted model to explain the progression of vulnerability and risk reduction. The PAR model indicates that there are certain underlying causes, dynamic pressures and unsafe conditions that contribute to vulnerability. Linking the above PAR model to a hazardous trigger event increases the risk in communities.

Vulnerability, then, is depicted in the PAR model as the progression of three stages (Table 3.3):

1. **Root causes:** a deep-rooted set of factors within a society that together form and maintain vulnerability
2. **Dynamic pressures:** a translating process that channels the effects of a negative cause into unsafe conditions; this process may be due to a lack of basic services or provision or it may result from a series of macro-forces
3. **Unsafe conditions:** the vulnerable context where women and men and property are exposed to the risk of disaster. The fragile physical environment is one element; other factors include an unstable economy and low income levels.

The progression of vulnerability model plays an integral part in understanding community vulnerability and why communities are susceptible to disaster risks. It clarifies that the main focus in reducing risks in communities is to address a significant number of development and socio-political issues. The pressure experienced through the progression of vulnerability needs to be reversed.

Table 3.3. Structure of vulnerability and disasters

Progression of vulnerability Pressure and Release (PAR) Vulnerability Framework			Disasters	Hazards
Root causes	**Dynamic pressures**	**Unsafe conditions**		
Limited access to: Resources Structures Power **Ideologies** Political systems Economic systems	**Lack of:** Institutions Training Skills Investment Markets Press freedom Civil society **Macro-forces** Population growth Urbanisation Arms expenditure Debt repayment Deforestation Soil degradation	**Fragile physical environment** Dangerous locations Unprotected structures **Fragile local economy** Livelihoods at risk Low income **Vulnerable society** Groups at risk Little capacity to cope **Public actions** Lack of preparedness Endemic disease	RISK = HAZARD + VULNERABILITY	Earthquake Wind storm Flooding Volcano Landslide Drought Virus and pest Heatwave

Source: Blaikie *et al.* (1994).

Although analysing disasters should not be segregated from everyday living, assessment of disasters frequently focuses only on the role of trigger climate factors, such as natural hazards or events. An example from South Sudan (Fig. 3.6) illustrates why such an approach is incomplete and inadequate for understanding disasters. Violent conflicts in South Sudan increase vulnerability by damaging social processes, capacities and opportunities to anticipate disaster-related needs or prioritize resilience and coping mechanisms. Consequently, the damage or loss of life and property at the time of a disaster is compounded by the affected communities' inability to rebuild homes and livelihoods, making them more vulnerable to the effects of future hazard events.

3.1.4 Drought risk management and gender

Environmental issues, such as adverse impacts of weather and climate, are gendered (WMO, 2019). Men and women have different socially constructed roles, resulting in different patterns of use and control rights over different natural resources specific to context, and subsequently, they are effected by risk in different ways (see Fig. 3.7). These complex interactions between socio-economic context, multiple inequalities and poverty, along with weather and climatic events, create an ever-shifting context of risk (Olsson *et al.*, 2014).

The significant and underlying challenge of sustainable and resilient dryland governance is the political framing of policies, along with the prioritization of economic policies, when they are essentially based on the notion of a male citizen, which can marginalize the interests of dryland communities, particularly pastoralists, and women (Forsythe *et al.*, 2015).

Policy attention needs to address women's ownership and access to resources, such as advisory services and farm inputs. Considering women's knowledge of management roles, design of technologies and policies needs to prioritize their relevance to women, building on women's knowledge and involving them in decision-making. Establishing partnerships and forums, enhancing capacities, promoting better access to educational opportunities and health care, legalizing women's land rights and developing gender-sensitive land ownership regimes are part of the solution.

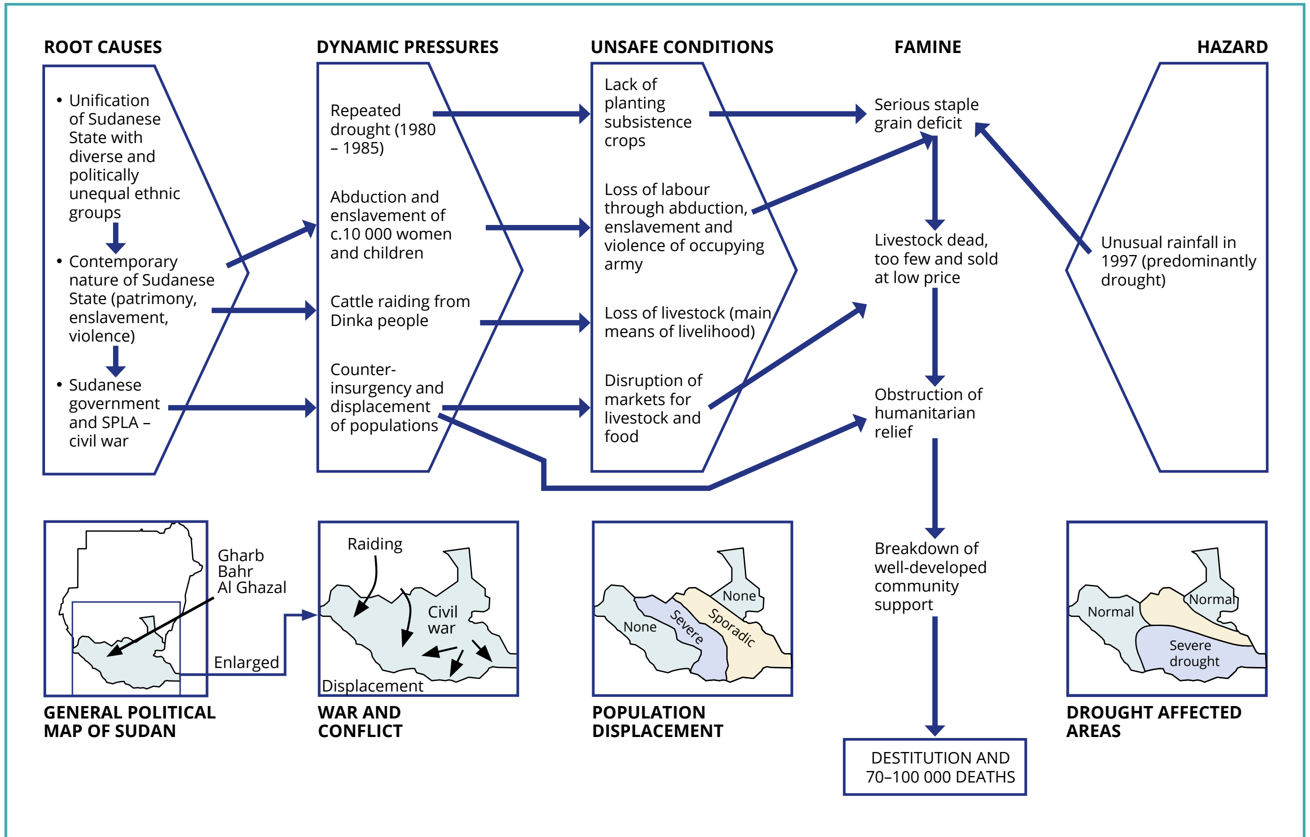

Figure 3.6. PAR model of famine in South Sudan. Source: Wisner *et al.* (2004).

Incorporating gender issues into the entire project lifecycle and stages of initiatives, with support from financial mechanisms and organisations that promote sustainable land management in drylands, would reinforce these measures (UNCCD, n.d.).

A review by the Global Water Partnership (GWP) on the key ingredients for supporting gender equality in water management has identified a general recommendation to strengthen the evidence and business case for inclusive water resources management (GWP, 2017) (Table 3.4).

3.2 Framework for impact and vulnerability assessment

At the moment, the assessment of drought impacts and vulnerability to drought are the key elements in proactive drought management and will enable informed preparedness actions to increase drought resilience. However, as addressed during the first part of this chapter, the identification of vulnerability to drought poses a variety of challenges due to its complex nature.

The draft framework proposed in this manual is intended to guide the process of impact and vulnerability assessment. It is important to realize that vulnerability is linked to the drought hazard (Pillar 1, chapter 2) and ultimately aims at identifying preparedness actions that reduce vulnerability (Pillar 3, chapter 4). Rather than presenting in-depth explanations of each step, the aim of this draft framework is to give a logical structure to how impact and vulnerability assessments can be approached and what questions should be asked (and answered) during the process.

It is important to note that even though the steps are mentioned in a linear order, the assessment process can be iterative in nature for many aspects. Also, stakeholders should be involved in all steps of the assessment to gather relevant information and address important aspects of the analysis, such as equity, cultural awareness, urgency and appropriateness (WMO and GWP, 2014). Stakeholder involvement also increases awareness and acceptance of decisions due to participation in the assessment process, which is a crucial part of an effective early warning system.

The following publications served as a base for the formulation of this draft framework, and further reading is encouraged:

- *National Drought Management Policy Guidelines: A Template for Action* (WMO and GWP, 2014)

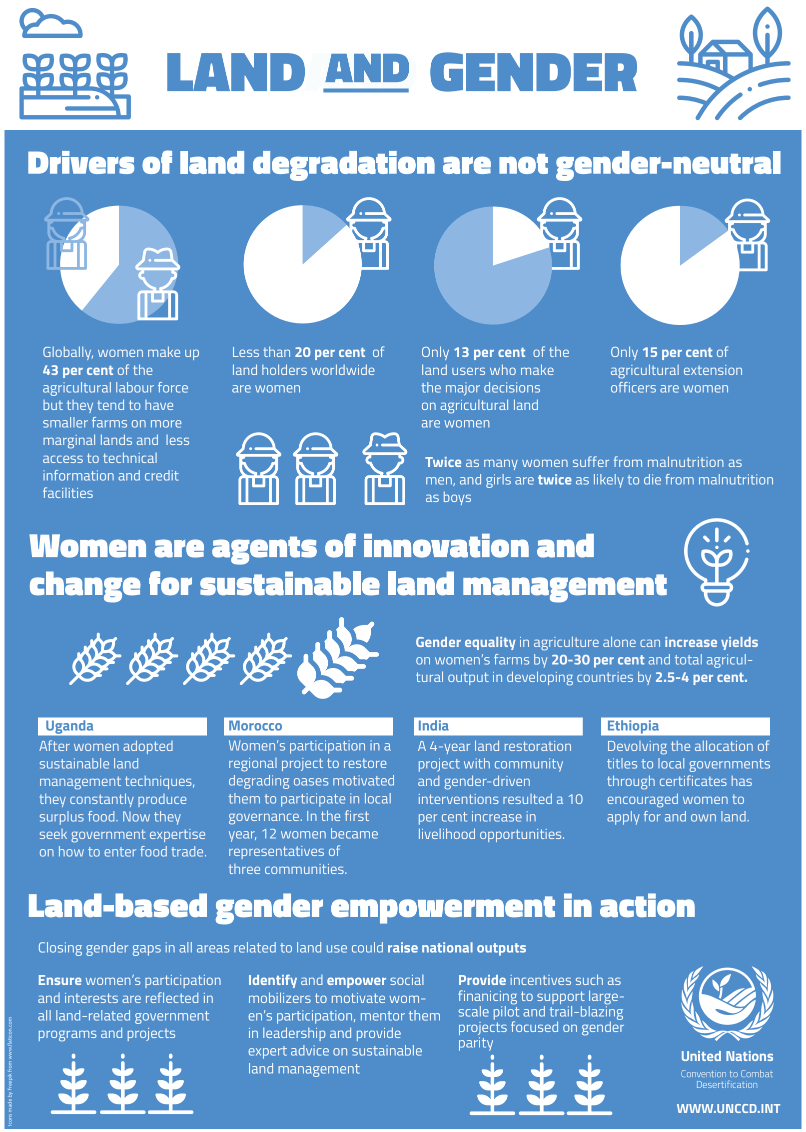

Figure 3.7. Facts on the status of gender equality in land and resource management. Source: UNCCD 2019); https://www.unccd.int/actions/gender-action-plan.

Table 3.4. Action areas identified in order to leverage gender equality in water resources management

Action area 1 – Institutional leadership and commitment **Make gender equality and inclusion a core business goal** Inclusive water programmes and policies lead to greater economic, environmental and social sustainability. To make this a reality, organisations must ensure they have the right processes, systems, leadership and resources. To institutionalize inclusive practices – and to bridge the gap between policy and practice – leadership is needed at all levels of an organisation. Young female leaders, for example, need to be taken seriously and have important roles in organisations.	**Action area 2** – Gender and inclusion analysis that drives change **Conduct gender and inclusion analysis at all levels** Quality analysis is necessary to ensure that equality is maximized. Analysis should include the current gender and equality context (to identify issues of exclusion) as well as the projected impacts of any intervention on members of the community (women and men, boys and girls, transgender people, people with disabilities and marginalized people). The analysis must then influence programme and project design, legal frameworks, etc. It is also important to draw on gender analysis frameworks to guide monitoring, evaluation, and learning choices.
Action area 3 – Meaningful and inclusive participation in decision-making and partnerships **Adopt a 'nothing about them without them' approach** To include people who will be affected by a water management decision is about more than just numbers, it is about 'meaningful' participation. This includes training, financial support, long-term engagement, and working in partnership with organisations such as women's, indigenous peoples' and disabled peoples' organisations.	**Action area 4** – Equal access to and control of resources **Create a level playing field with respect to access to and control of resources** Significant efforts are needed to ensure that access to and control of resources – both land and water – make ownership more inclusive. Legal barriers need to be addressed as well as customary law and cultural practices. Given the sensitivity of these issues, marginalized peoples themselves are best placed to inform strategies around unlocking these barriers to equality.

Source: GWP (2017).

- *Assessing Drought Hazard and Risk: Principles and Implementation Guidance* (World Bank, 2019).
- *A Framework for Climate Change Vulnerability Assessment* (GIZ, 2014).

3.2.1 Task A – scoping phase

In this phase, the purpose and the general approach of the assessment should be defined. The following questions can help with the scoping process:

- What is the problem and context?
- What is the objective of the assessment? Which questions should be answered by the assessment?
- What is the scope and/or the boundaries of the assessment?
  - What sectors should be included?
  - What spatial scale is addressed (i.e. local, (sub) national, regional, global)?
  - What is the time horizon captured (i.e. current/ future, short-term/long-term)?

3.2.2 Task B – impact assessment

In this phase historical, and possibly current, drought impacts are assessed by collecting and analysing data according to the scope of the assessment. Annex 1 of the *National Drought Management Policy Guidelines* (WMO and GWP, 2014) provides a checklist of possible impacts that can be used as a template. Since this checklist is focused on impacts on agriculture, it will likely have to be extended to suit the multisectoral approach to impact assessment established in recent years.

In a further step, different types of drought impacts are classified according to drought severity. Here, the progression of vulnerability must be considered, which may change the drought severity class assigned to a future impact. By analysing past, current and potentially future impacts, trends may become visible that are useful for proactive drought planning. Impact assessments lay the groundwork for vulnerability assessment by identifying sectors, populations or activities that are vulnerable to drought.

A ranking of the identified relevant impacts can help in identifying which impacts should be addressed as priorities and which ones are less urgent to deal with. Questions for prioritization of impacts may include (WMO and GWP, 2014):

- What are the costs of mitigation actions?
- What is the geographical extent of the impact?
- What is the impact's trend over time?
- Is this impact considered a public priority?
- Does targeting this impact increase fairness in drought recovery?

3.2.3 Task C – vulnerability assessment

Vulnerability assessments address the underlying causes to drought impacts, and thereby, bridge the gap between impact assessments and preparedness policy formulation. One way to approach a vulnerability assessment is to employ an impact tree diagram, starting with the assessed impacts and asking for the causes of these impacts, as depicted in Fig. 3.10 for the agriculture sector (WMO and GWP, 2014). In some cases, it might be helpful to distinguish between exposure, sensitivity and adaptive capacity of a system affected by drought in order to obtain a more precise image of the vulnerability of the system of interest (GIZ, 2014).

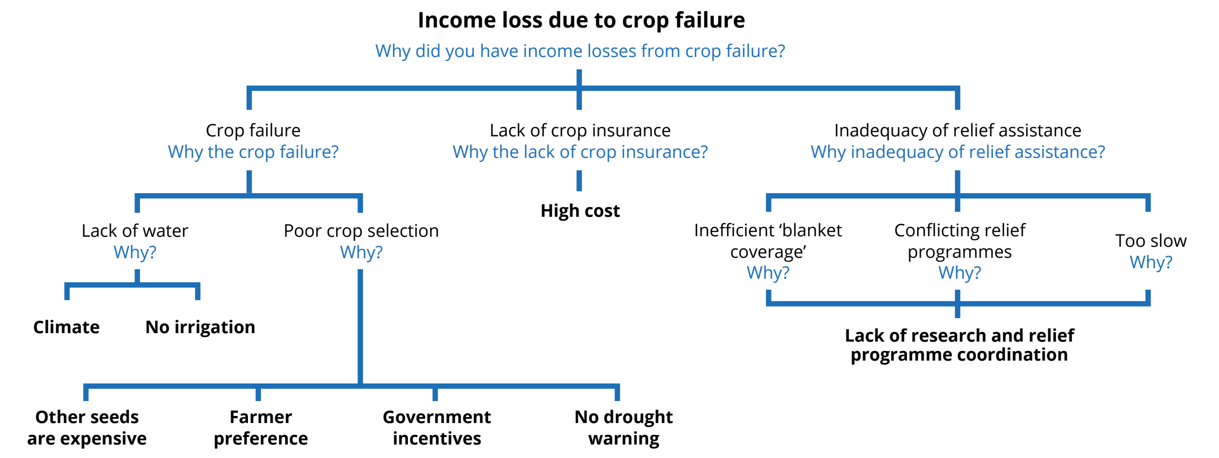

Figure 3.8. An example of a simplified agricultural impact tree diagram. Source: FAO and NDMC (2008).

3.3 Methods for impact and vulnerability assessments

3.3.1 Overview of methods, tools and datasets for impact and vulnerability assessments

A recent review by the United Nations Convention to Combat Desertification, FAO, GWP and WMO identified relevant approaches to drought impact and vulnerability assessment (UNCCD *et al.*, 2019). The appropriate methods for both impact and vulnerability assessment can be identified by answering the questions of Task A of the impact and vulnerabilities assessment framework. Table 3.3 summarizes relevant methodological approaches to impact assessment (Task B in the assessment framework). The approaches to vulnerability assessment (Task C in the assessment framework) presented here are largely bottom-up approaches, meaning that the focus of the assessment lies on the underlying development context of why people are sensitive and exposed in the first place. In other words, these assessments address the question of who and what is at risk and why. As described in the draft framework for impact and vulnerability assessment, the selection of an appropriate method depends on the defined scope of the assessment. The summaries of vulnerability assessment approaches given in Tables 3.4 and 3.5 are grouped into on-ground, national-level and global-level assessments.

Table 3.5. Methodological approaches to assessment of drought impacts

Methodological approaches	Short characterization of approach	Examples of relevant methods, tools and datasets	Links or references to examples	Strengths	Weaknesses
Post-disaster Needs Assessment (PDNA)	Inter-agency collaborative assessment done in-country to define scope and priorities for coherent disaster response	See two volumes of guidance materials (GFDRR, 2013). Relies mainly on national statistics	GFDRR (2018a; 2018b; 2017; 2012)	Economic case is presented. Methods are comprehensive: cross-sectoral, long-term view. The methods are intended to be multi-scale and include fieldwork	Time constraints may compromise application of the methods. The connection to the local level and affected communities is acknowledged to be weak, especially where time-frames are constrained. Heavily reliant on pre-existing data accessible in country
Global Rapid post-disaster Damage Estimation	Proposed new method for desk-based precursor to above	Relies mainly on remote sensing and WorldPop. Relatively new/untested	Gunasekera *et al.* (2018)	Compatible with PDNA. Rapid, inexpensive	Connection to the ground non-existent – approach is rapid and desk-based. Unlikely to consider the needs of most vulnerable. Heavily reliant on pre-existing data accessible outside country
Emergency Events Database	Compilation of cases	Relies on contributors' methods	https://www.emdat.be/	Economic case is presented for proactive management approach. Includes private sector, insurance companies, etc. Covers a long period	Incomplete; assessment methods depend on agencies contributing. Relies on secondary data, lacks in-depth details – e.g. does not identify geographical locations and extents

Source: slightly adapted from UNCCD *et al.* (2019).

Example: Drought impact reporter initiatives
US drought reporter

The National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln is addressing the lack of a consistent dataset on the consequences of water shortage by creating a web-based Drought Impact Reporter (DIR) for the USA that has the following primary functions (Wilhite *et al.*, 2007):

- to create a database archive of drought impacts information
- to provide an interactive map delivery system that is efficient and user-oriented
- to build links with government agencies, non-governmental organisations, university research groups and extension programmes, and others, including the public, to provide timely impact reports to ensure a comprehensive collection of drought impacts across all potential sectors and scales
- to foster a continual process of user feedback, evaluation, assessment and dissemination of drought impacts.

The DIR for the USA was launched in July 2005 and is available on the NDMC's website (http://drought.unl.edu).

European Drought Impact Database
http://www.geo.uio.no/edc/droughtdb/edr/impactdatabase.php

Table 3.6. Methodological approaches to assessment of drought vulnerability at the local and subnational scale

Sectoral focus of approach	Short characterization of approach	Examples of relevant methods, tools and datasets	Links or references to examples	Strengths	Weaknesses
Community-based resilience and livelihoods assessment approach	Focuses on people, their assets and ability to recover from drought	Participatory Rapid Appraisal (PRA) and secondary datasets: household surveys, census, project-driven databases, etc.	Dazé *et al.* (2009); PROVIA (2013) www.ihsn.org **See case study 2 in section 3.4**	Ensures people-centred analysis, broader than income only. Includes presentation of economic case at household level. Can accommodate long-term time horizon. Considers capacities of different kinds. Familiar to practitioners. Connects to agro-ecosystems	Data-intensive and time-consuming. Focuses on household scale – may not be multi-scale. May not capture effects on the national and regional economy. Can favour recommendations to diversify the livelihood portfolio. Often misses identification of strategic water management solutions
Ecosystem-based agroecological approach	Focuses on ecosystems, their productivity and responses to climate extremes	PRA: seasonal calendars Remote sensing of landcover/use systems and climate Crop-water response and bio-economic models (including livestock) Value chain analysis Ecosystem service valuation	www.seea.un.org. (See also: FAO LADA project [FAO, 2013] and CBD (2019); Cowie *et al.* (2018); ELD (2015); ELD and UNEP (2015); INWEH (2011); Swiderska *et al.* (2018)	Ensures coverage of resource-dependent production systems. Can connect to climate models and to economic models. Can be mapped and monitored at low cost using satellite-derived data. Many agricultural adaptation options likely to be identified. Familiar to agricultural extension systems and capacities in place	Inclusion of poor and marginal groups. Not always systematic. More orientated to agriculture than other sectors. May not capture vulnerabilities in urban areas. Not necessarily long-term. Focuses on field scale – may not be multi-scale. May have relatively short time horizons. Does not consider water needs in other sectors of the economy

Table 3.6. Methodological approaches to assessment of drought vulnerability at the local and subnational scale (continued)

Sectoral focus of approach	Short characterization of approach	Examples of relevant methods, tools and datasets	Links or references to examples	Strengths	Weaknesses
Water balance accounting and basin management approach	Focuses on water availability, and relation to demands from different sectors of the economy	Climate information and models, PAR: resource mapping Water resource accounting (Sustainable Development Goal [SDG] 6.4) and demand estimates Global and catchment hydrologic models, remote sensing and Geographic Information Systems (GIS)	He *et al.* (2017); Pedro-Monzonís *et al.* (2016); SEEA (2017); UN-Water (2017) https://seea.un.org/content/seawater	Considers water availability and demand across the economy, including in urban areas. Makes effective use of climate models and scenarios. Connects to drought monitoring and early warning systems. Can enable identification of capacity needs. Can enable identification of risk management actions	Institutional challenges to coordinate data collection, management and analysis. Data on water extractions often incomplete in drought-affected areas. May require information on groundwater management. Municipal and industrial water extractions growing faster and less well understood than agricultural water use. Transboundary issues, political and security sensitivities in some countries

Source: UNCCD *et al.* (2019).

Table 3.7. Methodological approaches to assessment of drought vulnerability at the national and international levels

Sectoral focus of approach	Short characterization of approach	Examples of relevant methods, tools and datasets	Links or references to examples	Strengths	Weaknesses
National approaches					
Macroeconomic assessment approach	Focuses on implications for national economic development planning	National wealth accounts and gross domestic product national economic growth models	GFDRR (2012); IBRD (2005); Venton (2018); Venton *et al.* (2019)	Can explore long-term economic effects of drought on the economy and justify improved national decision-making	Often overlooks informal economies where most vulnerable populations earn their living. Economic assessments are controversial and often contested/rejected
Institutional analysis	Focuses on stakeholder dynamics, communication and power relations	Mapping institutions, Venn diagrams, network analysis	King-Okumu *et al.* (2017) **See case study 1 in section 3.4**	Situates assessment in governance context. Provides roadmap for design of assessment process	Subjective, political, dynamic. To identify and include all relevant stakeholders can be challenging/endless

Table 3.7. Methodological approaches to assessment of drought vulnerability at the national and international levels (continued)

Sectoral focus of approach	Short characterization of approach	Examples of relevant methods, tools and datasets	Links or references to examples	Strengths	Weaknesses
Inclusive approach	Focuses on design of the consultation process	Targeting focus groups, e.g. gender analysis (SDG 5). Disaggregated datasets	Askin *et al.* (2012); IBRD (2010)	Ensures inclusion of women and marginal groups. Can identify capabilities of these groups as well as vulnerabilities	May be time-consuming and logistically challenging. Inclusion of random token representatives not always effective. In pre-existing conflict situations can be sensitive.
Global approaches					
Tracking of SDGs	Datasets tracked at the national level	SDG Targets 1.5, 6.4, 15.3	https://sustainabledevelopment.Un.org/?menu=1300	All countries have committed, and international community intends to support	Focus on national-level datasets. Does not effectively target the most drought-prone regions within countries
Global vulnerability map	Component of global drought risk map (alongside hazard and exposure maps)	Global generic indicators and GIS	Carrão, *et al.* (2016) **See also Fig. 3.4 and section 3.3.2**	Visual comparative exposure map is effective and powerful: http://edo.jrc.ec.europa.eu/scado/php/index.php?id=3000	Disconnected Timebound Vulnerability map does not stand alone without exposure map. Data flaws

Source: UNCCD *et al.* (2019).

3.3.2 The use of indicators and indices in impact and vulnerability assessment

Indicators and indices are considered valuable tools because of their functionality in synthesising complex conditions and developments. This is especially useful in the context of increasing tangibility of drought impacts and drought vulnerability during the development of policies and drought management plans. For example, recent efforts have led to the indicator-based visualization of vulnerability on a global scale – a powerful visual tool to acquire a first image of vulnerable regions (Fig. 3.4; Carrão *et al.*, 2016; UNDRR, 2019; Vogt *et al.*, 2018). Indicators appear to be useful because they synthesize and simplify the description of complex states of affairs, such as the vulnerability of households, regions or countries, into a single number that can then be easily used by policymakers (Hinkel, 2011).

However, a major concern is that many of the developed indicators have failed to live up to this expectation and have been criticized as not being scientifically sound or policy relevant. The detailed and diverse outputs of vulnerability assessments using bottom-up approaches are in danger of not being properly reflected because they are often qualitative and not quantitative of nature.

As an example, adaptive capacity can be estimated by the presence of certain village institutions that allow villagers to organize resource conservation activities. Indicators are chosen based on the identification of factors that drive vulnerability and adaptive capacity and are, therefore, case specific (Hinkel, 2011).

Despite the limitations of assessment approaches, indicators can be powerful tools if used carefully and with their limitations highlighted. Generally, vulnerability is assessed in a composite index using the aggregation of proxy indicators, thereby accounting for the different factors or aspects of vulnerability.

In the following, two examples are given that either assemble a vulnerability value based on vulnerability factors (Naumann *et al.*, 2014) or refer to vulnerability as a composite of exposure, sensitivity and coping capacity (Ortega-Gaucin *et al.*, 2018).

Drought vulnerability indicator

$$DV_i = \frac{Soc_i + Econ_i + Infr_i}{3}$$

where Soc_i, $Econ_i$ and $Infr_i$ are the social, economic and infrastructural vulnerability factors for region *I*, respectively (Naumann *et al.*, 2014).

This indicator was developed for a regional application in Africa (Naumann *et al.*, 2014), but it was also applied to map drought risk on a global scale, as shown in Fig. 3.4 (Carrão *et al.*, 2016). The latter study employed a separate approach to inventory drought exposure by identifying the different types of physical entities that are on the ground, such as built assets, infrastructures, agricultural land and people.

Standardized Drought Vulnerability Index

This approach uses the model proposed by the Intergovernmental Panel on Climate Change (IPCC, 2014), which explains vulnerability as a function of three components: exposure (*E*), sensitivity (*S*) and adaptive capacity (*AC*):

$$SPI = f(I — AC) = f(E + S — AC)$$

Here, *V* is the overall vulnerability, and *I* refers to the potential impact of the disaster. This approach was used for mapping vulnerability in Mexican municipalities (Ortega-Gaucin *et al.*, 2018).

In general, adequate indicators and methods of analysis are identified for each component of vulnerability, e.g. exposure, susceptibility and adaptive capacity. Following the vulnerability criteria identified, the areas are mapped and classified based on their levels of vulnerability, such as low, moderate, high and very high, according to a set of criteria. In a further step, all components of vulnerability are normalized and weighted in order to aggregate them into a vulnerability index.

Desirable attributes in a vulnerability index

Developing indicators requires care and a clear definition of the purpose and context to which it will be applied (Hinkel, 2011). Practically speaking, the development of indicators involves three basic steps (Hinkel, 2011):

1. Definition of what is to be indicated – scoping the assessment
2. Selection of the indicating variables that best describe best the goal of the assessment
3. Aggregation of the indicating variables.

Additionally, if the index is to receive support and be operational, it must satisfy a number of criteria:

- **Simplicity**. Ease of comprehension by decision-makers and other users of the index. It also permits replication by third parties for evaluation and verification.
- **Affordability**. Data must be relatively easy to obtain and process. Preferably they should be collected as a matter of routine together with the information required for the management of water.
- **Suitability for international and temporal comparisons**. Indices developed for the purpose of comparing scores across the country (or countries) must be based on variables that are measured in a homogenous manner geographically and temporally.

Finally, these are the main barriers to a comprehensive vulnerability assessment, irrespective of the scale of assessment:

- incomplete knowledge of the relevant vulnerability factors and their interactions
- challenge to include the perspectives of the affected resource users and marginalized groups
- insufficient data on existing conditions
- difficulty in developing the local and regional scenarios of future change, including climate change
- lack of appropriate analytical methodologies for some impacts.

Further information on the available tools for impact and vulnerability assessments can be obtained from these websites:

Examples of vulnerability and risk assessment reports for many countries and regions: http://www.droughtmanagement.info/pillars/vulnerability-impact-assessment/

https://knowledge.unccd.int/drought-toolbox

https://droughtcatalogue.com/en/index.php/catalogue

Customized assistance can be obtained from the Integrated Drought Management HelpDesk: http://www.droughtmanagement.info/ask/ask-form/

3.4 Case studies

3.4.1 Case study 1: Assessing vulnerability to drought at the basin level in Mexico

In Mexico, a series of drought events during 2010–2013 led to the establishment of the Intersecretarial Commission for Drought and Flood Attention to create and implement a national drought policy. The National Programme Against Drought (PRONACOSE) was initiated in 2013 as a guiding mechanism for this process under the coordination of Mexico's National Water Commission (CONAGUA). The programme's goal is to adopt a series of preventive and mitigating measures to reduce the population's vulnerability to drought.

In an attempt to standardize the approach to vulnerability assessment countrywide, Drought Prevention and Mitigation Measures Programmes (PMPMS) were created in 26 watershed councils across the country (as well as in 13 cities). Standardized guidance on the scope of the assessment was prepared by the Instituto Mexicano de Technologia and given to investigators of selected universities. The uneven and limited availability of datasets, however, hindered the application of consistent procedures or methods. Therefore, refinements were made, which resulted in the development of a standardized drought vulnerability index for vulnerability mapping to the level of municipalities (Fig. 3.9; see also section 3.3.2 on indicators). During this process, a strong focus was given to the scoping and selection of indicators, followed by the gathering of information and the weighting and normalization of the calculated indicators. For further information on the vulnerability indicators used, please refer to Ortega-Gaucin *et al.* (2018).

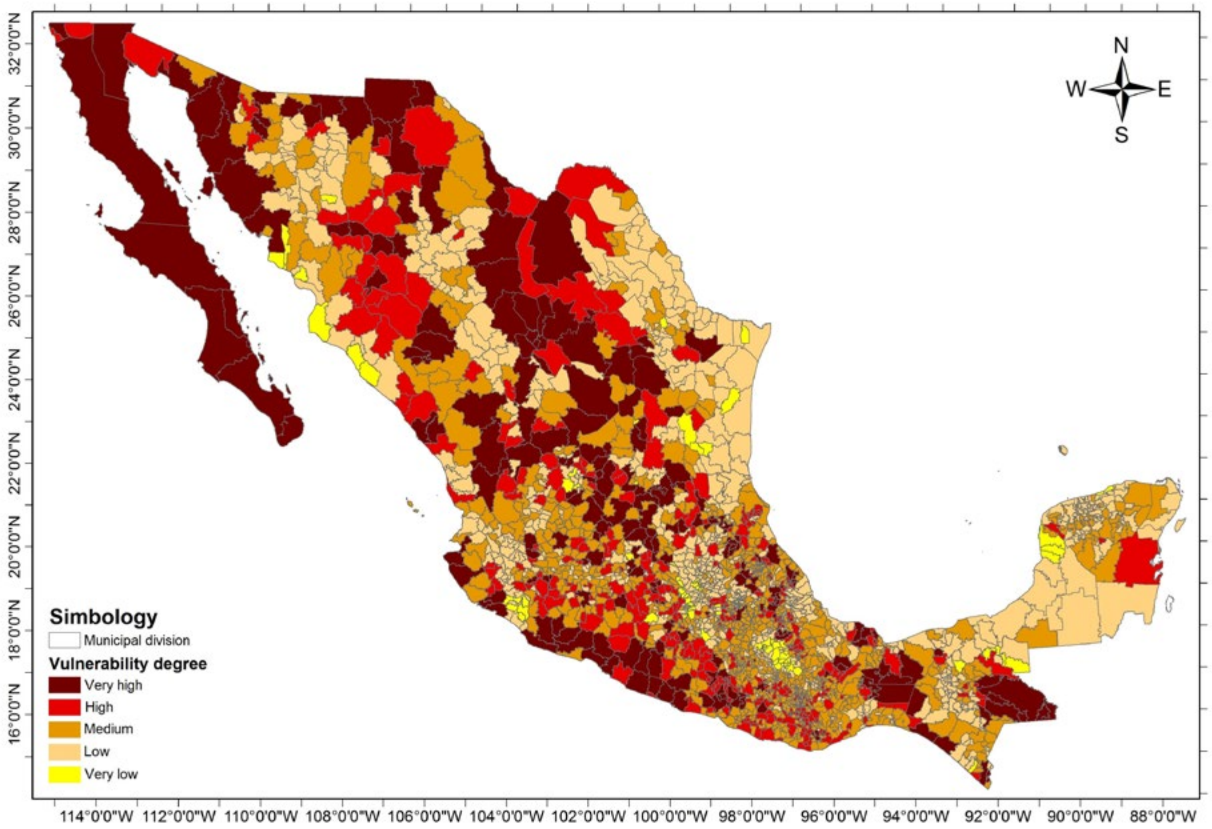

Figure 3.9. Map of overall vulnerability to drought as assessed with the standardized vulnerability index, using indicators for social, environmental and economic vulnerability. Source: Ortega-Gaucin *et al.* (2018).

CONAGUA staff and researchers from 12 national institutions were trained to standardize the activities and contents of these programmes, which were implemented in the second and third years of PRONACOSE (2014–2015). After evaluation of the implemented programmes in 2016–2017, the programmes were to be improved, updated and implemented again starting in the sixth year (2018). Ownership of the programmes by the basin councils will ensure the continuation of the gradual implementation beyond the sixth year.

The following lessons and best practices were learned during the process in Mexico:

- methodological debates, data limitations and uncertainties can be overcome by applying a pragmatic approach
- using the best available assessment tools enables participation by stakeholders in a practical review process
- a progressive use and review of methodologies and insights encourages improvements to available tools and methods over time
- the engagement of the watershed councils in the review process is essential to increase ownership because these councils include representatives of all water users.

The creation of ownership and stakeholder engagement is crucial to the process and is key to overcoming challenges that arise when trying to bring their members together to agree on actions that will reduce vulnerability to drought instead of increasing competition for scarce resources. As part of this process, councils require periodic training and re-training to be able to respond collectively, as proposed in PMPMS recommendations. In essence, the success of PRONACOSE and PMPMS relies on the watershed councils' ability to own the vulnerability assessment, collectively assimilate problems and build the necessary consensus among stakeholders to implement solutions. This inclusive consensus-based approach is a social process that requires time and proactive effort, but it is the best way forward because during drought, joint efforts will have the greatest chance to reduce vulnerabilities.

Source: Ortega-Gaucin *et al.* (2018); UNCCD *et al.* (2019).

3.4.2 Case study 2: Surveying, profiling and evaluating vulnerability to drought in Ethiopia

Since 2011, the Government of Ethiopia has been working to institutionalize Woreda Disaster Risk Reduction (DRR) Planning, which involves developing Woreda Disaster Risk Profiles (WDRPs) and DRR plans.[1] The vulnerable areas are mapped in WDRPs, which are managed by the Disaster Risk Reduction Directorate of the National Disaster Risk Management Commission. Various tools have been prepared for WDRP data collection and for implementing other disaster risk management and DRR activities, including a WDRP training manual, mitigation/adaptation plan guidelines, contingency plan guidelines, DRR mainstreaming guidelines and different standardized questionnaires and checklists. Capacity-building activities were carried out on WDRP and DRR planning and mainstreaming guidelines and tools.

The WDRPs were established with the participation of stakeholders from government and non-governmental organisations. These include the federal, regional, zonal and woreda experts and organisations such as the World Bank, UNICEF, United Nations Development Programme, World Food Programme, Spanish Aid, CordAid and others. In addition to their technical input, development partners also provided financial support for the exercise. Validation of the WDRPs and DRR plans was carried out immediately after the data collection. Endorsement by decision-makers was a key component at regional, zonal and woreda levels to ensure mainstreaming of disaster risk mitigation and adaptation strategies into sectoral development plans at woreda level. For each WDRP, sector-specific information was collected on crop production, livestock production, human health, water and sanitation, environment and other factors related to community coping mechanisms and suggestions.

Three kinds of study tools have been used as part of the primary surveys. The first two of these tools are qualitative, while the third one is quantitative:

- Focus group discussions
- Key informant interviews
- Household sample surveys.

As of April 2017, WDRP data were collected for 412 woredas. Out of these, profiles have been developed for 345 woredas. Through this exercise, the majority of disaster-prone woredas of Ethiopia have been covered. The vulnerability mapping and assessments of household assets are used to inform a major social protection planning and drought relief effort in Ethiopia.

Source: ACCRA (n.d.); European Commission (2018); UNCCD *et al.* (2019)

1 For more information on this process, please refer to https://www.weadapt.org/sites/weadapt.org/files/legacy-new/placemarks/files/5460989a93d42accra-eth-drm-planning-july14-fv-web.pdf

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4 Drought mitigation, preparedness and response (Pillar 3)

4.1 Introduction to drought management planning

Droughts are defined by their impacts, which depend on the severity and duration of drought coupled with societal vulnerability. Vulnerability to impacts can be reduced by ensuring that preparedness is the cornerstone of national drought policy (NDPC, 2000). In many places, that is not the case, and much effort and resources are spent in disaster relief, post-disaster recovery and rehabilitation rather than on pre-disaster preparedness and prevention measures. This invariably causes immense loss of lives, human dislocation and economic losses. In well-prepared situations, losses are relatively low for the same scale of events.

A passive attitude to drought risk creates a tendency simply to react when crises strike. While some element of reactivity is not entirely avoidable, it could be minimized with risk reduction measures put in place that are proactive, i.e. before a drought occurs. Drought management must anticipate the inevitable – droughts are a recurrent normal feature of the climate – and develop an approach that seeks to minimize the effects of drought before a drought episode occurs.

In general, disaster management is referred to as the organisation, planning and application of measures preparing for, responding to and recovering from disasters (UNISDR, 2017). It is important to note that disaster management may not completely prevent disasters or eliminate the threats; it focuses on creating and implementing preparedness and other plans to decrease the impact of disasters and to 'build back better'. Failure to create and apply a coordinated approach to risk management could lead to damage to life, assets and revenue (UNISDR, 2017). Disaster management should be distinguished from emergency management, even though these terms are used interchangeably. However, the term emergency can also refer to hazardous events that do not result in a disaster, meaning a serious disruption of the functioning of a community or society at any scale.

Most disasters occur over short periods of time (sometimes even very short, e.g. earthquake), whereas drought may develop and persist over several months or even years. A drought event is characterized by different stages: onset, intensification, persistence, recovery and endpoint (see chapter 1). Therefore, we cannot consider drought as only the moment it reaches the disaster level, since drought impacts are visible before this point. On the other hand, the term 'disaster' cannot be used to refer to the entire cycle of drought, since the word 'disaster' would consequently lose its emergency significance of an event that calls for urgent response. With this in mind, it is important to notice the difference between approaches to drought management, specifically mitigation, and management approaches for other natural hazards, such as floods, storms and earthquakes. Consequently, we refer to drought management instead of disaster management.

In this context drought management planning is a means to reach goals such as to:

- build societal resilience, resources and managerial and institutional capacity well in advance of drought, and thereby, raise **preparedness** so that the magnitude of impacts likely to result from drought can be **mitigated**
- put the necessary logistics (for **response** as well as **recovery**) in place to alleviate suffering during and immediately after drought and to 'build back better'.

4.2 Overview of drought preparedness, mitigation, response and recovery

4.2.1 Definitions and context

There are disaster risk reduction definitions related to preparedness, mitigation, response and recovery (UNISDR, 2017). However, as discussed in section 4.1, one cannot easily exchange the terms 'disaster' and 'drought' in these definitions, since droughts are slow-onset hazards that can develop into disasters over time.

Drought **preparedness** refers to policies and specific plans that are established before drought occurs to prepare people and increase institutional coping capacities, provide forecasts or warnings and ensure coordinated and effective response in a drought situation (UNW-DPC, 2015). Preparedness comprises mitigation, response and recovery measures (Fig. 4.1).

Drought impact **mitigation** refers to the measures and actions or activities that are taken before and during drought. These measures are designed to mitigate drought impacts and increase the level of resilience to drought impacts as well as the level of readiness to respond when drought reaches the stage of emergency. They include both long-term and medium-term measures and actions and can be of policy/regulatory, physical and institutional dimensions.

It is important to realize that mitigation in the context of natural hazards is different from mitigation in the context of climate change, where the focus is on reducing greenhouse gas (GHG) emissions. Mitigation in the context of drought management refers to the actions taken in advance of the drought event to reduce future impacts. The following definitions for mitigation were put forward by the Intergovernmental Panel on Climate Change (IPCC, 2012):

- *Mitigation (of disaster risk and disaster):* the lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure and vulnerability
- *Mitigation (of climate change):* a human intervention to reduce the sources or enhance the sinks of GHGs.

Mitigation assumes that community and property are vulnerable to hazards and that preparedness will be necessary to increase resilience to those hazards (since the hazards themselves cannot be controlled). There are many drought mitigation measures, but most are not physical/structural and may be less apparent to the general public compared to mitigation measures for earthquakes, floods and other natural hazards where the impacts are largely structural (e.g. appropriate crops, dams, engineering projects). The impacts associated with drought are generally non-structural (e.g. crop yield reduction, health problems, undernutrition and famines, environmental degradation or loss), more difficult to assess and do not require major physical reconstruction; however, they do call for significant measures, finances and actions to minimize or prevent them from occurring as part of the recovery process after a drought event.

Drought responses are efforts during or immediately after a drought disaster to preserve life and maintain the basic subsistence needs of people affected. These responses can be provided through assistance or interventions and can be of an immediate, short-term or protracted duration (UNW-DPC 2015). Effective response ought to be prompt, concerted and coordinated as a result of drought preparedness planning before drought conditions arise.

Drought recovery comprises decisions and actions taken after a drought with a view to restore or improve the pre-drought living conditions of the affected community, while encouraging and facilitating necessary adjustments to reduce future drought risk (UNW-DPC, 2015). This also includes the provision of food and water supplies and livestock feed, temporary employment and regaining of lost livelihoods (for example through the provision of seeds for farmers) and psychosocial rehabilitation of traumatized communities, etc.

Figure 4.1. Preparedness comprises mitigation, response and recovery measures and actions.

The *Sendai Framework for Disaster Risk Reduction 2015–2030* has developed the 'build back better' principle, which is one example of how to incorporate activities and programmes for more resilient policies. While this is a general principle, it can be adapted in the context of drought (UNISDR, 2017a).

4.2.2 Drought management measures and actions

Drought impacts concern all sectors affected by drought, based on their vulnerabilities, particularly agriculture, water and the environment, but also health, transport, tourism and others. Drought mitigation measures can be subdivided into two categories, **long-term or short-term,** depending on their implementation time and ultimate objectives (Table 4.1). Long-term measures are normally included in the long-term development strategies of the concerned sectors. These strategies can be an entry point to check the sectors' alignment with drought risk management when developing a national drought management policy. Medium-term and short-term measures are implemented in a timely manner, prior, during and after drought, based on triggers (or agreed given levels of the drought index) provided by monitoring and early warning systems (see also chapter 2). They target the mitigation of specific impacts prior to or during their occurrence, including increased emphasis on water conservation, increased or augmented water supplies through greater utilization of groundwater resources, water reutilization and recycling, construction of reservoirs, interconnecting water supplies between neighbouring communities or drought preparedness planning to build greater institutional capacity and education. Insurance programmes and schemes currently available in many countries would also fall into the category of mitigation. In the context of a drought preparedness plan, emergency response measures are implemented to respond to basic needs of the population affected while simultaneously contributing to long-term development.

It is important to note that mitigation actions that build on the sustainable use of natural resources and the conservation of ecosystems and their functions will have the longest-lasting beneficial impact on societies' resilience to drought and will also foster sustainable development. In line with this, approaches to address and overcome societal vulnerabilities by mitigation and preparedness measures have been developed in the context of integrated water resources management – for example, small natural water retention measures (GWP CEE, 2015) and ecosystem-based adaptation and disaster risk reduction (CBD, 2019). A technical paper by FAO provides a variety of case studies on Nature-based Solutions for agricultural water management (Sonneveld et al., 2018).

Apart from being distinguished as short- or long-term, mitigation measures can also be '**proactive'** (i.e. increase resilience in the long term) or '**reactive'**. Reactive mitigation measures have an emergency response characteristic or result in unsustainable management of resources, such as the exploitation of limited groundwater resources during drought, which may lead to groundwater shortage if drought conditions persist or reoccur. With progression of drought conditions, a set of mitigation measures can also be implemented on different levels, depending on the severity of water shortage (e.g. voluntary reduction of water use, mandatory reduction of water use, ban of water use). Water is a crucial asset for the agriculture, municipal water, health, food security, energy, transportation, tourism/recreation, industry, forest/rangeland fires, education, environment and ecosystem services/biodiversity sectors. Therefore, based on identified vulnerabilities and impacts, mitigation measures may be developed and implemented in these sectors.

Mitigation measures that are relevant to water resources management include (but are not limited to):

- legislation and public policy
- water conservation and demand reduction
- increasing or augmenting water supply
- water management measures other than demand and supply
- public education and participation
- conflict resolution.

The following tables list examples of short- and long-term mitigation measures for multiple sectors (Table 4.2) and exemplary mitigation measures specifically for the agricultural sector (Table 4.3), since in many countries this is the most sensitive sector affected by drought. Table 4.4 contains examples of systems and methods of water retention in rural areas to illustrate measures for enhancing water supply.

Table 4.1. Objectives and implementation of mitigation measures

Category	Long-term	Short-term	Response and recovery
Objective	Resilience-building	Drought mitigation	Impact reduction
Implementation framework	Regularly develop programmes	Drought plan	Response within drought plan
Implementation time	Continuous	Before, during, after drought	During, after drought

Source: UNW-DPC (2015).

Table 4.2. Multisectoral mitigation measures

<table>
<tr><th>Short-term measures</th><th>Both short- and long-term possible</th><th>Long-term measures</th></tr>
<tr><th colspan="3">Legislation and public policy</th></tr>
<tr><td>• Issue emergency irrigation permits for using state waters for irrigation</td><td>• Adopt an emergency water allocation strategy to be implemented during severe drought</td><td>Adjust legal and institutional framework by, for example:
• Preparing position papers for legislature on public policy issues
• Examining regulations governing water rights for possible modification during shortages
• Passing regulations to protect water flows
• Passing regulations to protect and manage groundwater
• Passing regulations providing guaranteed low-interest loans to farmers
• Imposing water use efficiency and limitation measures
• Developing a water plan
• Establishing natural hazard mitigation committees
• Providing technical support for developing contingency plans by all large water users</td></tr>
<tr><th colspan="3">Water conservation and demand reduction</th></tr>
<tr><td>• Restrict uses (agricultural, municipal)
• Divert water from given uses
• Over-draft aquifers (temporarily)
• Ration water supply
• Dual distribution networks for drinking water supply
• Adopt carry-over storage
• Conjunctive use</td><td>• Encourage and support voluntary water conservation
• Require water users to decrease reliance on groundwater and implement conservation measures
• Voluntary insurance, pricing and economic incentives</td><td>• Reduce use
• Reduce losses (e.g. line canals or install piping to control seepage)
• Review water allocation
• Conjunctive use (surface–groundwater)
• Establish stronger economic incentives for private investment in water conservation
• Improve water use and conveyance efficiencies
• Implement water metering and leak detection programmes
• Reduce consumptive use by changing the type of water application system or using water meters
• Promote innovative technologies, such as irrigation system improvements, waterless urinals and monitoring technologies</td></tr>
</table>

Table 4.2. Multisectoral mitigation measures (continued)

Short-term measures	Both short- and long-term possible	Long-term measures
Enhancing supply		
• Mix fresh and low-quality waters • Exploit high-cost waters • Adjust legal and institutional framework • Locate new standby resources (for emergency) • Provide permits to exploit additional resources • Provide drilling equipment • Issue emergency permits for water use • Provide pumps and pipes for distribution		• Storage capacity increase • Water transfers • Locate new potential resources • Aqueducts and canals • Groundwater recharge • Small-scale water collection/harvesting (see Table 4.3) • Artificial precipitation • Desalination of brackish and saline water • Water treatment and reuse of wastewater/recycling • Rehabilitate reservoirs and increase water storage • Inventory and review reservoir operation plans • Implement water quality management and wastewater reuse
Improve water management other than supply and demand		
• Temporary reallocation of water (on basis of assigned use priority) • Decrease transport and distribution costs • Provide emergency supplies • Inventory private wells; negotiate purchase of water rights for public use • Elaborate regulations on water markets • Elaborate alert procedures		• Inventory and monitor natural resources within the relevant areas

Table 4.2. Multisectoral mitigation measures (continued)

Short-term measures	Both short- and long-term possible	Long-term measures
Public education and participation		
	• Organize drought information meetings for the public and the media • Drought information centre that distributes real-time weather and drought monitoring data	• Establish a public advisory committee • Include public participation in drought planning • Implement water conservation awareness programmes • Organize workshops on special drought-related topics • Establish a drought information centre • Develop training materials in several languages • Advise people on potential sources of water
Conflict resolution		
	• Resolve emerging water use conflicts • Suspend water use permits in watersheds with low water levels • Work with community-based organisations to promote public participation in conservation programme	

Source: based on Bazza (2014); Cap-Net UNDP (2015); Vickers (2018).

Table 4.3. Examples of mitigation measures in the agricultural sector

Short-term measures	Both short- and long- term possible	Long-term measures
Agricultural water management (complying with water resources strategy/plan)		
		• Irrigation expansion if/where possible • Improve demand management (more efficient systems: water loss reduction, technological improvements for system optimization)
Crop production		
• Supplementary irrigation where water can be mobilized and made available on a short-term basis • Soil water conservation practices • Soil mulching and crop shading • Reduce crop density • Weeding	• Early warning, information and advice to farmers • Crop insurance	• Breed for drought-tolerant species and adaptation to short season • Cultural practices and techniques for conservation agriculture: — proper fertilization — no-till/reduced tillage systems — crop rotation/cropping systems — seeding rate/density — adapted pest management — mulching/adapted soil preparation — strip farming
Livestock, range and pasture lands		
• Destocking/incentives for owners to reduce • Livestock transfer where/when possible • Watering points/water hauling sources • Constituting feed stocks • Rapid inventory of grazing potential • Protective (natural) shelters • Alternative feed (by-products, less and unpalatable shrubs, etc.) • Supplementary, substitute feeds	• Early warning/advice to herders • Review available feed and reduce animal numbers • Locate potential sites of water for emergency	• Drinking supplies • Balance livestock in irrigated areas • Manage pasture and range supportive capacity • Use of indigenous breeds of feed and fodder • Genotypes of mammals/low water use • Forage reserves • Non-conventional fodder sources

Source: adapted from Bazza (2014).

Table 4.4. Systems and methods of water retention in rural areas

Water resources	Systems and methods
Landscape (habitat) retention: landscape planning	Systems shaping the poor structure of land use through: • system of arable fields, grasslands, forests, ecological lands and ponds • forestation, creation of protective belts, woodlots, shrubs, creation of bruises and terraces • increasing the area of wetlands, peatlands and swamps, rewetting of peatland
Soil water retention: agriculture technology	Cultivation systems shaping water management in a soil profile: • improvement of soil structure (differential porosity), agricultural drainage, liming, proper agro-techniques, proper crop rotations, increasing organic matter content in the soil
Groundwater: agriculture and landscape planning	Cultivation and drainage systems to limit surface runoff: • surface runoff limitation structures • increased soil infiltration capacity (deep-loosening) • anti-erosion measures, phyto-drainage and agricultural drainage measures • runoff regulation from the drainage system • ponds and infiltration wells for storage of precipitation runoff from sealed surfaces
Surface water: water management, hydraulic structures	Hydro-technical systems of division and storage of water: • ponds and small reservoirs • regulation of water runoff from ponds and small reservoirs • water management – retention of water in drainage – irrigation systems and water governance • regulated outflow of water from ditch systems • increase in river valley retention, including construction of polders

Source: GWP CEE (2015).

Sample response and recovery measures

There are many measures that can be used for response and recovery. These include (adapted from Bazza, 2014):

- drinking water supply (humans, livestock, wildlife)
- insurance compensation
- public aid to compensate loss of revenue
- relief employment
- tax relief (reduction or delay of payment deadline)
- rehabilitation/recovery programmes
- food programmes
- feed programmes
- cattle camps and fodder supply
- fire control programmes
- resolving conflicts
- postponing payment of credits
- implement set-aside regulations
- financing relief expenditure
- information and media coordination.

4.2.3 Determination and prioritization of actions

Relevant or appropriate drought mitigation measures are identified on the basis of 'drought vulnerability and impact assessment', which is carried out in the first stage of the development of a drought management plan (see chapter 3). These actions should address the root causes of the identified impacts, rather than the symptoms, and are normally specific to different locations, societal scales (national, regional, local) and time scales.

After the impacts, causes and relevant potential actions have been identified (see chapter 3, section 3.1), the next step is to determine the sequence of actions to mitigate the impacts they relate to. This selection should be based on concerns such as feasibility, effectiveness, cost and equity, social problems and environmental losses. In choosing the appropriate mitigation and response actions, the following questions will be helpful:

- What are the cost–benefit ratios for the actions identified?
- What are the co-benefits of the actions identified?
- Which actions are considered to be feasible and appropriate by the general public?
- Which actions are sensitive to the local environment (i.e. sustainable practices)?
- Are actions addressing the right combination of causes to adequately reduce the relevant impact?
- Are actions leading to short-term and long-term solutions?
- Which actions would equitably represent the needs of affected individuals and groups?

This process has the potential to lead to the identification and implementation of effective and appropriate actions that will reduce drought risk through proactive drought policies.

Prioritizing potential drought mitigation actions should include an assessment of the relative costs and benefits of the possible options, since monetary evaluations often provide easily understandable results (Table 4.5). The framework publication on the *Benefits of Action versus the Costs of Inaction* (BACI) provides guidance on this approach (Venton *et al.*, 2019). Although the core of a BACI assessment requires quantification of the costs of action versus inaction, it is very important to note that this should be only one measure used in a multi-criteria analysis to determine the most effective package of mitigation options. Additionally, the *Voluntary guidelines for the design and effective implementation of EbA & Eco-DRR* provide guidance on prioritizing, appraising and selecting Ecosystem-based Adaptation and Ecosystem-based Disaster Risk Reduction options (CBD, 2019). There are many benefits that cannot be quantified – for example, social impacts – that are as valid as the monetized impacts. Equally, other factors such as political or cultural aspects will be important decision-making criteria.

4.3 Identification of appropriate triggers for drought actions

The implementation of mitigation measures during a drought event is triggered by a given drought severity as determined by drought indicators (see chapter 2). Such triggers are specific values of an indicator or index that initiate and/or terminate each level of a drought plan and associated mitigation and emergency management responses. In other words, they trigger action and allow for accountability as to who is doing what and when they need to do it, and are ideally defined in a drought plan or policy (WMO and GWP, 2014). It is essential to have a complete list of triggers for indicators or indices, which should also be aligned with an action plan to guide a coordinated set of actions by individual agencies or ministries. This alignment assures timely action at the onset of drought in an area or region.

To prompt suitable mitigation action, drought triggers need to inform on drought conditions, onset and termination and consider drought effects on different sectors. Therefore, the preferred approach is to use different thresholds with different combinations of inputs. Ideally, this will involve prior study to determine

Table 4.5. An example of monetizing direct avoided losses and benefits

Elements at risk	Description of elements at risk – without mitigation scenario	Description of elements at risk – with mitigation scenario	Monetised avoided losses and benefits
Economic	In a high-magnitude drought, 100 percent of the crop is lost; in a medium-magnitude drought, 50 percent of the crop is lost; in a low-magnitude drought, 20 percent of the crop is lost.	In a high-magnitude drought, irrigation would reduce losses from 100 percent to 50 percent; in a medium-magnitude drought, irrigation would reduce losses from 50 percent to 25 percent; in a low-magnitude drought, irrigation would reduce losses from 20 percent of the crop to zero.	The cost of mitigation is USD5.0 million. See 'A Worked Example of a BACI Analysis'.
Environmental	In a high-magnitude drought, 50 percent of tourism revenue is lost for approximately three months as a result of depletion of recreational water bodies.	In this example, it is not possible to prevent depletion of water bodies; therefore, no change.	For example, damages are estimated at 50 percent of tourism lost over three months.
Social	In a high-magnitude drought, families have to migrate for water, causing psycho-social stress, especially for women and children.	Rehabilitation of water points allows families to stay where they are, eliminating migration entirely.	This can be assessed only qualitatively.

Source: Venton *et al.* (2019).

which indicators/indices are best suited to the timing, area, sectors and populations affected as well as the type of climate in which a drought occurs. This takes time because it requires a trial-and-error approach. Decision-making based on quantitative index-based values is essential to the appropriate and accurate assessment of drought severity and as an input into an operational drought early warning system or comprehensive drought plan (WMO and GWP, 2016).

The *Handbook of Drought Indicators and Indices* proposes a series of questions that may help users decide which indicators and indices are most appropriate for their current situation (WMO and GWP, 2016):

- "Do the indicators/indices allow for timely detection of drought in order to trigger appropriate communication and coordination of drought response or mitigation actions?
- Are the indicators/indices sensitive to climate, space and time in order to determine drought onset and termination?
- Are the indicators/indices and various severity levels responsive and reflective of the impacts occurring on the ground for a given location or region?
- Are the chosen indicators, indices and triggers the same, or different, for going into and coming out of drought? It is critical to account for both situations.
- Are composite (hybrid) indicators being used in order to take many factors and inputs into account?
- Are the data and resultant indices/indicators available and stable? In other words, is there a long period of record for the data source that can give planners and decision-makers a strong historical and statistical marker?
- Are the indicators/indices easy to implement? Do the users have the resources (time and human) to dedicate to efforts and will they be maintained diligently when not in a drought situation? This can be better justified if such a system is set up for monitoring all aspects of the hydrologic or climatic cycles, not just droughts."

For more detailed information on tools for the assessment of climatological drought conditions as well as drought impact, vulnerability and risk, which may be used in the formation of triggers, please refer to chapters 2 and 3, respectively.

4.4 Institutional arrangements for the development and implementation of drought management plans

Drought preparedness also comprises the identification of institutional bodies to develop and implement the whole plan, not only the mitigation and response actions. At the national level, a drought commission composed of representatives from multiple agencies/ministries and key stakeholder groups is assembled to oversee and guide the development of a drought plan. This process begins with the establishment of a series of committees to oversee the development of the institutional capacity necessary for the plan as well as its implementation and application during times of drought when the various elements of the plan are activated. At the heart of the mitigation plan is the formation of a drought task force at the subnational level (e.g. state or province, community) that reflects the makeup of the national drought commission. The same sub-committees of the national drought commission address both drought risk assessment and management/mitigation of drought. Please refer to chapter 5 for an overview of the 10-step drought policy and preparedness process.

There can be many organisational structures for the development and implementation of the drought plan (Fig. 4.2), but the structure should reflect the three primary elements of the plan: 1) monitoring, early warning and information delivery; 2) risk and impact assessment; and 3) mitigation, preparedness and response. The drought task force may, therefore, be subdivided into two parts: 1) one committee to focus on the first part (monitoring/early warning/information) and 2) a second committee in charge of the last two parts (risk assessment and mitigation/response) of the plan, which are, in most instances, heavily policy oriented (WMO and GWP, 2014). It should be stressed that if existing natural hazard or climate change committees already exist, these existing structures should be modified, if possible, to incorporate these functions related to drought. Countries have limited resources, and these institutional structures that focus on drought should be efficiently integrated into existing structures as much as possible. More detail on the drought task force can be found in chapter 5 and in the *National Drought Management Policy Guidelines* (WMO and GWP, 2014).

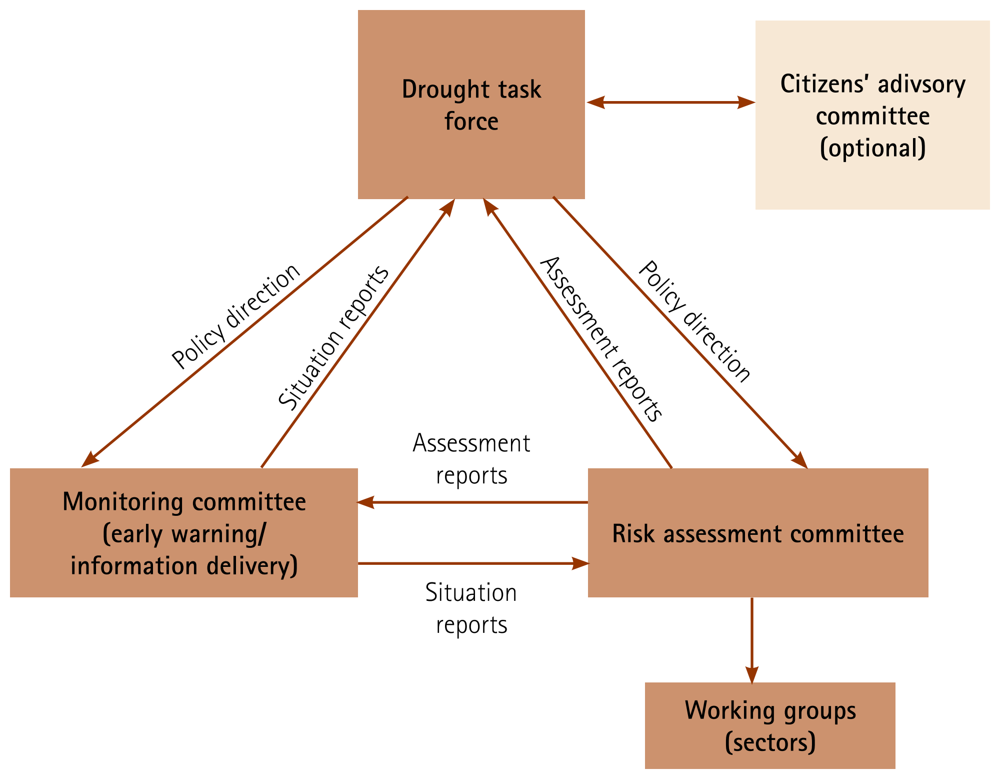

Figure 4.2. One example of a drought preparedness and mitigation plan structure. Source: WMO and GWP (2014).

The main actors for the identification and implementation of mitigation actions are determined by the impact and vulnerability assessment (chapter 3), which informs the development of a preparedness plan. This plan ultimately defines who does what and when. As a primer to the drought preparedness plan, a list may be elaborated to include the prioritization of impacts, selection of mitigation activities for these impacts, defined triggers for action, and institutional responsibilities for these actions (Bazza, 2014).

4.5 Examples of national mitigation strategies and plans

In 2018, a survey was conducted by the World Meteorological Organization (WMO) to assess countries' advances in drought management planning. All 28 responding countries stated that they had some kind of drought preparedness plan, and 18 countries indicated they had drought policies in place.[1] The 2018 survey was followed up in 2019 by the Integrated Drought Management Programme (IDMP), a targeted web search on publicly available information about mitigation measures mentioned in drought plans and policies in the countries that participated in the 2018 survey. The following key words, in combination with 'drought', were used in the web search: 'national plan', 'mitigation', 'monitoring', 'forecasting', 'ministry for agriculture/water' and 'emergency response'. Despite dealing with a limited number of countries and identifying only measures that are accessible via websites, as well as the encountered intra-national complexity with plans and measures adapted to regions or watersheds, the analysis resulted in some interesting insights.

The 2019 survey identified 12 main areas concerned by mitigation actions in relation to how often they were mentioned in national preparedness plans (see Fig. 4.3).

As displayed in Fig. 4.3, most countries have monitoring and/or forecasting tools in place as a preparedness measure. Within the proactive measures, agricultural water management is mentioned in the larger part of the countries, mitigation strategies, while some form of financial support is the most frequently mentioned reactive measure.

Some examples of countries' current mitigation strategies resulting from the IDMP survey are included in Table 4.6.

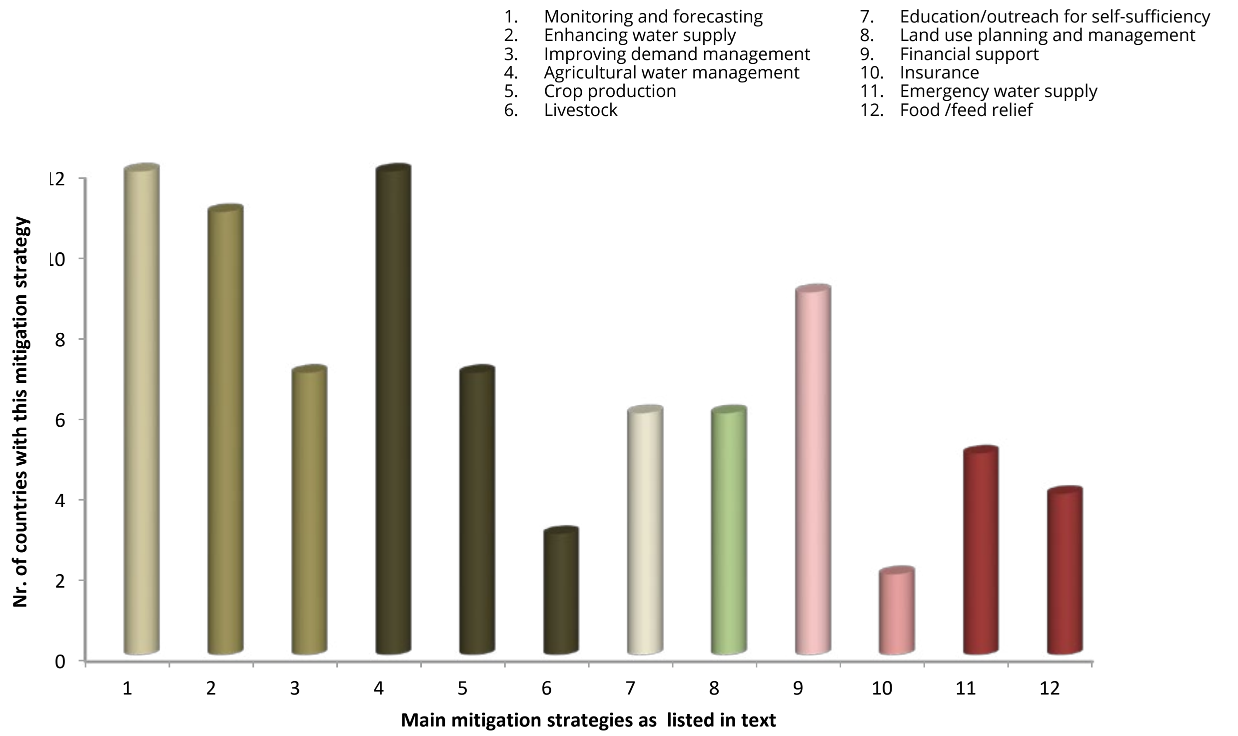

Figure 4.3. Illustration of the distribution of mitigation measures at the national scale by main area identified from the 2019 IDMP survey. Colouring refers to a possible topical grouping of the areas.

1 Argentina, Australia, Austria, Brazil, Chile, China (PRC), Dominican Republic, Greece, Israel, Jordan, Lithuania, New Zealand, Pakistan, Russian Federation, Slovenia, Spain, Thailand, Turkey, Uzbekistan, Belarus, Canada, Hong Kong, Jamaica, Libya, Peru, Switzerland, Tanzania, USA

Table 4.6. Examples of national mitigation strategies resulting from the IDMP survey

Country	Strategies	Source information
Spain	• outreach and education – water saving campaigns • restrictions on water usage depending on drought severity, prioritization of vital sectors, nocturnal decreases in water pressure, water cuts • attenuation of water usage from sensitive or protected areas	https://www.miteco.gob.es/es/agua/temas/observatorio-nacional-de-la-sequia/planificacion-gestion-sequias/
Pakistan (early stage of drought management plan development)	• emergency response measures to current drought (International Federation of Red Cross and Red Crescent Societies): — provision of safe drinking water through solar boreholes and storage facilities — conduct hygiene and water treatment awareness activities — provision of unconditional cash grants for immediate needs such as food, fodder for livestock	http://ndma.gov.pk/files/NCWD%20Report-11.2.2019.pdf, https://reliefweb.int/sites/reliefweb.int/files/resources/MDRPK015do.pdf
Australia	• self-reliance: — farm business training: develop and monitor business plan and manage risk — rebate scheme for self-reliant improvement of water infrastructure (pipes, pumps, etc.) — social support and well-being assistance • financial aid: — farm household allowance for families in hardship, farm management deposit scheme, drought communities programme (including work opportunities)	http://www.agriculture.gov.au/ag-farm-food/drought/drought-policy/national-drought-agreement, http://www.agriculture.gov.au/ag-farm-food/drought
Chile	• **long-term measures**: construction of 19 reservoir lakes by 2024, desalination plants • **mid-term measures:** construction of small reservoir lakes, micro-desalination plants, hydro-efficiency in housing projects • **short-term measures:** — farmer support: financial support for feed, seeds or materials, food provisions — household water storage systems, geomembranes for decreased water loss — groundwater exploitation, channelling of rivers or channel restoration, improvement of irrigation techniques — water trucks	https://www.gob.cl/noticias/las-medidas-que-componen-el-plan-nacional-para-la-sequia/

For more information on preparedness, mitigation and response, please refer to http://www.droughtmanagement.info/pillars/mitigation-preparedness-response/

The United Nations Convention to Combat Desertification Drought Toolbox contains a compilation of mitigation and response solutions that can be filtered for specific regional and climatological conditions (https://knowledge.unccd.int/drought-toolbox/solutions/risk-mitigation/2346).

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5 Making the political case – the drought plan

5.1 Synthesis of the three-pillar approach to integrated drought management

Historically, drought responses by governments and other organisations have been generally reactive: poorly coordinated, ineffective and untimely. This 'crisis management approach' is associated with the provision of drought relief or assistance in response to a drought event to those most affected. Without a coordinated national drought policy that includes comprehensive monitoring, early warning and information delivery systems, vulnerability and impact assessments, the identification and adoption of appropriate local-level mitigation and response measures aimed at risk reduction, nations will continue to respond to drought in a reactive, crisis management mode. It is imperative that nations adopt a new paradigm for drought risk management. The material for this section and section 5.2 is based on work published by Wilhite (1991), Wilhite *et al.* (2005) and Wilhite *et al.* (2000).

As illustrated in Fig. 5.1, to create a successful drought policy aimed at risk reduction, it is vital for that policy to emphasize the three pillars of a comprehensive monitoring and early warning system, vulnerability and impact assessment, and mitigation and response. The three-pillar approach, discussed in depth in the previous chapters, requires an emphasis on each of these pillars, with appropriate linkages and interactions between each one (Pischke and Stefanski, 2018).

5.1.1 Pillar 1: Drought monitoring and early warning systems

A drought early warning system (DEWS) is the foundation of effective proactive drought policies. Governments maintain DEWSs to warn their citizens and themselves about impending drought conditions.

Figure 5.1. The interconnected three pillars of effective integrated drought management.

A DEWS identifies climate and water supply trends and detects the emergence or probability of occurrence and the likely severity of drought and its impacts. Reliable information must be communicated in a timely manner to water and land managers, policy makers, decision makers and the public through appropriate communication channels to trigger actions outlined in a drought plan. That information, if used effectively, can reduce vulnerability and improve mitigation and response capacities of people and systems at risk.

5.1.2 Pillar 2: Vulnerability and impact assessment

The goal of Pillar 2 is to determine the primary historical, current and likely future impacts associated with drought (impact assessment) and to assess the root cause of these impacts, i.e. vulnerability assessment. Drought impact and vulnerability assessment is directed at gaining an understanding of both the natural and human processes associated with drought and the impacts that occur. An outcome of Pillar 2 is the creation of a vulnerability profile for each sector, region, population group or community, i.e. vulnerability mapping.

Vulnerability is dynamic because of societal changes that occur over time that may increase or decrease vulnerability. For example, vulnerability drivers include factors such as population changes, population shifts (regional and rural to urban), demographic characteristics, technology, government policies, environmental awareness, degradation, water use trends and social behaviour. Vulnerability assessments provide a framework for identifying the social, economic and environmental causes of drought impacts, i.e. who and what is at risk and why. It bridges the gap between impact assessment and policy formulation by directing policy attention to the underlying or root causes of vulnerability rather than to its result: the negative impacts that follow triggering events, such as drought. Drought impacts cut across many sectors and across normal divisions of government authority, reinforcing the need for cooperation and coordination between government ministries and non-governmental organisations.

5.1.3 Pillar 3: Mitigation and response

The outcome of Pillar 2 is an assessment of who and what is at risk and why. The goal of Pillar 3 is to determine appropriate mitigation and response actions aimed at risk reduction, identify appropriate triggers to phase in and phase out mitigation actions during drought onset and termination, particularly short-term actions, and finally, to identify agencies, ministries or organisations to develop and implement mitigation actions. Triggers are defined as specific values of an indicator or index that initiate and/or terminate responses or management actions by decision makers based on existing guidelines or preparedness plans (Hayes *et al.*, 2018). Triggers should link indices or indicators to impacts that are occurring on the ground.

Mitigation in the context of natural hazards is different from mitigation in the context of climate change, where the focus is on reducing greenhouse gas emissions. Mitigation in the context of drought management refers to actions taken in advance of the event to reduce future impacts. Drought mitigation measures are numerous, but they may be less apparent to policymakers and the public in comparison to mitigation measures for earthquakes, floods and other natural hazards where the impacts are largely structural. Impacts associated with drought are generally non-structural, and thus, the impacts are less visible, more difficult to assess (e.g. reductions in crop yield) and do not require reconstruction as part of the recovery process. Drought mitigation measures can be both short- and long-term.

5.2 Approaches to the development of national drought management plans and policies

Nations face complex challenges in the development of a risk-based national drought management policy. The process requires political will at the highest level possible and a coordinated approach within and between levels of government and with diverse stakeholders who must be engaged in the policy development process. A national drought policy could be a stand-alone policy. Alternatively, it could contribute to or be a part of a national policy for disaster risk reduction or climate change adaptation with holistic and multi-hazard approaches centred on the principles of risk management. Regardless of the path chosen, the policy would provide a framework for shifting the paradigm from one traditionally focused on reactive crisis management to one that focuses on a proactive risk-based approach. This approach will increase the coping capacity of the country, reduce recovery times and increase resilience to future drought episodes, which is the goal of integrated drought management.

To facilitate the development of national drought policies, the IDMP published the *National Drought Management Policy Guidelines: A Template for Action* (WMO and GWP, 2014). These guidelines provide a template for development of a national drought policy based on the principles of drought risk management and following the three-pillar approach. This 10-step process is generic, i.e. nations are encouraged to adapt this process to their national needs and institutional capacity, as exemplified in central and eastern Europe (GWP CEE, 2015) as well as Brazil, Mexico and Morocco (Wilhite and Pulwarty, 2018; WMO and GWP, 2014).

The formulation of a national drought policy, while providing the framework for a paradigm shift, is only the first step in vulnerability reduction. The development of a national drought policy must include development and implementation of preparedness and mitigation plans at the subnational level, an outcome of the three-pillar approach. These plans will be the instruments for implementing a national drought policy.

A national drought policy should establish a clear set of principles or operating guidelines to govern the management of drought and its impacts. It should be consistent, equitable for all regions, population groups and economic sectors, and consistent with the goals of sustainable development. By following the three-pillar approach, policy is directed towards reducing risk by developing better awareness and understanding of the drought hazard, the underlying causes of societal vulnerability and how being proactive and adopting a wide range of mitigation and response measures can increase societal resilience. Risk management promotes many proactive actions that have been discussed previously.

5.2.1 Drought policy objectives

The objectives associated with a national drought policy will vary from nation to nation but, in principle, will likely reflect some common themes. These objectives would likely:

- encourage vulnerable economic sectors and population groups to adopt self-reliant measures that promote risk management
- promote sustainable use of the agricultural and natural resource base
- facilitate early recovery from drought through actions based on the philosophy of risk management.

Drought planning refers to actions taken by individual citizens, industry, government and others before drought occurs, with the purpose of reducing or mitigating impacts and conflicts arising from drought. It can take the form of response planning or mitigation planning. Response planning represents the traditional approach taken by most governments and is reactive in nature, i.e. crisis management. The three-pillar approach emphasizes mitigation planning that leads to risk reduction. It is important to note that planning must occur on multiple government levels, from national to subnational, and the objectives of these policies at the local, state or regional levels must reflect the goals of national drought policies. Stakeholder engagement is critical at all levels.

The 10 steps for the development of a national drought policy (WMO and GWP, 2014) are:

1. **Appoint** a national drought management policy commission
2. **State** or **define** the goals and objectives of a risk-based national drought management policy
3. **Seek** stakeholder participation, **define** and **resolve** conflicts between key water use sectors, considering transboundary implications
4. **Inventory** data and financial resources available and **identify** groups at risk
5. **Prepare/write** the key tenets of a national drought management policy and preparedness plans, which would include the following elements: monitoring, early warning and prediction; risk and impact assessment; and mitigation and response
6. **Identify** research needs and **fill** institutional gaps
7. **Integrate** science and policy aspects of drought management
8. **Publicize** the national drought management policy and preparedness plans and **build** public awareness and consensus
9. **Develop** educational programmes for all age and stakeholder groups
10. **Evaluate** and **revise** national drought management policy and supporting preparedness plans.

It is of high importance that even though these steps are numbered and certain steps might be more logically taken early in the process, the 10-step methodology needs to be understood as a cycle (Fig. 5.2): each step is equally important, and they are not necessarily consecutive, unrepeatable or part of a linear logic. Further, these steps should be seen as an iterative process. Hence, although the steps are sequential, many of these tasks are addressed simultaneously under the leadership of a drought commission or task force and its complement of committees and working groups. Addressing steps 1–4 means bringing the right people together to gain a clear understanding of the process, to build knowledge on what the drought preparedness plan must accomplish and to give adequate data to make fair and equitable decisions when formulating and writing the actual drought plan. Step 5 describes the process of developing an organisational structure or framework for completing the necessary tasks of the preparedness plan, essentially emphasizing the three

Figure 5.2. Illustration of the 10-step process to develop drought policy and preparedness. The circular presentation of the steps indicates that each step is equally important, and they are not necessarily consecutive, unrepeatable or part of a linear logic. Source: WMO and GWP (2014).

pillars of drought management referred to previously. The development of the plan is a process, rather than a discrete event that produces a static document. A vulnerability assessment, completed in conjunction with this step, provides a vulnerability profile for key economic sectors, population groups, regions and communities (see chapter 3). Steps 6 and 7 detail the need for ongoing research and coordination between scientists, ministries and policymakers. Steps 8 and 9 stress the importance of promoting, building capacity and testing the plan before drought occurs. Finally, step 10 emphasizes revising the plan to keep it current and evaluating the plan's effectiveness following each drought event.

5.3 Challenges to the development and implementation of national drought management plans and policies

The development and implementation of national drought plans and policies requires a concerted effort and a variety of coordinated actions. While the adoption of the integrated drought management approach has improved resilience to drought in a number of countries (see section 5.5), and technical support is provided by international and intergovernmental organisations, there are several challenges that must be overcome by national and local governments to successfully implement drought policies. The following points, resulting from experience in drought planning, were highlighted in a white paper by the Food and Agriculture Organization of the United Nations in collaboration with the United Nations Convention to Combat Desertification, WMO, GWP, IDMP and the Global Framework on Water Scarcity in Agriculture (FAO, 2019) and have been slightly adapted for this training manual:

- **Political will**. Political will is often recognized as a key factor to drought resilience – the lack of it is a root cause of vulnerability. Authorities must be convinced that it is important to have a drought policy; that the economic, social and environmental costs of doing nothing are excessively high; and that planning and executing a drought policy requires key decisions around institutions, coordination and resource allocation. Governments and society alike must be fully convinced that developing and implementing a drought policy will benefit society, with few negative impacts.
- **Institutions**. It is necessary to define the institutional framework for managing the national drought policy. This could require giving new responsibilities to existing institutions or creating new ones.
- **Coordination**. Managing droughts calls for joint actions at different levels of government. While the responsibility for sectoral implementation will fall upon specific institutions, success will require that decisions are intergovernmentally and intersectorally coordinated. An effective national policy requires, for example, leadership from a high-level collective body with participation by all ministries and organisations responsible for drought planning and implementation.
- **Adequate resources**. The availability of adequate resources, in terms of institutions, human and technical capacity and budget, is critically important. Usually, middle-income countries have some resources and only need technical and methodological assistance. Less developed countries, however, usually lack sufficient resources to define and implement a national drought policy, and these will need to be procured internally or from external donors.
- **Capacity-building**. Training should be a component of every drought policy. All three pillars require people with the capacity to plan and implement the required actions. Capacity-building should extend not only to government staff but include people and organisations responsible for tasks such as monitoring, early warning, vulnerability and impact studies and policy evaluation.
- **International cooperation**. Cooperation with international and regional organisations and civil society promotes the exchange of experience, information, knowledge and technology. It avoids the waste of resources and increases the effectiveness of the overall effort.
- **Linking science to policy**. A major challenge is how to transmit information to policymakers. Often, the information generated by scientists does not find its way into the decision-making process. A possible solution is to 'translate' technical information into a language that can be understood by decision makers. It is also necessary to create adequate channels for information dissemination.
- **Policy integration**. A national drought policy is likely to complement or even overlap with other national development and risk reduction strategies. The national drought plan is likely to be more effective if it is formulated in line with national development policies and international agreements, particularly those related to the National Adaptation Plan, Nationally Determined Contribution under the Paris Agreement on climate change and the Sustainable Development Goals processes.

- **Communication**. A national drought policy should be communicated to the general public, particularly the people who are most affected by drought. An appropriate communication strategy should be prepared to bring the drought policy information to different publics.
- **Evaluation**. It will be necessary to evaluate the national policy on a regular basis to ensure that it is meeting its goals and that the resources are being used effectively.

Question for discussion: What are the specific challenges regarding the adoption of a drought plan and policies in your national context? How could they be addressed?

5.4 Benefits of action and costs of inaction for a proactive approach to drought management

Drought events lead to numerous economic, social and environmental costs of a magnitude modulated by social and household vulnerability and resilience to drought. This can be illustrated by comparing the costs of inaction when a drought occurs to taking *ex ante* and *ex post* actions against drought. The costs of action against droughts can be classified into three categories: 1) preparedness costs, 2) drought risk mitigation costs and 3) drought relief costs (WMO and GWP, 2017).

In showing that a proactive approach to drought risk management is economically beneficial compared to solely investing in disaster relief (Fig. 5.3), a strong argument is built for the establishment of national drought policies.

The difficulty of accurately assessing the costs of droughts presents substantial challenges for costs and benefits analysis of investments and policy actions taken against droughts. At the same time, droughts are not weather or climatic anomalies; rather, they are a recurrent and normal feature of almost any climate, even in comparatively water-rich countries.

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 (Box 5.1). As a result, continued vulnerability makes crisis management costlier to society than *ex ante* investments that mitigate drought risks by building resilience. Though drought and its consequences have rarely been a cause of conflict, they may contribute to the worsening of tensions, which can lead to conflict, as in the Syrian case (Box 5.2). 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 current estimates. Climate change is expected to increase the frequency and severity of droughts (IPCC, 2014; 2018; 2019). 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 costlier than they are today.

Yet the shift from crisis management to risk management is happening slowly. To enhance political will, research and development partners need to demonstrate to governments that it will be unaffordable to continue with drought relief in the

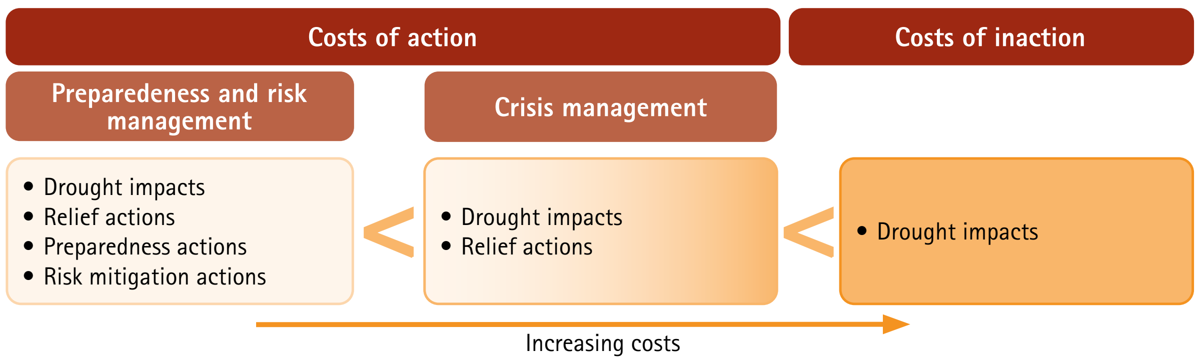

Figure 5.3. Summary of costs of drought under different action scenarios. Source: WMO and GWP (2017).

Box 5.1. Case Study: Reactive responses to drought in Somalia have not strengthened resilience and may even have exacerbated the crisis (World Bank, 2017)

The 2017 drought in Somalia was caused by variability and failure of the Gu and Deyr seasonal rains, which generally bear the risk of recurrent droughts. During this event, the water availability underwent an estimated reduction of 80 percent, drying out *berkhads* (cisterns), dams, hand-dug wells and springs. This had severe consequences for agriculture, livestock production and the availability of drinking water. Emergency response to these impacts was largely composed of short-term reactive measures, such as water trucking, which saved lives but did nothing to address underlying vulnerability. To the contrary, humanitarian aid may even have led to the price of vended water increasing by 50 percent. An estimated USD20 million was added to the cost of vended water during the critical four-month phase of the drought period by the spike in water prices. The high vulnerability of the population and their agriculture was caused by their dependence on surface-water resources and shallow wells. Drought impact mitigation potential could be accessed by developing boreholes that tap into deeper groundwater, which is not affected by drought, and more infrastructure for rainwater harvesting and water storage. However, prior to and during the humanitarian responses, little was done to strengthen drought resilience in this way.

Box 5.2. Case Study: Vulnerability to drought in Syrian Arab Republic was amplified by deterioration of the economy and by government indifference (De Châtel, 2014; Ward and Ruckstuhl, 2017)

Drought is a normal recurring climatic feature and is especially endemic to arid countries such as Syria, where intense droughts hit in 2006, 2007–2008 and 2011. The 2007–2008 drought was particularly devastating. Rainfall deficits were as high as 60 percent, with some regions receiving no rain at all, which caused severe impacts on national agricultural production. The 2007–2008 wheat harvest came in at 2.1 million tonnes, compared to the long-term average of 4.7 million tonnes, forcing Syria to import wheat for the first time in 15 years. These droughts were not only particularly intense, but their impact was also increased. This was partly due to changes in demographics and greater vulnerability in the agricultural economy because of higher population, more pressure on rangeland and depleted groundwater resources. Additionally, public policies heightened vulnerability. State projects that strained land and water resources increased poverty in the north-eastern part of the country, traditionally the nation's breadbasket. The gap between urban and rural living standards had widened, and unemployment was rising fast. The political system was closed and oppressive, and corruption was widespread. Vulnerability expressed itself in growing food insecurity. The United Nations estimated that between 2008 and 2011, 1.3 million people were affected by the drought, with 800,000 people 'severely affected'. With prolonged drought conditions extending into a second and third year, the population in the north-east was less and less able to cope. Crop failure for two consecutive years caused farmers to no longer have seeds, and herders were forced to sell or slaughter their flocks because of the lack of pasture and fodder. Already widespread malnutrition rapidly increased, with "up to 80 percent of those severely affected surviving on a diet of bread and sugared tea". The incidence of nutrition-related disease soared between 2006 and 2010, with 42 percent of infants suffering from anaemia in Raqqa governorate. The situation was notably worsened by the lamentable failure of the government to respond with adequate humanitarian assistance or to help farmers ride out the drought and restore their productive capability. By 2010, the United Nations estimated that 3.7 million people, or 17 percent of the Syrian population, were food-insecure, and that 300,000 people had migrated because of the drought, leaving more than two thirds of villages in two governorates (Hassakeh and Deir ez-Zor) deserted. An estimated 65,000 families migrated from the north-east to the tent camps situated around Damascus and Aleppo. The families that settled in a tent camp in Mzeirieb near Dara'a from 2008 onward found relatives and friends there who had been subsisting in these conditions for a decade or more. Not only do these events highlight the complexity of vulnerability, they also played a foundational role in the subsequent uprising in Syria.

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 (Fig. 5.4). A case study in a small community in Honduras highlighted the strong socio-economic benefits of proactive drought management (Box 5.3). 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.

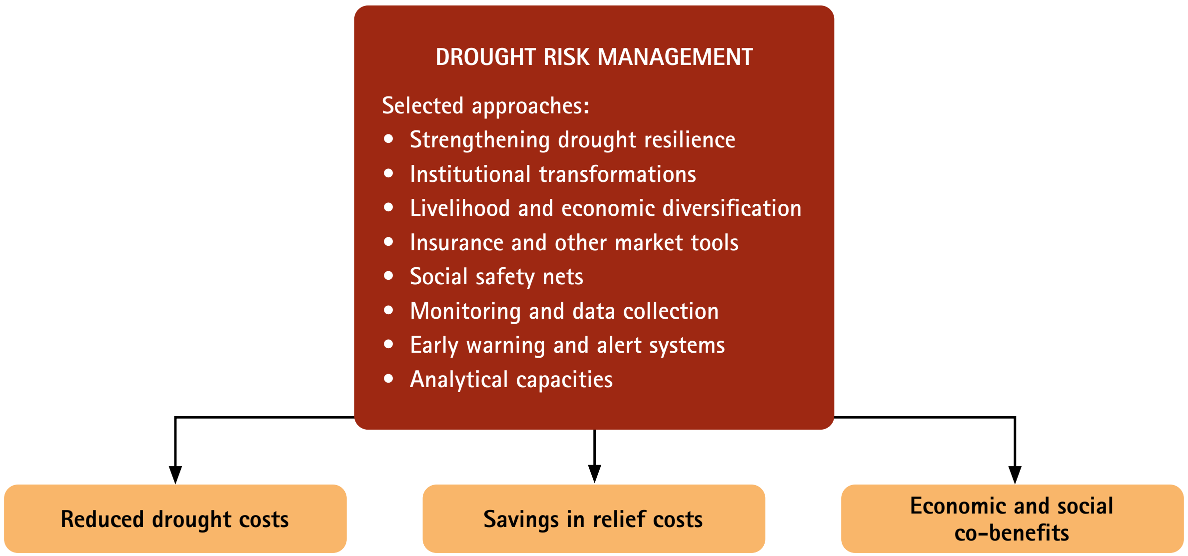

Figure 5.4. Approaches to drought risk management and benefits. Source: WMO and GWP (2017).

Building from the specialized literature and interaction with experts, a publication by WMO and GWP in the framework of the IDMP (Venton *et al.*, 2019) has developed a conceptual framework for assessing drought risk and analysing the benefits of action and costs of inaction (BACI). The approach to this framework is adapted to and integrated into the structure of the 10-step process for drought policy and preparedness, as introduced earlier in this chapter (WMO and GWP, 2014). The BACI framework introduces the key steps to take for a BACI assessment within each of the 10 steps. It guides efforts to systematically assess the BACI by including BACI expertise and considerations into the first four steps of the process. For step 5, BACI assessment tools of hazard, impact and vulnerability assessment are proposed, among others, by monetizing direct avoided losses and benefits in different mitigation scenarios. The BACI considerations are then also integrated into steps 6 and 7 by identifying research needs for BACI assessments and carving out the key role of BACI assessments in integrating science policy aspects. Steps 8 and 9 stress the importance of promoting and testing the plan before drought occurs – BACI assessments can play a vital role in communicating preparedness plans using the economic argument for action. Finally, as in step 10 the drought plan's revision and evaluation is addressed, the same should be done for the components of the BACI assessment.

The BACI approach is designed to be a tool for a systematic integration of BACI assessments into the process of drought policy development. By uncovering the value of drought preparedness, it can support the shift away from reactive drought responses towards proactive drought risk management.

5.5 Drought plans – examples

5.5.1 Mexico

A recurrent drought across most parts of the country during 2010–2013 led the President of Mexico to announce the National Programme Against Drought (PRONACOSE) in January 2013, to be coordinated by the National Water Commission (CONAGUA). The timing of the drought and political cycle was fortunate; with a newly elected Mexican government under pressure to shift the approach to drought management, PRONACOSE was initiated. Tools with a

Box 5.3. Case Study: The drought risk management benefits of action and costs of inaction by improving access to water in a community in Honduras

The small Honduran community of Azacualpa (1,600 inhabitants) is economically highly dependent on horticultural production. Drought in this Central American region is mainly characterized by a lack of rainfall during the rainy season. Improving access to water for year-round agricultural production has been critical to reducing drought risk, leading to the construction of 27 reservoirs. These measures had many positive consequences: drought risk management was improved; significant improvements in employment were made (from 30 percent to 70 percent); organisational capacity was improved; more productivity, social cohesion and well-being was achieved; income levels were increased (from USD1.60 to USD3.84 per day); profitability was augmented (36 percent return on investment); crops could be diversified; cropping intensity could be increased, with as many as four crops a year on the same piece of land; food security was improved (increase of 26 percent in maize production and 23 percent in beans production); market access was improved, and access to financial services increased; land value was raised (by 47 percent); and a decrease in migration was detected.

Source: GWP CA (2017).

new proactive and preventive approach for integrated drought management were developed at the level of the basin councils. The objectives of PRONACOSE can be summarized as follows:

- initiate a targeted training programme on the basic concepts of drought and best practices to develop local capacity to ensure the sustainability of integrated drought management in Mexico
- raise awareness at the basin level and develop a host of preventive and mitigation measures against droughts
- establish an inter-agency committee to coordinate and direct existing drought programmes, guide and assess PRONACOSE and fund the actions proposed by stakeholders at the basin level
- involve experts and researchers in responding to the identified needs in drought management
- develop a communication and outreach programme which emphasizes vulnerability, participation, prevention and the evolution of drought.

In addition to the five points above, an important component of the PRONACOSE framework is an evaluation mechanism to assess the effectiveness of each implemented activity/strategy and ensure sustainability by including continuous feedback and lessons learned in the various implementation phases. The PRONACOSE activities are structured along the following three main activity lines:

- Formulation and implementation of measures to prevent and mitigate drought impacts, including monitoring and early warning
- Establishment of a legal framework to ensure continuous drinking water supplies during droughts
- Coordination of institutional response towards drought mitigation measures.

In the framework of the PRONACOSE, CONAGUA monitors droughts monthly at the basin, state and municipal levels according to the standard agreed with the North American Drought Monitor programme in 2013.

In the beginning, CONAGUA developed 26 programmes on drought prevention and mitigation measures (PMPMS) for each water basin council. These programmes addressed the drought characteristics and vulnerability of each water basin. A guide was developed, and major actors in the each PMPMS were trained to standardize activities and contents of the PMPMS. The PRONACOSE framework allowed for these PMPMS to be implemented, evaluated and improved and then re-implemented. The aim was to ensure ownership of the programmes by the basin councils and sustained implementation.

5.5.2 Brazil

Brazil has a long, rich history of coping with and managing droughts, particularly in the semi-arid north-eastern part of the country. An extreme drought occurred in the region in 2012, which caused significant crop and cattle losses and reduced many reservoirs to critically low levels. This drought grabbed the attention of the Brazilian population, the media, decision makers and international experts. Based on the experience of this drought event, Brazil undertook proactive actions to reform drought management and planning.

Brazil played an active role in the High-Level Meeting on National Drought Policy (HMNDP) in Geneva in

March 2013 (UNCCD *et al.*, 2013). Under the leadership of the Ministry of National Integration, the Government of Brazil followed up on the meeting and partnered with the United Nation organisations involved in the HMNDP to plan and host a Latin America regional workshop to build drought policy and management capacity. This 2013 workshop engaged governments from Latin America and the Caribbean region to help conduct a 10-step planning process for developing a national drought policy. After these meetings, several activities occurred at the national, regional, state and local levels in Brazil to draw further attention to drought issues. These include the organisation of a formal process for the federal and state governments to discuss the composition of a national drought policy and the design and implementation of a Northeast Drought Monitor (http://monitordesecas.ana.gov.br/). The convergence of such efforts presented a unique opportunity, based on the 2012 drought event, for Brazil to make significant progress on improving drought preparedness and resilience over the coming years (WMO and GWP, 2014).

5.5.3 Morocco

Drought is a recurrent natural phenomenon in Morocco. A study of historical tree rings reconstructed the history of drought over the last millennium (1000–1984). The study indicated that over 89 droughts of one- to six-years duration occurred, with an average return period of about 11 years. The average duration of a drought is around 1.6 years, with the 1901–2000 period one of the driest in the last nine centuries. Based on these experiences, Morocco has gradually established an integrated drought management system, structured around three essential elements (WMO and GWP, 2014):

1. Monitoring and early warning system. Morocco developed national institutional and technical capacities, especially in the areas of climate modelling, remote sensing and crop forecasting. A National Drought Observatory was established in 2000 to improve forecasting, assess impacts and develop strategies and tools for decision support and drought preparedness.

2. Emergency operational plans to alleviate the impacts of drought. They include:
   a. securing safe drinking water, particularly for rural populations
   b. preserving livestock through feed distribution
   c. implementing income generation and job creation activities (maintenance of rural roads and irrigation infrastructures)
   d. conserving forests and natural resources.

3. Long-term strategy to reduce vulnerability to drought. This strategy is based on a risk management approach that aims to reduce the vulnerability of the national economy to drought, with an emphasis on agriculture and the rural economy. It involves a diverse array of policies that consider the drought risk across the country, including economic and social implications, as well as in its long-term recurrence. The three pillars of the strategy are:
   a. An integrated approach to water resources management by mutually reinforcing policy and institutional reforms
   b. Improve access to water supply and sanitation and increasing waste-water treatment capacity through optimized financing strategies and increased budget support for public good infrastructure
   c. Conserve water and improve efficiency, productivity, cost effectiveness and the sustainability of irrigated agriculture.
      The integrated approach strives to make improvements in three major interrelated areas:
      i. the hydraulic efficiency of irrigation systems
      ii. the managerial capacities of irrigation agencies
      iii. productivity.

5.5.4 Slovakia

During the summer of 2017, an interministerial working group was established and tasked with the preparation of the the Slovak National Action Plan to Combat Drought (GWP CEE, 2018; WMO, 2017). It comprised experts from the Ministry of Environment, Slovak Hydro-meteorological Institute, Water Research Institute, Slovak Water Management Enterprise, Ministry of Agriculture and Rural Development, National Food and Agriculture Centre, Hydro-meliorations, Slovak Technical University, Faculty of Natural Sciences at Comenius University, Office of the Government, Global Water Partnership Central and Eastern Europe and other institutions.

A Drought Action Plan was developed that mainly focuses on green infrastructure and improvement of water retention in the urban environment, agriculture, forestry and hydro-morphology. The plan is in line with the European Union (EU) catalogue of Natural Water Retention Measures. The Drought Action Plan was inspired by the seven steps that are described in the *Guidelines for preparation of the Drought Management*

Plans in the context of the EU Water Framework Directive, which is an adaptation of the 10-step process (section 5.2) to the policy context in the EU, developed by WMO and GWP Central and Eastern Europe (CEE) (GWP CEE, 2015).

The Integrated Drought Management Programme (IDMP) CEE was established in 2013 as a regional programme of the WMO/GWP IDMP. It is implemented in 10 countries in Central and Eastern Europe. A central goal of the IDMP CEE is to increase the resilience of the countries against drought and climate change adaptation. Within the IDMP CEE, GWP CEE organized two rounds of National Dialogues in 2013 and 2015. The third dialogue was held in the frame of the DriDanube project (http://www.interreg-danube.eu/news-and-events/project-news/746) in 2017. The dialogues brought together stakeholders responsible for different areas/policies and identified horizontal strategies connected to drought, such as agriculture, forestry, hydrology and energy, etc. They provided a platform for dialogue and played a catalytic role in the discussion on the steps and actions needed to establish a proactive drought management framework at national level.

Sharing the Slovak experiences within and outside Central and Eastern Europe is equally important, since the region is sensitive to variability and changing precipitation patterns. Future climate scenarios forecast increased frequency and severity of extreme weather events, which will result in the increase of droughts.

For more information and national examples on drought policy and plans, please see http://www.droughtmanagement.info/drought-policies-and-plans/. Tailored guidance can be requested via the IDMP HelpDesk: http://www.droughtmanagement.info/ask/ask-form/.

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Global Water Partnership
IDMP Integrated Drought Management Programme
ITC University of Twente.
REMERH Cap - Net - Méx
SCaN SaciWATERs-CapNet Network
SIWI
UNEP-DHI Partnership Centre on Water and Environment UNEP DHI
WaterCap Water Capacity Building Network
World Meteorological Organization