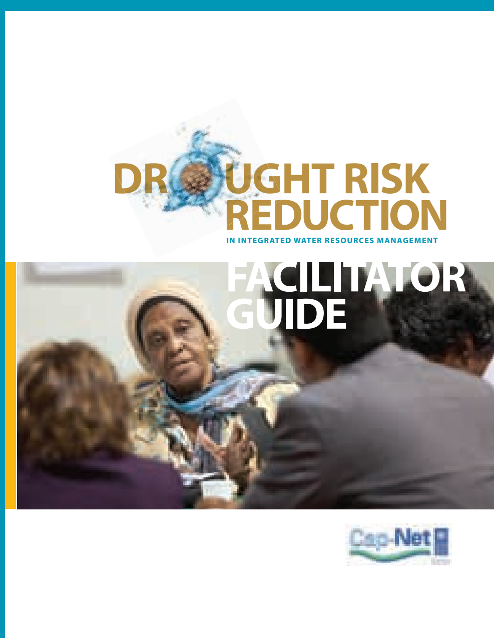
DROUGHT RISK REDUCTION

IN INTEGRATED WATER RESOURCES MANAGEMENT

TRAINING MANUAL

Cap-Net UNDP

Companion guide for facilitators



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Cap-Net UNDP

PARTNERS

Global Water Partnership

REMERH

SaciWATERs

SIWI

SCaN

ITC

UNEP-DHI Centre for Water and Environment

WaterCap Water Capacity Building Network

ACRONYMS

Cap-Net	International Network for Capacity Development in Sustainable Water Management (UNDP)
CMI	Crop Moisture Index
CSF	Critical Success Factor
DPSIR	Driver-Pressure-State-Impact-Response
ENSO	El Niño/La Niña Southern Oscillation
ET	Evapotranspiration
ETDI	Evapotranspiration Deficit Index
EWS	Early Warning System
FEWSNET	Famine Early Warning Systems Network
HFA	Hyogo Framework for Action 2005-2015
IWRM	Integrated Water Resource Management
IWMI	International Water Management Institute
MAP	Mean Annual Precipitation
NVDI	Normalized Difference Vegetation Index
OECD	Organisation for Economic Co-operation and Development
PAR	Pressure and Release Model
PCSA	Planning and Coordination Strategic Area
PDSI	Palmer Drought Severity Index
PSR	Pressure-State-Response
RTM	Radiative Transfer Models
SCaN	SaciWATERs-CapNet Network
SIWI	Stockholm International Water Institute
SMDI	Soil Moisture Deficit Index
SPI	Standardized Precipitation Index
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USGS	United States Geological Survey
VIC	Variable Infiltration Capacity
WMO	World Meteorological Organization
WRSI	Water Requirement Satisfaction Index
UANL	Universidad Autónoma del Estado de México
UNDP	United Nations Development Programme
UNEP-DHI	Centre for Water and Environment at the United Nations Environment Programme

CONTENTS

FOREWORD

Drought is a growing threat to many people and economies in both developing and developed countries, with characteristics differing considerably across the world. Droughts are considered to be the most far-reaching of all natural disasters, causing short and long-term social, economic, and ecological losses and having significant secondary and tertiary impacts. A drought does not trigger an emergency by itself; whether it becomes an emergency depends on its impact on local people, and that, in turn, depends upon people's 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 community. In the same light, the level of disaster risk prevalent in a community is linked to the developmental choices exerted by that community (UNDP, 2004). The magnitude of droughts and number of people affected are both increasing across the world, with extreme effects on poor countries and communities. Ironically, the most affected countries lack sufficient capacity to reduce the risk to a desired level.

To reduce societal vulnerability to droughts, a paradigm shift of drought management approaches is required in order 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 multifaceted and requires the involvement of a variety of stakeholders. From a drought management policy perspective, capacities in diverse ministries and national institutions are needed.

People's vulnerability and capacity in the context of drought hazards are very important in understanding the potential drought 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 urbanization or 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 realized through collective action within a favourable institutional framework.

Drought risk management, therefore, is the concept and practice of avoiding, lessening, or transferring the adverse effects of drought hazards and the potential impacts of drought disasters 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 the immediate risks and impacts of drought on water resources.

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

This manual is intended primarily for 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 through 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, the manual will:

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

The approach of this manual emphasizes an improved understanding of both the natural hazard and the human exposure to this climatic event. The different elements of drought risk management and how they contribute to better understanding and management of drought risk are explained.

The first part of the manual focuses on defining the interaction and relationship between drought, integrated water resources management, and types of vulnerability domains. Module 3 builds on the Hyogo Framework of Action to provide an understanding of how drought risk management functions as an integrated approach within the context of sustainable development. After presenting the theoretical foundation for the understanding of drought occurrences and monitoring, the emphasis shifts towards risk assessment and vulnerability analysis by taking livelihood factors into account in order to understand the potential and actual effects of drought on people. The last part of this manual will provide insight into the prioritization and practical measures for mitigation and preparedness.

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

ACKNOWLEDGEMENTS

This Drought Risk Reduction in Integrated Water Resources Management manual was put together thanks to the tremendous efforts of experts in Africa, Asia, Europe and Latin America, lead by Wangai Ndirangu of WaterCap/Jomo Kenyatta University of Agriculture and Technology, Kenya. Experts included Carlos Díaz Delgado (REMERH/ Universidad Autónoma del Estado de México), Jan Hassing (UNEP-DHI), Joris Timmermans (University of Twente-ITC), Nick Tandi (Stockholm International Water Institute - African Regional Centre) and Shantha Mohan (SCaN).

A three day pre-write workshop was organized in Pretoria, South Africa to conceptualize and firm-up the content. Pilot workshops in Kenya and Mexico provided highly beneficial platforms to share participants' experience, case examples, and feedback, which further enriched the content

Gratitude goes to the Regional Centre for Resource Mapping for Development, Nairobi, Kenya and University of Nuevo León, Monterrey, México for organizing the pilot workshops.

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MODULE 1:

DROUGHT OCCURRENCES, VULNERABILITY AND INTEGRATED WATER RESOURCE MANAGEMENT

GOAL

The purposes of this module are to briefly introduce occurrences of droughts globally and conditions that make areas vulnerable to droughts; to distinguish droughts from water scarcity conditions; and to introduce basic principles and concepts of Integrated Water Resources Management (IWRM) and how it can assist in addressing droughts.

LEARNING OBJECTIVES

At the end of this module, participants are expected to:

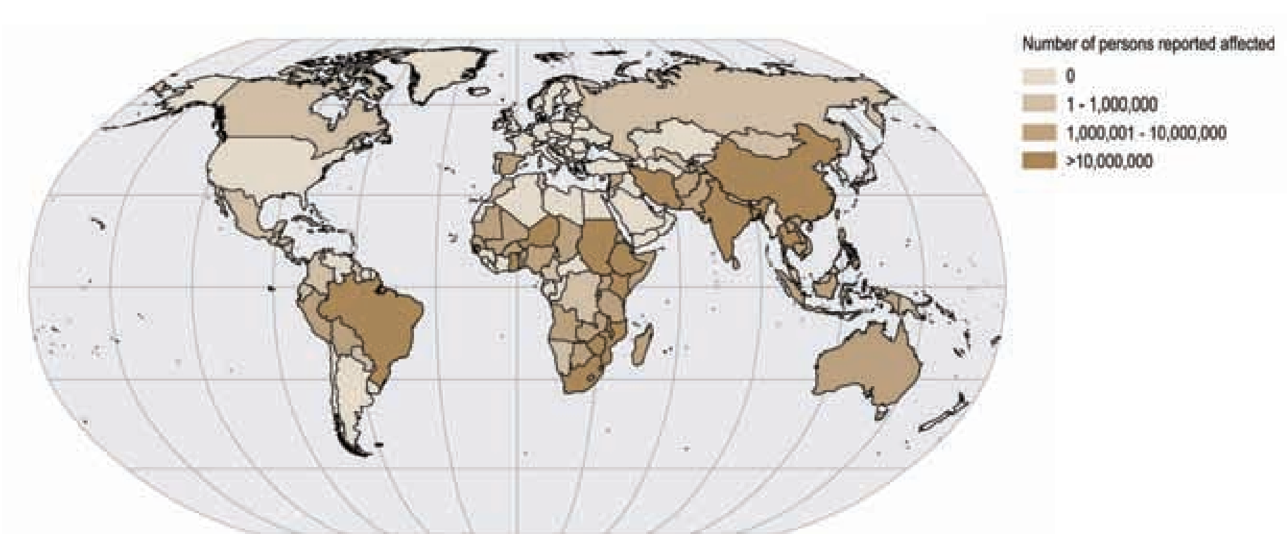
- Understand the risks of drought occurrences;
- Distinguish between droughts and water scarcity;
- Understand how IWRM approaches can assist in addressing droughts through water management; and
- Understand the role of climate change in drought risks.

1.1 INTRODUCTION

Since 1900, more than 11 million people have died due to, and over 2 billion have been affected by, droughts across the world, more than any other single physical hazard (Buurman J. *et al*, 2014). Droughts are thought to affect more people than any other hazard today. Furthermore, the frequency and magnitude of future droughts are very likely to increase due to climate change (IPCC, 2007). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change stated that while there is low to medium level confidence correlating drought incidences to climate changes, there is nonetheless a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions.

FIGURE 1.1 | Number of people affected by droughts globally, 1970–2008

Source: UNISDR, 2009:4.



Case studies show that drought risk is only partly a result of deficiencies in the rainfall. Other drivers include poverty; vulnerability; increasing water demand from urbanization, industrialization, poor water and soil management; weak or ineffective governance; and climate variability and change (GAR, 2011).

Risk is a function of exposure to a hazard and vulnerability to that hazard. Drought is a hazard, and exposure to drought (drought occurrence) can be analysed to identify drought prone areas. The occurrence of drought can also be monitored and even forecast; however, it cannot be managed. The only way to manage drought risk is to manage the impacts of drought by reducing vulnerability to drought (ISDR, 2009).

Drought has myriads of impacts which depend on the capacity of communities and ecosystems to cope. These include agricultural losses, economic impacts, psychological and societal impacts, among others. Polices and plans are necessary to reduce vulnerability to drought.

SESSION | What is a drought?

Ask participants to come up with words and ideas and put them on a mind map together. The aims are to get a sense of where participants are coming from, to share ideas, and to get people thinking.

1.2 DROUGHT CONCEPTS

1.2.1 DROUGHT HAZARD DEFINITIONS

Drought has no global definition, as definitions relate to region-specific climates. One conceptual definition may be: "Drought can be conceived as a temporary lack of water, which is, necessarily but not exclusively, caused by abnormal climate and which is damaging to an activity, a group, or the environment"(Kallis, 2008).

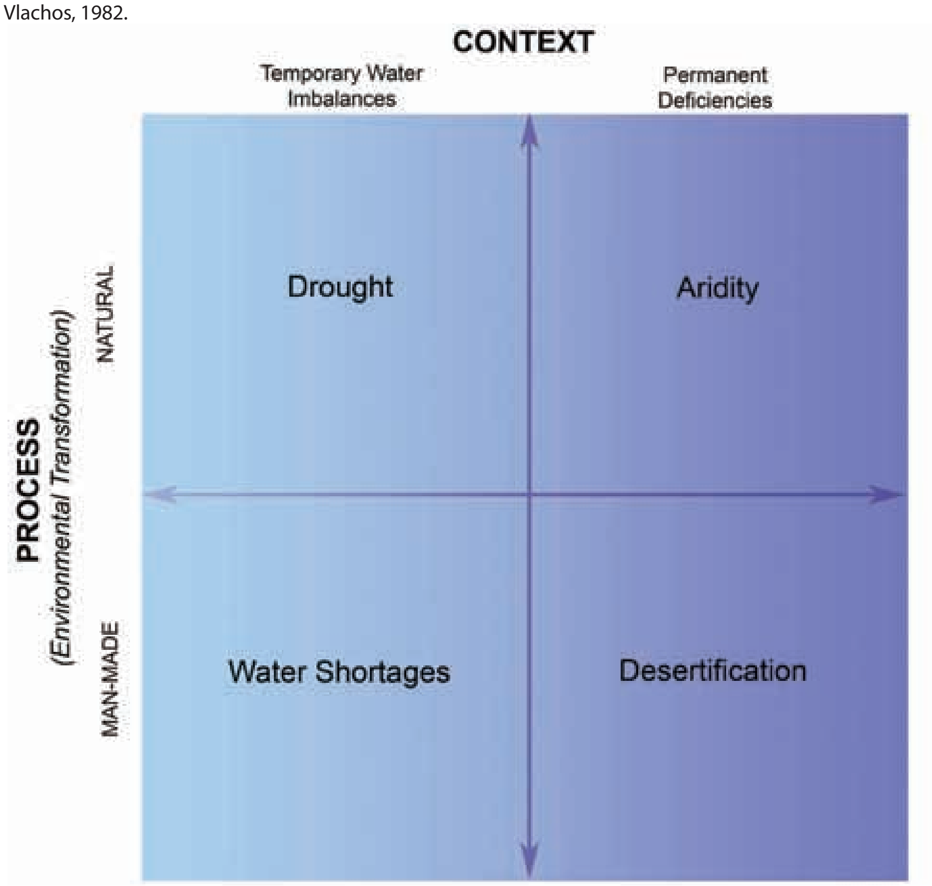
Drought is a normal feature of climate in all parts of the world (even in more humid regions) and is a recurrent event seen in relation to "normal conditions". For instance, drought in Libya (less than 180 mm rainfall per year) is hugely different from what is considered as drought in Bali (six days without rain).

SESSION | Definitions and perceptions

What is the common definition or perception of drought in your region or country?

FIGURE 1.2 | Definition of drought in context

Source: Vlachos, 1982.



Drought needs to be distinguished from aridity, scarcity and desertification.

- Aridity is a **permanent** feature of climates with low levels of moisture/rainfall, as precipitation is much lower (less than 20%) than plant requirements for growth in that environment.
- Water scarcity is a **long-term** water imbalance, where the level of water demand exceeds the supply capacity of the natural system.
- Drought is a **temporary period** of deficiency in rainfall **relative to 'normal' conditions** that leads to insufficient water to meet the demands of human activities.
- Desertification is **aridity** that is **aggravated** by human pressure.

1.2.2 DROUGHT CHARACTERISTICS

There are three essential characteristics of any drought: **intensity**, **duration** and **coverage**. Also important is the timing of onset, for example with regard to crop development stages and wet and dry seasons. **Intensity** is measured using a drought index. There are various indices in use, with some of the best known internationally being the Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI) and the decile method. The **duration** of a drought may include a minimum of 2-3 months to set in, and can last for months or years. **Coverage** of droughts refers to geographical areas, which are often large. The region of maximum intensity may shift from season to season.

Drought characteristics are described by a 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.

Drought differs from other natural hazards and therefore the approach to managing drought risk is different from the approaches used for other disasters. The following features are especially important considerations when managing drought risk:

- Drought has a slow onset and development and its effects accumulate over time and last for years after the event. This makes it difficult to determine when the drought has begun. The impacts are also long-term, which is also why droughts have been argued to be the most damaging natural hazard.
- There is no exact, universally accepted definition about drought occurrence and severity. The definition of drought should therefore be meaningful and related to impacts rather than an arbitrary statistical property.
- Damages are non-structural and spread over larger geographical areas than other natural hazards. Non-structural impacts are harder to quantify and the large spatial scales make relief provision more difficult. A focus on pre-drought activities to reduce vulnerability is therefore necessary.

1.3 TYPES OF DROUGHT

There are four categories of drought that are generally accepted across the world: meteorological, agricultural, hydrological, and socio-economic drought. This classification is cascading from minor to major impacts, as illustrated in Figure 1.3.

Meteorological drought is based solely on the degree of dryness relative to a long-term statistic or as a lack of precipitation over a region for a period of time. It is often related to a temporary aberration of rainfall, but temperatures, wind speeds and relative humidity can also play an important role in exacerbating the situation. Therefore, meteorological drought can also occur if precipitation amounts remain stable, but evapotranspiration increases. Meteorological drought becomes hazardous only when translated into agricultural or hydrological drought (UNISDR, 2011).

BOX 1.1 | Resources on rain and air masses

There are many online resources and tutorials on the water cycle and how rain occurs, such as http://www.curriculumbits.com/geography/types-of-rainfall and http://www.metoffice.gov.uk/learning/rain/why-does-it-rain.

An important complementary tool on air pressure is at: ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/fw/prs/def.rxml.

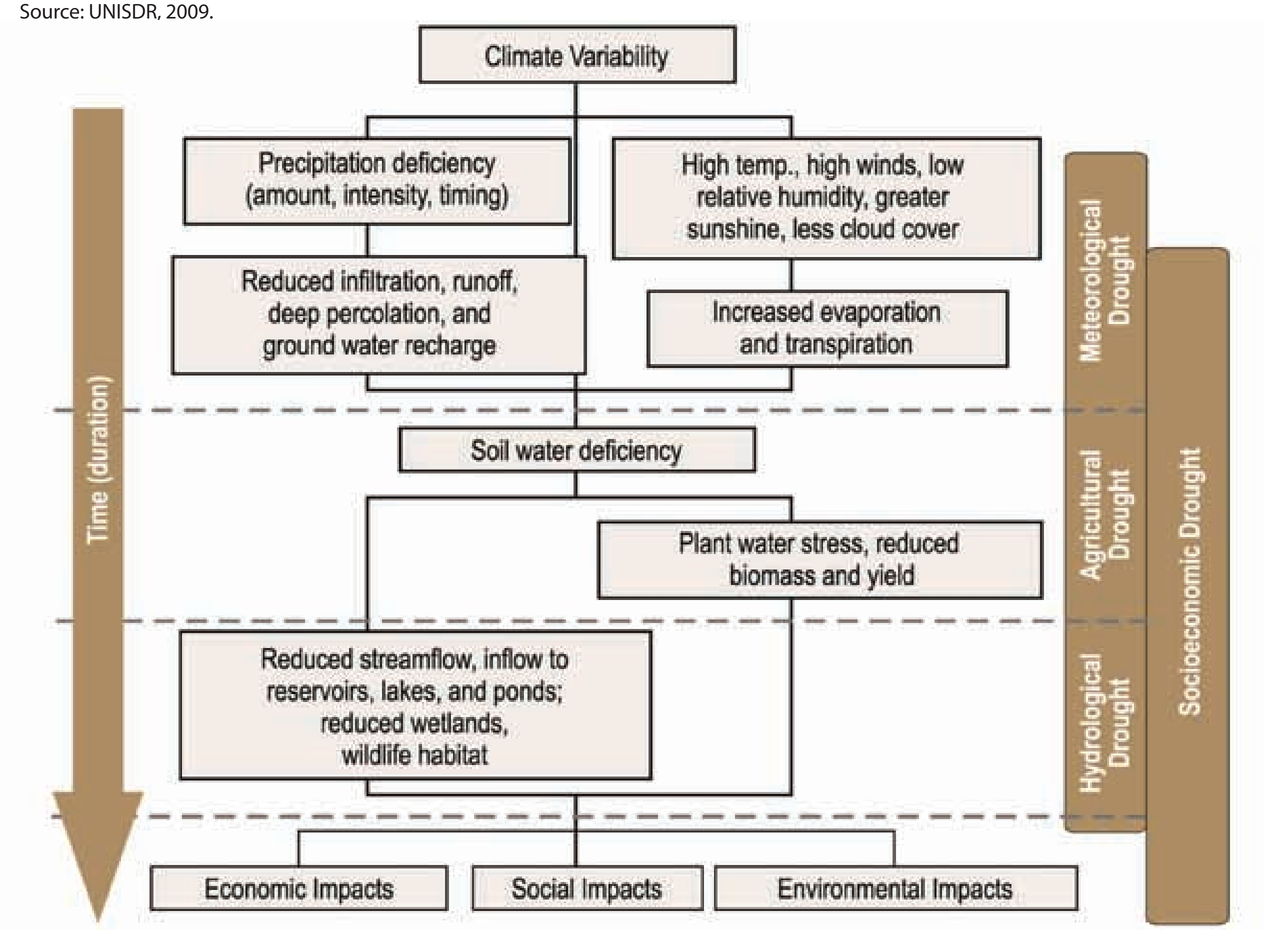
Agricultural drought links meteorological drought to agricultural impacts. It focuses on precipitation shortages, evaporation and soil moisture deficits. It is also linked to susceptibility of crops at different stages of growth.

Hydrological drought is associated with the effects of lower precipitation on surface and sub-surface supplies, rather than with the precipitation itself.

Socio-economic drought associates the supply and demand of some socio-economic good or service with meteorological, hydrological and agricultural droughts. It occurs when the demand for water of an economic good exceeds supply as a result of a weather-related shortfall in water supply. It is therefore less of a physical drought definition, as it also takes into account the risks that specific stakeholders face due to specific water deficits. As such, this particular drought can only be monitored when all the risks of the above droughts have been characterized.

FIGURE 1.3 | Summary of drought definitions and types of impacts

Source: UNISDR, 2009.



1.4 OCCURRENCE OF DROUGHT

1.4.1 HOW DROUGHT OCCURS

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 that are defined as droughts. 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 there are anomalies in the global circulation system and high pressure that inhibits cloud formation. Extended droughts occur when large scale anomalies persist for months or years.

BOX 1.2 | Drought has become more frequent and intense worldwide

Source: FAO, nd.

The Horn of Africa has been affected by droughts almost every year for the past 12 years. Recent years include the most dreadful droughts in the Horn, and severe droughts in 2009 and 2011 in Kenya. Available crop data for 2009 indicate that Kenyan agriculture was the most severely affected, with wheat yields dropping by 45 percent compared to 2010.

Australia suffered multi-year droughts between 2002 and 2010. Based on FAO statistics, total Australia wheat yield in 2006 dropped by 46 percent (below 1960-2010 yield trend level).

The 2010 drought in **Russia** was very long and intensive; it spread over a sizeable area and caused serious damage to the environment, economy and human health. The 2010 drought was the worst in the last 38 years in Russia.

The **2011 US drought** covered southern states; Texas, Oklahoma and New Mexico were most adversely affected. Drought also affected parts of Arizona, Kansas, Arkansas, Georgia, Florida, Mississippi, Alabama, and South and North Carolina.

The extreme **US great grain belt drought of 2012** pushed up world food prices, exerting pressure on the cost of living and affecting food security. At the time, it was estimated that US retail food prices would increase between 3 and 4 percent in the next year after the drought.

In 2012, a devastating drought in southwestern **China's Yunnan province** entered its third year. The drought affected more than 6.3 million people; 2.4 million experienced difficulty in seeking access to drinking water.

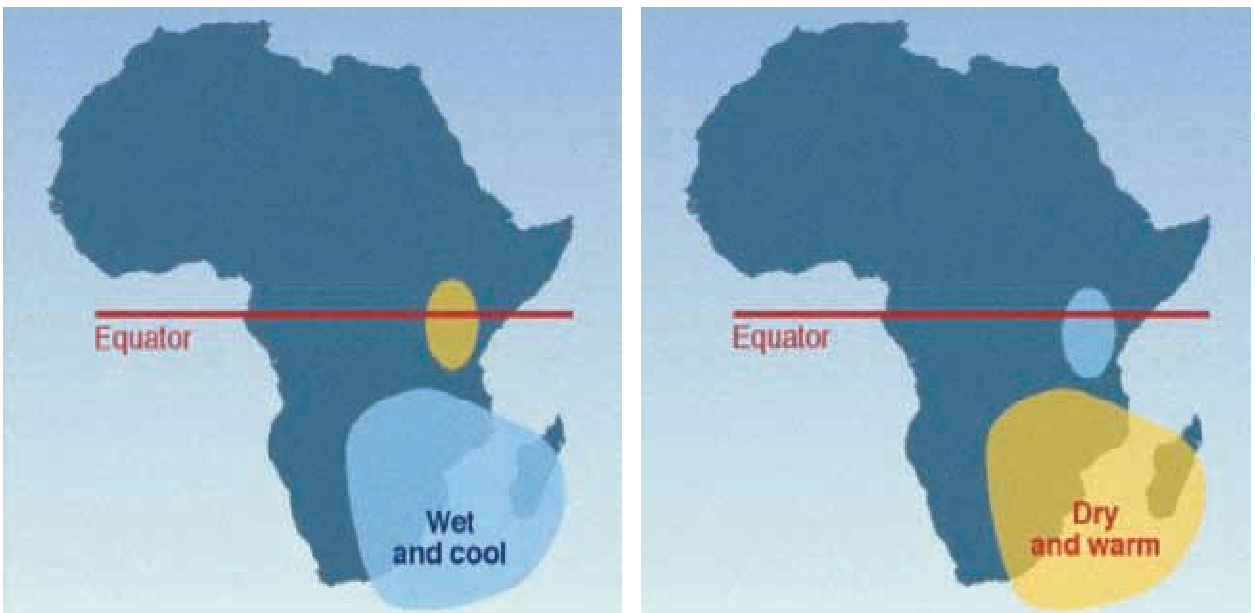
Examples of extended drought periods include the following:

- The dust bowl in the USA in 1935; eventually the entire country was affected, and 100 million acres of farmland lost most or all of the topsoil to the wind.
- The Murray-Darling River Basin in Australia has seen two decade-long droughts in the last century. Since 2001, it has been experiencing the worst drought in recorded history.
- In 2010, the worst drought in southwest China in six decades has plunged more than 2 million people into poverty.

There are many other examples in the rest of the world, including East Africa and the Amazon.

FIGURE 1.4 | ENSO impact on Southern Africa

Source: UNEP, 2002.



La Niña (1999-2000) El Niño (1997-1998)

The El Niño Southern Oscillation (ENSO; also called El Niño/La Niña Southern Oscillation) is arguably the phenomenon with the strongest weather fluctuations associated with droughts (and other climate disasters) globally. The Southern Oscillation refers to (i) the variation in the temperature of the surface of the tropical eastern Pacific Ocean, with warming referred to as El Niño and cooling as La Niña; and (ii) the variation in air surface pressure in the tropical western Pacific. Combinations of the two variations lead to El Niño, which accompanies high air surface pressure in the western Pacific, while the cold La Niña accompanies low air surface pressure in the same area. These anomalies have effects on weather in many parts of the world. For example, a strong correlation has been established between ENSO events and droughts in Eastern and Southern Africa and the Horn of Africa.

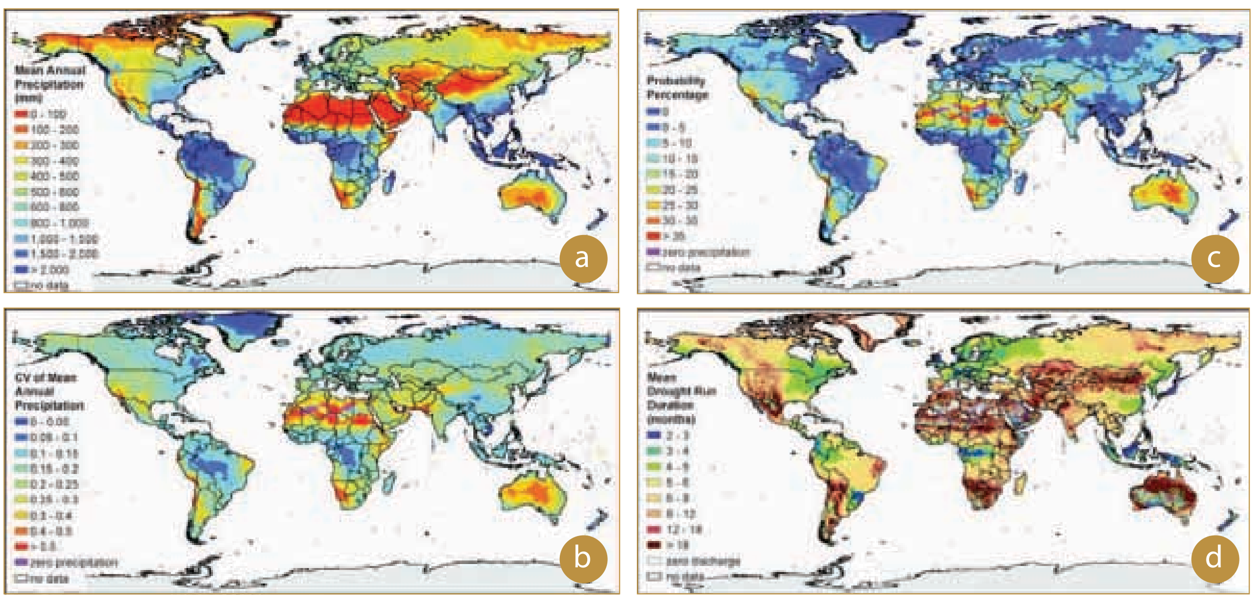
1.4.2 WHERE DROUGHT OCCURS

Despite, the non-existence of a generic operational definition for drought, a study by the International Water Management Institute (IWMI) has examined the global patterns of droughts through the mapping of several drought-related characteristics (Eriyagama et al, 2009). By comparing mean annual precipitation (MAP) and its coefficient of variation, it is apparent that in arid and semi-arid areas, the intra annual variability of precipitation is generally higher than in humid areas. Arid areas also have a higher probability of MAP falling below 75 percent of its long term average (an arbitrary but generally accepted meteorological drought indicator). It is because of this that there is some confusion between drought and aridity. More importantly, the implication is that water management measures to manage variability and inadequate water supplies in arid and semi-arid areas are also important for managing drought risk.

Figure 1.5 describes intra annual and long term variations in precipitation in relation to what is normal. What is more difficult to map globally, however, are the types of drought.

FIGURE 1.5 | Global distribution of annual precipitation and drought

Source: Eriyagama et al, 2009.



(a) Global distribution of long-term mean annual precipitation, (b) Its coefficient of variation, (c) Probability (%) of annual precipitation in any year being less than 75 percent of its long-term mean, and (d) Mean drought duration in months

SESSION | What are the impacts of drought?

Write ideas on cards in groups or pairs, and then, all together, see how they can be grouped.

1.5 IMPACTS OF DROUGHT

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 being reduced yield. Secondary or tertiary impacts that can follow are loss of income and farm closures. The impacts of droughts can be grouped into economic, environmental and social; they are dealt with in more detail in Module 2.

SESSION | Why do those impacts occur?

Ideas on cards? Mind maps?

1.6 INTEGRATED WATER RESOURCES MANAGEMENT

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

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 Challenge Programme on Water for Food (2011), 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 the management of blue and green water. Applying the principles of IWRM is expected to lead to better drought risk management, as detailed in Table 1.1.

Integrated approaches to water management have become a dominant approach, 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.

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

1. Integration of Water Resource Management in the broader **development context**;
2. **Sectoral integration** that encompasses considering different uses of water (including the environment) and different water using sectors together;
3. Integration of the (biophysical) **resource base** including the different forms of available water such as rain, surface and groundwater as well green and blue water. An important part of integrating the resource is the recognition that the resource is finite, and thus improvements in water services and water use have to come not only from resource development and capture but also from efficiency gains;
4. **Spatial integration** that incorporates downstream upstream and downstream interlinkages.

Ultimately, the success of water management is evaluated based on whether or not it sustainably contributes to the societal goals of economic viability, social equity and environmental sustainability.

TABLE 1.1 | IWRM and drought risk management

IWRM principle	Applicability to drought risk management
Water is a finite and vulnerable resource	Using participatory evaluation of water allocations regimes under different water availability conditions and putting in place conditional water use licenses that depend on the available water 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 such as disaster teams or agencies and others key to drought risk management should be involved in risk preparedness and mitigation.
Role of women	Since the impacts of drought differ for the different 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.
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 that the resource is in short supply can drive behaviour change that reduces wastages by domestic users, agriculture and industry. It also incentivises 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 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.

SESSION | Discussion: thinking about integration

Water management means a lot of different things to different disciplines, professionals and users. What does water management mean to you? Group the ideas to get a full meaning of water management. Identify any gaps that illustrate whether there are other key stakeholders not represented in the group. Draw the connections of how the definition of water management coincides with that of drought risk management.

TABLE 1.2 | Example – integrated management of a river basin

Function	Example of activities
Stakeholder participation	• Develop and maintain an active stakeholder participation process through regular consultation activities. • Provide specialist advice and technical assistance to local authorities and other stakeholders in IWRM.
Water allocation	• License water uses, including enforcement.
Pollution control	• Identify major pollution problems. • License and manage polluters.
Monitoring of water resources, water use and pollution	• Carry out hydrological, geographical and socio-economic surveys for the purposes of planning and development of water resources. • Develop, update and maintain a hydrometric database required for controlling compliance of water use allocation.
Information management	• Define the information outputs that are required by the water managers and different stakeholder groups in a river basin. • Organize, co-ordinate and manage the information management activities so that the water managers and stakeholders get the information they require.
Economic and financial management	• Set fees and charges for water use and pollution.
River basin planning	• Conduct situation analysis with stakeholders. • Assess future developments in the basin.

SESSION | How should drought risk management be defined as a separate function for managers working in basin organizations?

What are the activities and indicators associated with this function? If not, how can drought risk management be adequately included in other water management functions?

For further reading, you may refer to the Cap-Net RBM manual or Climate Change Adaptation Manual at: http://www.cap-net.org/training-materials

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

- Water pricing, cost recovery, investment
- 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

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PHOTO: UN PHOTO/E DARROCH

MODULE 2:

VULNERABILITY AND IMPACTS OF DROUGHTS

GOAL

The purposes of this module are to introduce briefly occurrences of droughts globally and conditions that make areas vulnerable to droughts; distinguish drought from water scarcity conditions; and introduce basic principles and concepts of IWRM and how it can assist in addressing droughts.

LEARNING OBJECTIVES

At the end of this module, participants will be able to:

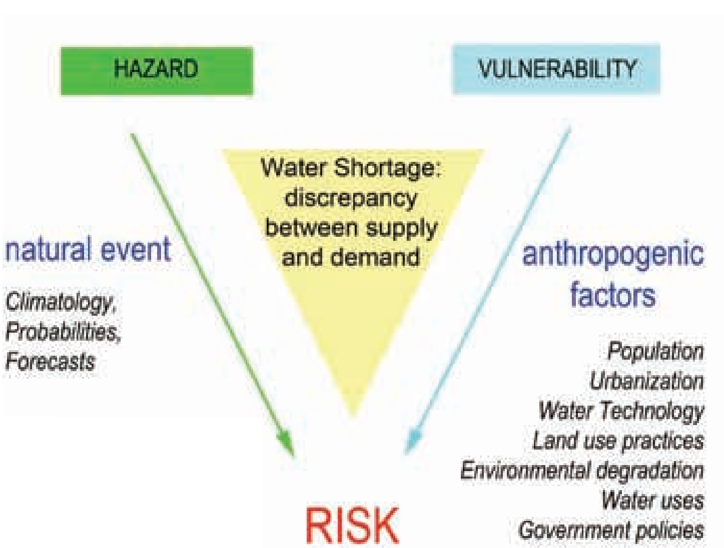
- Appreciate that vulnerability to drought is uneven and impacts differentially on diverse sets of water users;
- Distinguish the nature and determinants of vulnerability and the most vulnerable people;
- Examine the relative influence of different socio-economic and biophysical factors to the levels of drought vulnerability;
- Identify measures that could help to decrease vulnerability/increase resilience.

2.1 INTRODUCTION

This module examines how the interaction between hazards and vulnerability translates into disaster risk. In the process, we will identify the political, economic, physical, social, and ecological factors that interact to increase the susceptibility of individuals, households and communities to the impact of hazards.

FIGURE 2.1 | Hazard and vulnerability contributing to risk

Source: Karavitis, 2005.



Identifying these factors provides the basis for the prioritization of initiatives which will contribute to reducing vulnerability and thus to eliminating and/or reducing disaster risk. The initiatives so prioritized should then be integrated into sustainable management and development of water resources.

Disaster risk reduction is only valuable once one understands 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 droughts.

2.2 LINKING DROUGHT HAZARD TO 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 had on lives, property and infrastructure; the environmental damage; 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 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 two elements – vulnerability and hazard.

A hazard is defined as "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR, 2009). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, probability and likely frequency.

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 even forecasted. However, the occurrence of drought cannot be managed. The areas of the world most exposed to this hazard include sub-Saharan Africa, India, China and Brazil, Australia, and North America. During the 1990s, more than 90 percent of the victims of weather-related natural disasters lived in poor countries with high vulnerabilities.

Studies show that drought risk is only partly a result of deficiencies in the rainfall. Other drivers include poverty, structural vulnerability, increasing water demand from urbanization, industrialization, poor water quality and poor soil management, weak or ineffective governance and climate variability and change.

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

2.3 DROUGHT IMPACTS

Droughts have significant impacts with respect to the social fabric of nations and communities, economic systems, agricultural, livestock losses, loss of labour opportunities, health status of individuals and communities and societal impacts amongst others. However, drought impacts people differently and unevenly, thus increasing the vulnerability of some over others.

Assessing the impact of drought will depend on:

- the probability of its occurrence;
- its intensity and characteristics;
- the susceptibility of the elements at risk based on the prevailing political, physical, social, economic and environmental conditions; and
- the capacity of the affected individual, household and community to cope, withstand and recover from the impact of the hazard (UNISDR 2002).

Therefore, responses to the impacts of drought have to grapple with the political economy of access and control over the critical water resource. Interventions to address these impacts are both immediate in the form of reactive and immediate set of measures like relief, and long term in the form of structural mitigation of droughts.

Table 2.1 shows an example of the huge economic losses a country can suffer due to drought. This is particularly critical in a developing country like Kenya.

FIGURE 2.2 | Raising resilience to minimize risk

Source: Christos *et al*, 2004.

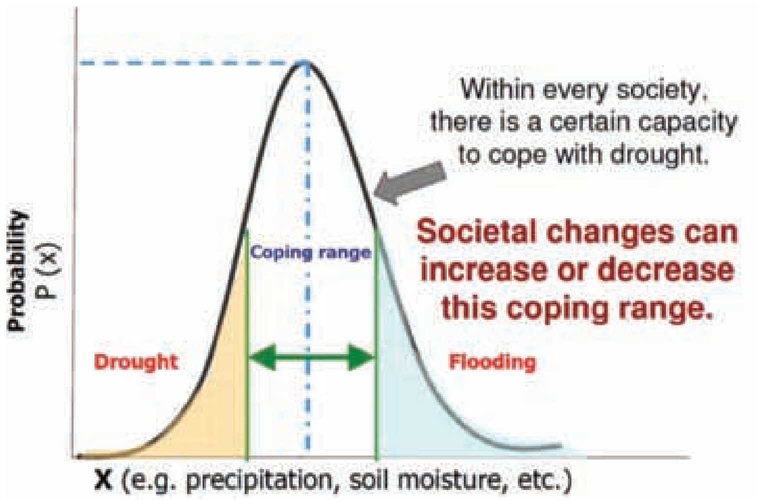


TABLE 2.1 | Crop depletion associated with the 1998-2000 ENSO-induced drought in Kenya

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
Damages 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: UNDP, 2011.

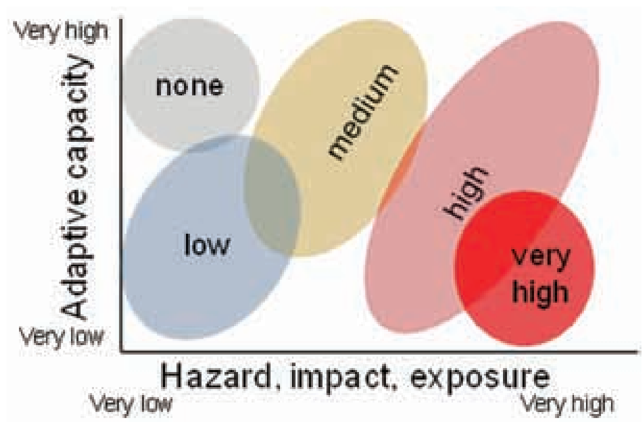
2.4 VULNERABILITY

Vulnerability refers to proneness to damage from external forces. "Vulnerability is a set of prevailing or consequential conditions arising from various physical, social, economic and environmental factors which increase the susceptibility of a community to the impact of hazards" (UNISDR, 2002:24). In other words, it 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. "When ecosystems are vulnerable to destruction, livelihood security is often equally under threat" (Springer et al 2002:79).

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

FIGURE 2.3 | Proposed definition of vulnerability levels

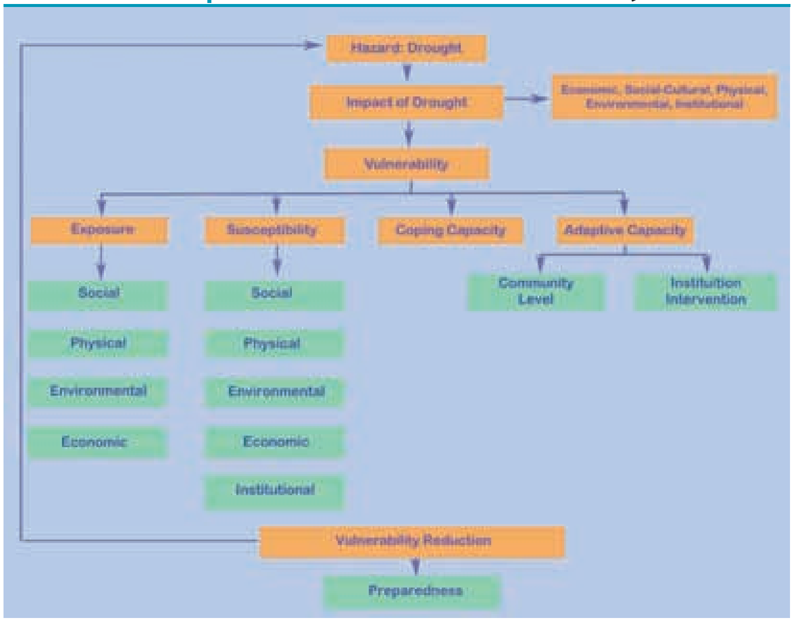
Source: Hydrologic Ensemble Prediction Experiment; hepex.irstea.fr



The factors that define vulnerability to drought – for example, 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.

Figure 2.4 demonstrates how hazard occurrences and exposure will not automatically result in risk. Several regions in Africa, Asia, South America, North America and Australia have somewhat comparable drought potential, but vulnerability is not evenly distributed throughout these areas but rather converges in certain regions and places depending on biophysical factors, improvement to water management infrastructure and economic diversification.

FIGURE 2.4 | Elements of vulnerability



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 the future. As a future-focused concept, vulnerability is a way of using strengths and strategically improving weaknesses. In summary, vulnerability is constituted by the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a hazard.

BOX 2.1 | Drought in Moldova

Source: FAO, nd.

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, 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 Program of Disaster Risk Reduction identifies five technical aspects as critical bottlenecks that worsened the impact of the 2012 drought on small-scale farmers:

- Lack of fodder conservation
- Inappropriate seed varieties
- Absence of climate smart agronomic techniques
- Poor pasture management
- Weak irrigation infrastructure for small farmers

The implementation of the 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.

The opposite of vulnerability is resilience, or the ability to resist and/or recover from damage. In other words, something is vulnerable to the extent that it is not resilient, and vice versa.

In practice, relating vulnerability to risk analysis involves three key considerations:

1. **Exposure** – the number of people or places affected;
2. **Susceptibility** – sensitivity to impacts, stresses, perturbations and shocks caused by hazard exposure; and
3. **Resilience –** adaptive capacity of people, places, and ecosystems.

2.4.1 UNDERSTANDING VULNERABILITY

There is common consensus on the factors which compound or alleviate vulnerability. These will be discussed below.

Political factors

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

A set of deep-rooted socio-economic elements that may include 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, together have the ability to create and maintain extreme levels of vulnerability. Political action is fundamental to 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 find themselves (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 probably has the single most important influence; therefore, the eradication of poverty is crucial to vulnerability reduction. The economic status of the 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 wealthiest members of the population (both women and men) 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 instrument to fall back on). More often than not, 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 wellbeing, with physical, mental and psychological health being critical aspects.

Vulnerability is not equally distributed. Minority groups, the aged, orphans, nursing mothers and their offspring, and the disabled are more vulnerable than others. The issue of gender and in particular the role of women requires special consideration (UNISDR 2002).

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 effective dissemination and response procedures.

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:

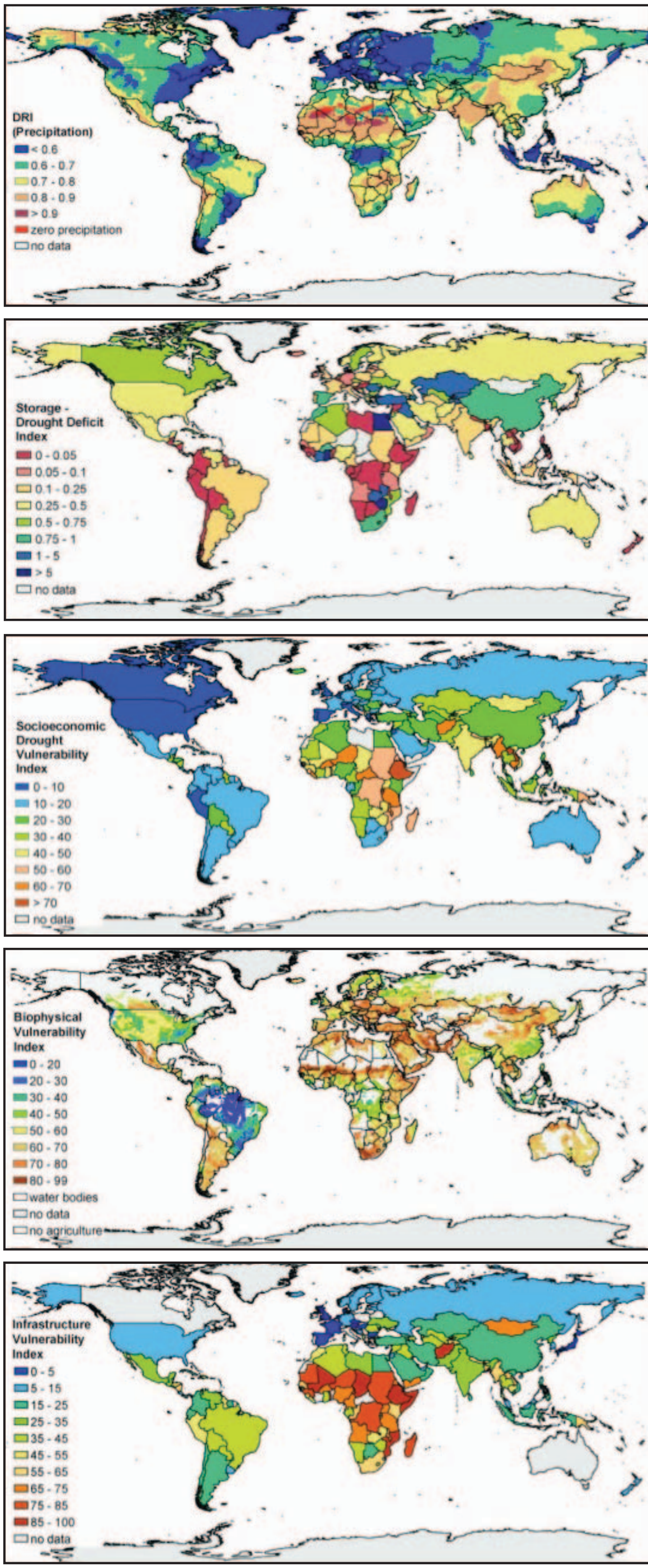
- The extent of natural resource depletion;
- The state of resource degradation;
- Loss of resilience of the ecological systems;
- Loss of biodiversity; and
- Exposure to pollution, especially water pollution that reduces freshwater water availability during drought.

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

- Poor cropping patterns;
- Overgrazing;
- The stripping of topsoil;
- Poor conservation techniques;
- Depletion of both the surface and subsurface water supply; and
- Unchecked urbanization.

FIGURE 2.5 | Comparison of drought potential and vulnerability

Source: IWMI, 2009.



Drought Risk Index with respect to Monthly River Discharge based on the frequency of hydrological (river discharge) drought occurrence and drought intensity (deficit below long-term mean)

Biophysical Vulnerability Index based on mean annual surface runoff, mean annual groundwater recharge, soil depth and soil degradation severity within 0.50 grid cell

Storage-Drought Deficit Index – how much of the long-term annual hydrological (river discharge) drought deficit is satisfied by the existing storage capacity in a country

Infrastructure Vulnerability Index based on the percentage of people having access to an improved water source and general accessibility of rural areas through the road network

Socioeconomic Drought Vulnerability Index based on the crop diversity of individual countries and their dependence on agriculture for income and employment generation

2.4.2 PROGRESSION OF VULNERABILITY

The Disaster Pressure and Release Model (PAR) has become the internationally accepted model for the explanation of the progression of vulnerability and the progression to risk reduction. The PAR Model indicates that there are certain underlying causes, dynamic pressures and unsafe conditions that contribute to vulnerability. Linking the above to a hazardous trigger event increases the risk in communities.

Vulnerability then is depicted in the model as the progression of three stages:

- **Root causes:** a deep-rooted set of factors within a society that together form and maintain vulnerability.
- **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.
- **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.

TABLE 2.2 | Structure of vulnerability and disasters

Source: Blaikie *et al.*, 1994

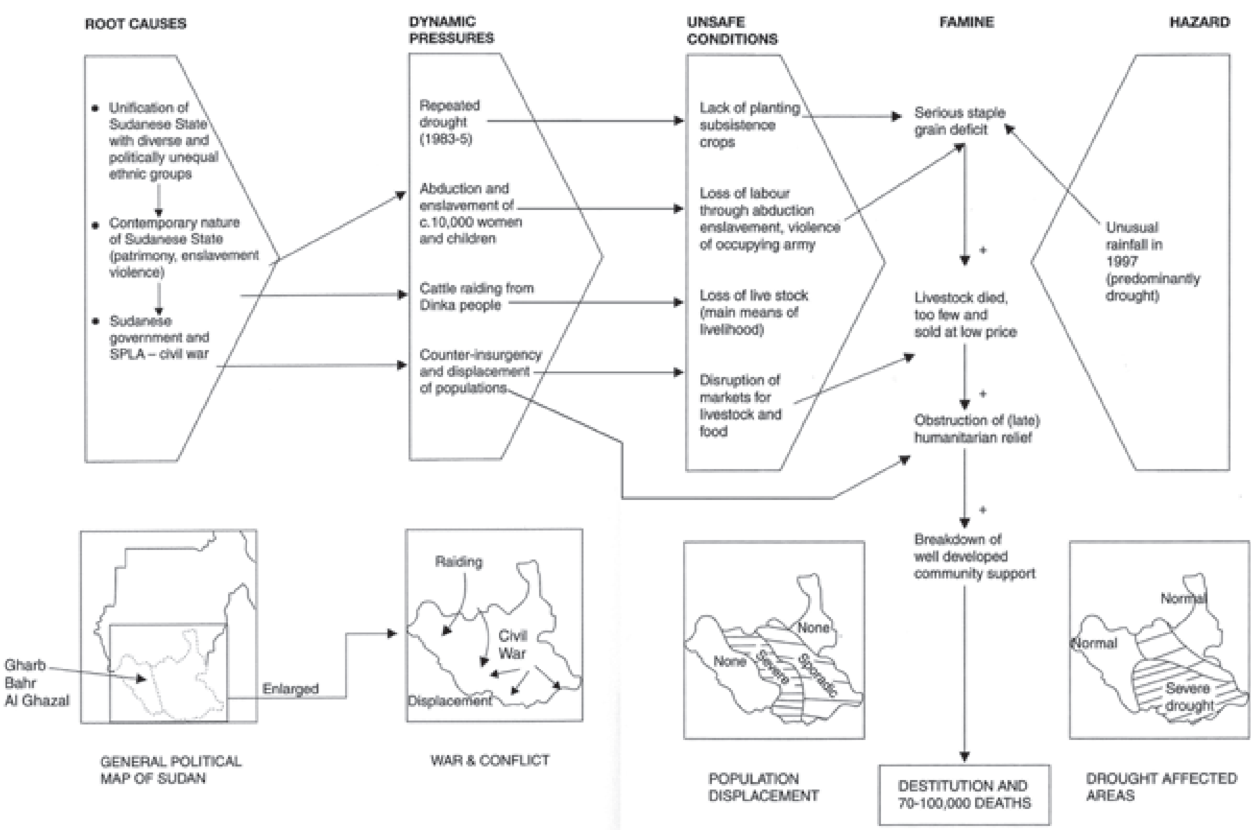
PROGRESSION OF VULNERABILITY Pressure and Release (PAR) Vulnerability Framework			DISASTERS	HAZARDS
ROOT CAUSES	DYNAMIC PRESSURES	UNSAFE CONDITIONS		
Limited access to • Resources • Structures • Power **Ideologies** • Political systems • Economic systems	**Lack of** • Institutions • Training • Skills • Investment • Markets • Press freedom • Civil society **Macro-forces** • Population growth • Urbanization • 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 Heat wave

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

Although analyzing disasters should not be segregated from everyday living, assessment of disasters frequently focus only on the role of trigger climate factors, such as natural hazards or events. An example from South Sudan (see Figure 2.6) 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.

FIGURE 2.6 | Pressure and release (PAR) model: famine in South Sudan

Source: Wisner *et al.*, 2004



2.5 MEASURING VULNERABILITY

There are large numbers of indicators that may be used to characterize the natural and social aspects of drought vulnerability. The characteristic indicators of vulnerability include:

- Limitation and fragility of resource base;
- Level of exposure to drought hazards – history of extreme hydrological events;
- Geographic remoteness and isolation;
- Diversification and size of economies;
- Colonial history and its continuing influences on views and attitudes;
- Institutional capacity and costs of basic infrastructure;
- Level of centralization and effectives of political leadership;
- Range of social factors including dependency, inequity and limited access to resources, prevailing value systems, and attitudes and behaviours;
- Management of waste disposal;
- Literacy level;
- Diseases burden;
- Level of unemployment or underemployment;
- Food import dependency ratio;
- Water scarcity;
- Energy imports as percentage of consumption;
- Access to safe water;
- Percentage expenditures on health and education;
- Urban population growth;
- Child mortality;
- Maternal mortality;
- Income per capita;
- Degree of democratization and human freedoms;
- Economic disparities;
- Social marginalization;
- Inadequate warning systems; and
- Lack of community mobilization.

The selection of vulnerability indicators may be considered along themes, for example;

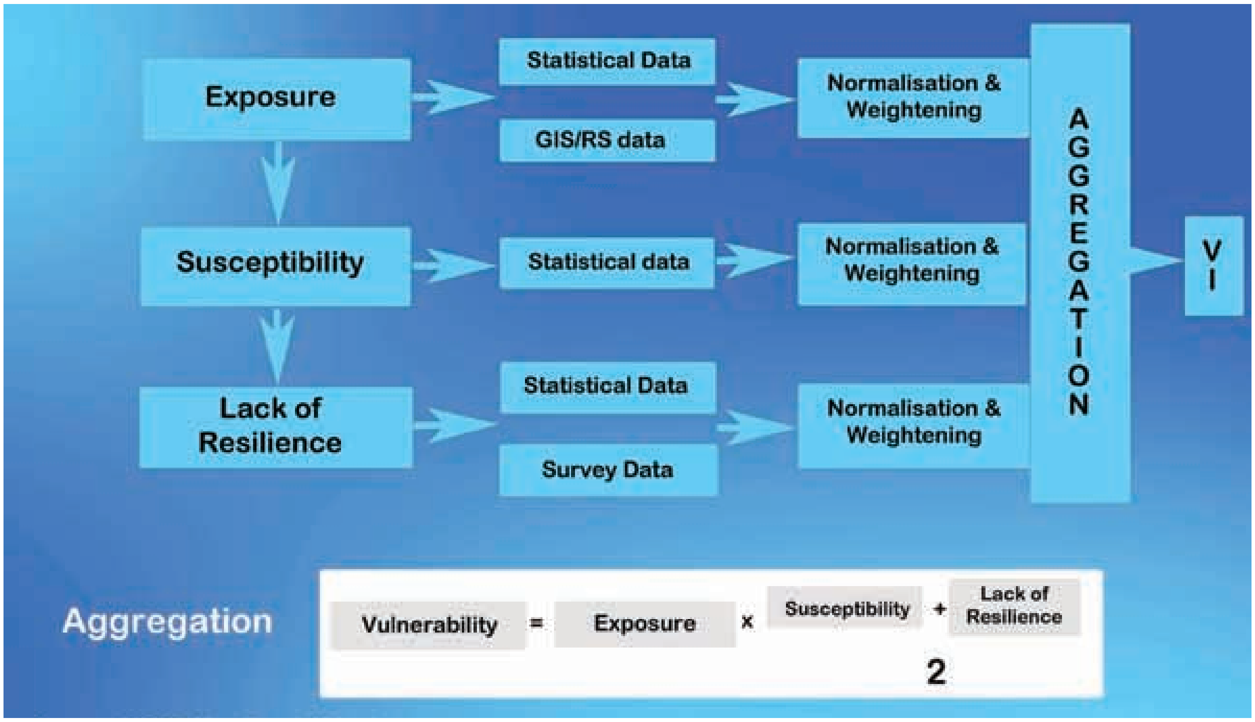
- Hydrological and meteorological indicators;
- Ecological and resource indicators;
- Economic indicators;
- Health indicators;
- Social and demographic indicators; and
- Political indicators.

Other methods evaluate vulnerability grouped differently under exposure, susceptibility and resilience.

2.5.1 METHODS OF COMPUTATION OF INDICES

FIGURE 2.7 | Computing indices

Source: European Commission, 2011.



Adequate indicators and methods of analysis are identified for each component of vulnerability, e.g. exposure, susceptibility and resilience. 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, based on a set of criteria.

While the exposure component aims to identify the number of people or areas affected, the susceptibility and coping capacity component focuses more in depth on factors that cause vulnerability and affect response capacities. The exposure is derived by using forecast techniques. Socio-demographic and socio-economic data may be used to derive the susceptibility and lack of resilience.

All components of vulnerability are normalized and weighted in order to aggregate them into one vulnerability index. The weighting is mainly done by expert judgments and the aggregation uses a weighting equation to determine rank. For example:

- Low drought vulnerability – 1-5
- Moderate drought vulnerability – 6-8
- High drought vulnerability – 9-10
- Low drought vulnerability – 11-12

BOX 2.2 | Selection of drought indicators

For practical applications, the selection of drought indicators may include the following criteria:

- Require only existing and readily available data;
- Be easy and cheap to apply;
- Be appropriate to represent the particular rainfall and stream flow conditions in the area under consideration;
- Discriminate to a reasonable degree between different levels of intensity; and
- Be valid, the results being reasonable predictors of the results of more detailed studies.

2.5.2 DESIRABLE ATTRIBUTES IN A VULNERABILITY INDEX

If the index is to receive support and be operational, it has to 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 it should be collected as a matter of routine together with the information required for the management of water.
- **Suitability for international and temporal comparisons**. Indexes 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.

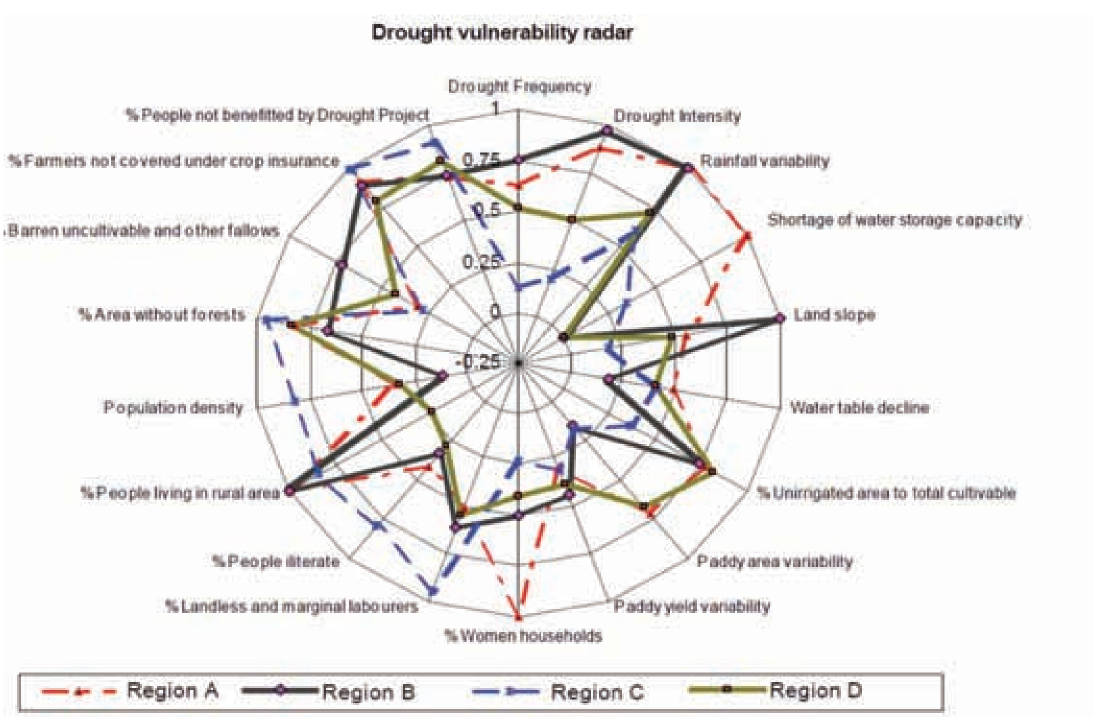
There are four main barriers to a comprehensive vulnerability assessment, irrespective of the scale of assessment:

- Incomplete knowledge of the relevant vulnerability factors and their interactions;
- Insufficient data on existing conditions;
- Difficulty in developing the local and regional scenarios of future change, including climate change; and
- Lack of appropriate analytical methodologies for some impacts.

FIGURE 2.8 | Techniques of representing vulnerability assessment

Source: Swain, nd.

Indicators of Composite Drought Vulnerability Index (CDVI)							
SI No.	Bio-physical Indicators of Drought Vulnerability			SI No.	Socio-economic Indicators of Drought Vulnerability		
	Indicators	Proxy for Indicator	Weights		Indicators	Proxy for Indicator	Weights
1	Drought Frequency	Frequency of Occurrence of Drought (%)	0.1	7	Irrigation	% Area without any irrigation potential	0.1
2	Drought Intensity	% Decrease in precipitatopn from long-term normal in Drought Years (%)	0.1	8		% Unirrigated area to total cultivable area	0.005
3	Rainfall	Average annual rainfall variability (CV %)	0.05	9	Major crop production	Paddy area variability (CV%)	0.005
4	Soil	Available water holding capacity of soil (Rank*)	0.05	10		Paddy area variability (CV%)	0.045
5	Land topography	Land slope (%)	0.05	11	Poverty	% Households below poverty line	0.075
6	Ground water table	% Decline in post monsoon water level in drought year compared to normal	0.05	12	Social factors	% Landless and marginal labourers to total main workers	0.1
				13		% People illiterate	0.1
				14		% People living in rural area	0.05
				15		Population density (per sg. Km)	0.05
				16	Land use pattern	% of geographical area not covered under forest	0.05
				17		% Barren uncultivable and other follows	0.007
				18	Institutional factors	% Farmers not covered under crop insurance	0.005
						% People not benefited by IRDP	0.008



2.5.3 SUMMARY

- Disaster risk is a societal commonality. It affects everyone and all the systems on which we depend.
- Some people and places are highly vulnerable and likely to experience more impact damage because they are already living under the strain of political environmental, health, and socioeconomic pressures.
- Drought vulnerability patterns are dynamics of vulnerability and depend on the frequency, intensity and spatial scale of the hazard.
- Drought risk is linked with development issues; considered together, they provide an ideal opportunity to address and solve many of the issues associated with disaster risk and their impacts.
- The limitation of information and effective communication impedes efforts to improve assessment and reduce vulnerability.

SESSION | Exercise: vulnerability and capability

RESOURCES	VULNERABILITY	CAPABILITY
Physical/material		
Social/organizational		
Motivational/attitudinal		

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PHOTO: UN PHOTO/STUART PRICE

MODULE 3:

DROUGHT RISK MANAGEMENT FRAMEWORK

GOAL

The goal of this module[1] is to explain some of the basic concepts of drought risk management, the five elements of the Drought Risk Management Framework, their application and the importance of pro-active drought risk management in an IWRM perspective.

LEARNING OBJECTIVES

By the end of this module participants will:

- Be familiar with the context of Drought Risk Management Framework and its five main components
- Understand the importance and roles of:
  - Policy and governance
  - Drought risk identification
  - Risk monitoring and early warning
  - Awareness and knowledge management
  - Reducing underlying factors of drought risk and enhancing mitigation measures and preparedness
  - Monitoring and evaluation
- Appreciate the importance of a thoroughly considered, pro-active drought risk management.

3.1 MANAGING DROUGHT RISK

The goal of risk management is to promote the adoption of preventative or risk-reducing measures and strategies that will mitigate the impacts of future drought events, thus reducing societal vulnerability. Drought policies and preparedness plans aim to move societies away from the traditional approach of crisis management, which is reactive in nature, to a more pro-active risk management approach.

The objective of drought risk management is to promote the adoption of preventative or risk-reducing measures and strategies that will mitigate the impacts of future drought events, thus reducing societal vulnerability. Mitigation and preparedness measures may take many forms such as water conservation, changing of local social and agricultural practices, diversifying livelihoods, emergency water supplies. These measures are not only applied over different time scales but also over different spatial scales, with some measures that may be implemented nationally and others locally. Early warning systems can be of critical value for mitigation and preparedness.

This paradigm shift emphasizes preparedness and mitigation. "Many governments and others now understand the fallacy of crisis management and are striving to learn how to employ proper risk management techniques to reduce societal vulnerability to drought and therefore lessen the impacts associated with future drought events" (Wilhite, 2010:4).

1 The material and text in this module is largely extracted from *Drought Risk Reduction Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action* (UNISDR, 2009).

BOX 3.1 | Famine Early Warning Systems Network – a tool to assist mitigation and preparedness in 17 countries in Africa

The Famine Early Warning Systems Network (FEWSNET) is an initiative funded by the United States Agency for International Development (USAID), since its creation in 1985. 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 a number of periodical reporting products, such as the monthly Food Security Updates, monthly Weather Hazards Impact Assessments and Rain Watches and one page reports issued every ten days assessing the progress of the current rainy season and its implications for food security in a specified area.

There has been a shift in the way drought risk management is approached, as it has been realised that preparedness measures, i.e. actions taken before the onset of drought, are the most definite way to reduce its impacts. Emergency measures after the onset of drought will always be necessary, but most drought risk management efforts should take place before the onset of drought. Mitigation and preparedness measures may take many forms, such as water conservation, changing of local social and agricultural practices, diversifying livelihoods, emergency water supplies. Measures are not only applied over different time scales but also over different spatial scales, with some measures implemented nationally and others locally.

In order to take action before the onset, some measures rely on monitoring and early warning of drought as an essential part of a management plan. Drought is monitored using indices to trigger action when a certain intensity of drought is reached (UNISDR, 2011).

3.1.1 DROUGHT RISK MANAGEMENT AND IWRM

There is a close link between drought risk management and IWRM. When droughts occur, they create a need for tight management in the water stressed situation where water resources become scarce. The scarcer the water resources, the more need there is to manage them rationally and satisfy the highest priorities. Reallocation and reduction in allocations would become necessary. The principles and approaches of IWRM apply here.

The management structure based on the three pillars of IWRM, enabling environment, institutional roles and management instruments, is valid in the drought situation, meaning that the policy and legal instruments are ready to support management decisions during the drought. The institutional framework includes properly trained staff and coordination mechanisms to deal with the diverse requirements of the drought situation and its implications. Management tools, regulations, emergency and contingency plans and impact assessment methodologies are developed and internalized in the institutions.

The basic concepts of IWRM in terms of equity in access, economic efficiency in interventions and environmental sustainability are directly applicable also in a drought situation. In this situation, the cross-sectoral balancing is needed between water for people, water for food, water for nature and water for industry and power.

The key management options to be applied in an IWRM framework during a drought situation include, among others:

- **Decrease demand/demand management** – this option requires wide participation, ideally by all users, thorough awareness-raising through the appropriate media and temporary regulations curtailing the water use.
- **Increase supply from other sources** – this option is seldom feasible in a drought situation where reservoirs are drying out and groundwater levels are decreasing and where drought is usually covering a very large area.
- **Reallocate water** – water is reallocated in full or in part from users with non-vital roles to users with vital roles in the socio-economy. This option needs advanced preparation, beginning at the time of preparing an abstraction permit that would contain the necessary clauses allowing water authorities to temporarily decrease the allocated amounts on a temporary basis in the event of a drought.

3.1.2 CHARACTERISTICS AND FEATURES OF DROUGHTS IN RISK MANAGEMENT

Droughts have a number of characteristic features that makes them difficult to deal with. Droughts have a slow onset whereby a water deficit becomes scarcity and then develops into what one would call a drought. However, there is no universal definition of a drought and the location and the vulnerability will mean that different groups of stakeholders will have different perceptions of when the situation is a drought. A drought is developing slowly and there is often a considerable time lag before impacts are experienced. This means that the start of a drought is difficult to define. The same goes for the end of a drought. Even when soil moisture is restored, it will take time before plant growth is experienced. The severity of a drought is likewise difficult to establish. Severity is one of the decision parameters for declaration of emergency, where the government starts a series of mitigation measures such as supporting agriculture and livestock and hauling water in tankers.

The time scale of droughts varies from months to years and impacts may be felt for a long time even after average levels of rain have occurred. Warning systems and parameters are difficult to establish and impacts are often diverse and felt over large areas such as regions and countries. "Downstream" impacts are appearing within hydropower production, cooling in energy plants, reduced plant growth or wilting due to soil moisture deficits, loss of grazing areas for livestock, water quality reduction in streams and serious changes in ecosystems. Water sources for drinking water will often be affected and emergency supplies have to be arranged. Thus, impacts are defined by the unique economic, social and environmental characteristics at the specific location.

A drought has a low visibility and, in contrast to floods, deals with something which is not there. The lack of visibility and the slow development make it difficult to raise support compared to other serious natural events or catastrophes.

3.2 DROUGHT RISK MANAGEMENT FRAMEWORKS

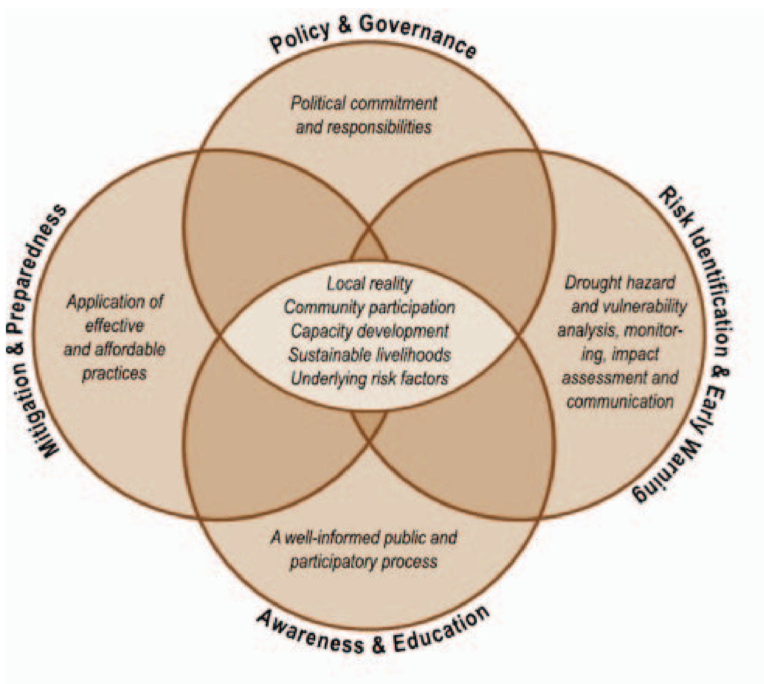
The "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (HFA) is a 10-year plan to make the world safer from natural hazards. It was adopted by 168 governments, who committed to the substantial reduction of disaster losses, in lives and in the social, economic and environmental assets of communities and countries by 2015, with the aim of reducing global disaster risk and contributing to the sustainable development of nations.

The UNISDR Drought Risk Management Framework approach was subsequently developed by government representatives, international, regional and UN organizations, and civil society organizations in order to guide the implementation of the Hyogo Framework for Action with respect to drought.

Drought Risk Reduction Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action (UNISDR, 2009) outlines a conceptual framework for addressing the risks associated with droughts, whereby practitioners are guided in identifying, adopting and applying the most relevant and realistic management tools to address the root causes of vulnerabilities. These root causes typically stem from socio-economic, political, environmental, and technical-physical factors. Five key elements are described and explained below. Figure 3.1 shows these five elements (with mitigation and preparedness pooled together).

FIGURE 3.1 | Key elements of the Drought Risk Reduction Framework

Source: United Nations Office for Disaster Risk Reduction (UNISDR) and National Drought Mitigation Center, University of Nebraska-Lincoln, USA.



The five elements of the Drought Risk Reduction Framework outlined here relate directly to the five priorities of the Hyogo Framework for Action, which is the overall disaster risk reduction framework.

1. **Policy and governance** as essential elements for drought risk management and political commitment. Relating to HFA Priority Action 1: Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.

2. **Drought risk identification**, **impact assessment**, and **early warning**, which includes hazard monitoring and analysis, vulnerability and capability analysis, assessments of possible impacts, and the development of early warning and communication systems. *Relating to HFA Priority Action 2: Identify, assess and monitor disaster risks and enhance early warning.*
3. **Drought awareness and knowledge management** to create the basis for a culture of drought risk reduction and resilient communities. *Relating to HFA Priority Action 3: Use knowledge, innovation and education to build a culture of safety and resilience at all levels.*
4. **Reducing underlying factors of drought risk** such as changing social, economic and environmental conditions, land use, weather, water, climate variability and climate change. *Relating to HFA Priority Action 4: Reduce the underlying risk factors***.**
5. **Strengthening preparedness** for drought to move from policies to practices in order to reduce the potential negative effects of drought. *Relating to HFA Priority Action 5: Strengthen disaster preparedness for effective response at all levels.*

3.2.1 POLICIES AND GOVERNANCE FOR DROUGHT RISK REDUCTION

In generic terms, a policy is a set of goals and objectives, guiding rules and principles that are intended to guide the way society, a group or an organization is managed, while governance is the system of management that is responsible for formulating, implementing, and monitoring and evaluating a given policy.

What is a policy?

Policy is a definite course of action adopted for expediency, facility, etc.

Source: dictionary.com.

Water crises are often governance crises!

A water crisis is ultimately a management crisis that can be solved through the application of IWRM approaches with emphasis on stakeholder dialogues, institutional roles and water sector reforms.

Policies concerned with drought risk reduction are important for setting overall goals or objectives in order to reduce negative impacts from situations of drought. Policies, including related strategies and plans that are required to operationalize policies, are the responsibility of governments, who in many cases will consult with stakeholders who form part of the governance structure. Stakeholder roles in governance structures can range from powerful and influential decision-makers to consumers and may, for example, include different ministries, affected sectors, non-government organizations and interest groups, media and individuals. Policy implementation requires associated legislation giving the government the power to regulate.

A drought policy may take many forms: a legislative act, a planning document, group of related programmes or even an informal understanding among collaborators. The UNISDR Drought Risk Reduction Framework and Practices document outlines the most important factors in a drought policy:

- The policy should have a clear set of principles, strategy objectives, operating guidelines for drought risk mitigation and preparedness, drought response and early recovery and livelihood rehabilitation.
- It should consider the main elements of the drought risk reduction framework.
- It should focus on prevention, mitigation and preparedness rather than solely crisis management.
- It should include the identification and monitoring of information to understand hazard and provide early warning; risk identification to identify most vulnerable groups, areas, and sectors, so that risk management reactions can be identified and implemented to reduce those risks.
- It should promote self-reliance by addressing the main issues in specific regions.

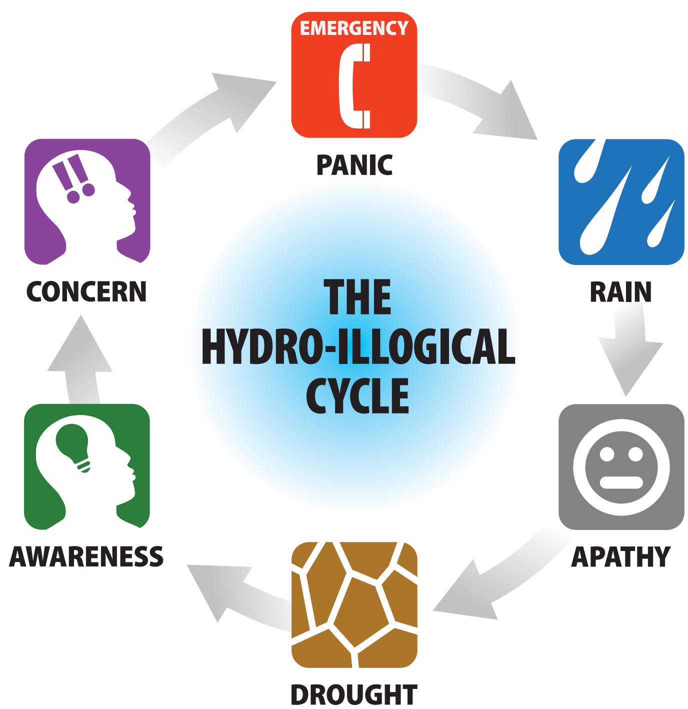
Plans required by the policy should improve coordination between and within different levels of government, information flow and efficiency of resource allocation. The goal of such plans is to reduce water shortage impacts, personal hardships and conflicts between water users and other natural resource users. Further, it is necessary to have supporting legislation to ensure that drought risk reduction policies are carried out.

It is also important to understand existing drought management policies. In many parts of the world, the approach is largely reactive and focused on crisis management. Emergency response is often ill-timed, uncoordinated and lacking integration, significantly increasing droughts' economic, social and environmental impacts. Although the assistance provided addresses a short-term need, it may also decrease individual and community coping capacity in the long term—by fostering dependence on external actors rather than self-reliance.

This hydro-illogical cycle (see Figure 3.2) ignores—and thus precludes—vulnerability reduction, as the assistance provided to affected communities does not require them to change behaviours or resource management practices. Reducing vulnerability requires proactive risk management: advance preparedness planning focused on increasing coping and response capacities to reduce drought impacts.

FIGURE 3.2 | The hydro-illogical cycle

Source: WMO, 2014



Effective drought policy and preparedness plans include organizational frameworks and operational arrangements, developed by governments or other entities in advance of droughts and maintained between individual drought events. This approach aims to build or increase institutional capacity focused on improved coordination and collaboration among stakeholders and various government actors (WMO and GWP, 2014).

Key considerations within policy implementation and governance

Putting a drought risk reduction policy into practice is a major task and requires efforts across many levels of government and sectors. The most important points to consider include:

- **Political commitment and alliances** – the commitment of leading politicians is essential for the policy implementation process. Their involvement during policy development will improve the chance that they are "on board" and feel a certain ownership. Finding and encouraging a champion of the cause will improve the possibility for maintaining the required momentum throughout.
- **Involvement of all relevant horizontal and vertical levels** – the vertical levels, from transboundary levels to community levels, have to be involved in policy implementation and governance. User/user group cooperation agreements on sharing of the scarce water resources have to be established. Horizontal levels have to be involved in order to cover wide drought stricken areas.
- **Mainstreaming drought risk management in sustainable development** – the necessary steps in the mainstreaming process will include the identification of entry points, the mainstreaming into national development frameworks, mainstreaming into sectoral frameworks and mainstreaming into local development planning. See also Table 3.1.
- **Capacity development and knowledge development** – knowledge is the key to selecting the appropriate actions and interventions and implementing them. Relevant levels have to have the capacity to make informed choices. Knowledge has to be updated at frequent intervals to comply with a "use it or lose it" approach.

TABLE 3.1 | Entry points for mainstreaming of drought risk management into sustainable development

Elements of Disaster Risk Management	Possible entry points
Short-term options	⦿ Disaster preparedness plans ⦿ Contingency plans ⦿ Annual national, regional and local development plans
Mid-term options	⦿ Relevant sectoral programs and projects ⦿ Mid-term sectoral strategic plans
Long-term options	⦿ Drought related laws, regulations and by-laws ⦿ Relevant sectoral policies, e.g. drought management policy, water policy, land allocation or resettlement policy, energy policy ⦿ Poverty reduction strategy papers ⦿ Long-term national, regional and local development plans ⦿ National action programmes for international conventions ⦿ Hyogo Framework for Action strategic national action plan

3.2.2 DROUGHT RISK IDENTIFICATION, RISK MONITORING AND EARLY WARNING

A starting point for reducing drought risk and promoting a culture of resilience lies in gaining knowledge about hazard occurrence, the potential effects of the hazard, and the related vulnerabilities of potentially affected people and activities. The latter includes the physical, political, social, economic, and environmental vulnerabilities to drought that most societies face and the ways in which hazards and vulnerabilities are changing in the short- and long-term. Understanding the physical nature of the drought hazard and the corresponding impacts and underlying vulnerabilities, and communicating these dangers in an effective manner, forms the basis for developing informed drought mitigation and preparedness measures to reduce the impact of drought while contributing to drought resilient societies.

Drought risk identification, impact assessment and early warning activities should be guided by the following principles:

- Drought risk is the combination of the natural hazard and the human, social, economic and environmental vulnerability of a community or country, and managing risk requires understanding these two components and related factors in space and time.
- Increasing individual, community, institutional and national capacities is essential to reducing vulnerability to drought impact.

- Impact assessment plays an important role in drought risk management, in particular identifying most vulnerable groups and sectors during drought.
- Drought monitoring and early warning systems play an important role in risk identification, assessment and management.
- Changing climate and the associated changing nature of drought poses a serious risk to the environment, hence to sustainable development and society.

Table 3.2 provides an overview of some key actions to focus on during the different phases of drought, ranging from pre-drought to emergency and final recovery.

TABLE 3.2 | Key actions during the successive stages of drought

Drought phase	Preparedness actions
Pre-drought	• Policy and governance (who, what, how, when) • Risk identification (where, how much, impacts) • Vulnerability assessments • Monitoring and drought indicators • Awareness and knowledge management • Learning from earlier droughts • Drought risk management plan
Early warning	• Real-time forecasts
Droughts and impacts	• High intensity monitoring of drought indicators • Monitoring of impacts (economic, environmental, social)
Drought phase	**Response actions**
Response/ mitigation	• Reducing underlying factors of drought risk • Enhancing mitigation measures
Emergency response	• Temporary reallocation, demand reduction, supply increases, transfers
Recovery	• Financial assistance, insurance

Learning from past events is key to understanding the impacts of droughts and developing appropriate, effective response actions when a drought strikes again. An impact assessment serves this purpose. Box 3.2 shows the example of an impact assessment made in Portugal.

BOX 3.2 | Portugal: Assessing drought impacts

Source: WMO, 2006:20.

Portugal was affected by a severe drought in 2004-2005. The government conducted an assessment of impacts that occurred during the drought to better understand the effects of drought on the country, its people, and their livelihoods. The primary impacts identified were related to agriculture and cattle breeding, energy, urban water supply, and forest fires. This type of impact assessment is essential for identifying vulnerable sectors and populations, and targeting limited resources to high-priority needs.

For example, the drought caused the drying out of water sources and the loss of their annual replenishing capacity. The people and municipalities primarily affected were those with small caption systems in small river basins, or small underground reservoirs. The number of municipalities (out of 308) that were forced to increase water supplies or implement water supply cuts/reductions were 66 and 37 respectively, at the height of the drought.

3.2.3 AWARENESS AND KNOWLEDGE MANAGEMENT

Knowledge and information about disaster risk reduction and the compiling, collecting, sharing and the pro-active use of this information through awareness raising and educational initiatives allow people to make informed decisions and take action to protect themselves, their property and their livelihoods.

Awareness and knowledge management could be guided by consideration of the following principles:

- The effects of drought can be substantially reduced if people are well informed and motivated toward a culture of disaster prevention and resilience;
- Effective information management and exchange requires strengthening dialogue and networks among disaster researchers, practitioners, and stakeholders in order to foster consistent knowledge collection and meaningful message dissemination;
- Public awareness programmes should be designed and implemented with a clear understanding of local perspectives and needs, and promote engagement of the media to stimulate a culture of disaster resilience, including resilience to drought and strong community involvement;
- Education and training are essential for all people in order to reduce local drought risk.

> “ **Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.”** KOFI ANNAN

Four main awareness challenges have been identified in the UNISDR Drought Risk Management Framework (2009). These are:

- Drought must be recognized as a natural hazard, not just as a natural event within the community of scientists and policymakers working on natural hazards. The lack of recognition of the importance of drought as a natural hazard is an important factor in obtaining research and financial support and it is an obstacle to building awareness among policy makers.
- **Build awareness of drought as a natural part of climate not simply as a rare and random event. Climate change is an additional variable to be considered in hazard identification, monitoring, mitigation and preparedness.** Drought can occur anywhere, though its features vary from region to region; therefore, defining drought is difficult from different perspectives. It is often considered to be a random event, which results in the lack of emphasis on preparedness. Improved understanding of the difference of the types of droughts is necessary.
- **Erase misunderstandings about drought and society's capacity to mitigate its effects.** Some consider drought to be a purely physical phenomenon, which leads to the idea that there is nothing that can be done to mitigate it. Drought has physical, social and economic components like other natural hazards, and the risk of drought is determined by the social factors. Well-conceived policies, preparedness and plans and mitigation programmes can greatly reduce societal vulnerability and therefore the risks associated with drought.
- **Convince policy and other decision-makers that investments in mitigation are more cost effective than post-impact assistance or relief programmes.** Present investments in preparedness and mitigation will generate large dividends in reducing the impacts of drought and a growing number of countries are realizing the potential benefits of drought planning. The crisis management approach of responding to drought has existed for many decades and is engrained in the culture. Movement from crisis to risk management will require a paradigm shift. In part as a result of the crisis management approach, those vulnerable to drought have become accustomed to government assistance programmes. Governments have come to realize that many programmes are not linked to changing practices and instead reinforce unsustainable actions and decrease self-reliance. Governments must support capacity development at the local level for understanding and using drought risk and related information for decision making. As the themes become engrained in society, people will become responsive to the implementation of drought policies and plans.

3.2.4 REDUCING UNDERLYING DROUGHT RISK FACTORS

Reducing drought vulnerability requires reducing underlying risk factors through effective environmental and natural resource management, social and economic development practices, and land-use planning and other technical measures. The factors that have an impact on vulnerability to drought need to be reflected in national poverty reduction strategies, development plans, sector development planning and programmes, and environment and natural resource management strategies as well as in post-disaster situations so that effective preparedness and mitigation measures can be considered.

The most important principles that can guide the work towards reducing underlying factors of drought risk include:

- Mechanisms that systematically can bring practitioners together in disaster risk reduction (e.g. national platform members) and key institutions involved in environmental management (e.g. adaptation to climate change, desertification and biodiversity).
- Areas of overlap and synergy should be identified between existing environmental programmes and disaster risk reduction activities.
- A mechanism for carrying out joint assessments should be institutionalized to integrate disaster risk reduction and environmental protection parameters (e.g. integrated risk-and environmental-impact assessments).
- Specific attention should be given to socioeconomic high-risk factors such as age, disabilities, social disparities and gender. By focusing on protection of the most vulnerable groups, the impacts of disasters can be reduced.
- Post-drought recovery planning can incorporate drought risk reduction strategies for the future.
- Safety nets such as insurance mechanisms for properties as well as microcredit and financing for ensuring minimum livelihood means can accelerate post-drought recovery process.

Environmental degradation such as land degradation, deforestation, desertification and loss of biodiversity has detrimental effects on the local communities in coping with droughts and are among the underlying factors of drought risk. On the other hand, more sustainable land management, including protecting soils from erosion and eventual desertification through better land-use planning and sustainable farming and ranching practices, helps to reduce people's vulnerability to droughts. Maintaining watersheds by avoiding deforestation and diversion of waterways protects water quality and quantity. Better management of water resources and conservation of fragile ecosystems will allow diversification of livelihoods and sustain local economies during and after drought. Clear identification of climate change related risk, exchanging relevant data and information and leveraging political support and funding can contribute to effective and efficient use of existing resources and maximize synergy between drought risk reduction and climate change related programmes.

3.2.5 ENHANCING MITIGATION MEASURES AND PREPAREDNESS

The goal of drought mitigation and preparedness is to reduce drought vulnerability and foster drought-resilient societies. "Mitigation" in this context is defined as the lessening or limitation of the adverse impacts of hazards and related disasters. "Preparedness" is defined as the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

Before drought, mitigation actions can be implemented to build resilience into an enterprise or system so it will be less affected when drought eventually occurs. Some mitigation actions can require relatively small changes, while others may require the re-evaluation and modification of more basic elements of livelihoods and production systems. An important mitigation measure is the development of drought preparedness and contingency plans (see Box 3.3) that detail specific measures to be taken by individuals or responsible agencies both before and during drought. Effective drought mitigation and preparedness planning are based on established policies and institutional capacity, sound drought risk identification and early warning, and drought awareness and knowledge management.

Drought impacts and losses can be substantially reduced if authorities, individuals, and communities are well-prepared, ready to act, and equipped with the knowledge and capacities for effective drought management. It should be recognized that mitigation and preparedness have a greater impact on reducing the scale and effects of drought disasters than ad-hoc emergency response measures.

Guiding principles

- Prevention, mitigation and preparedness are central components of disaster risk reduction, and are more important than relying solely on ad-hoc emergency response measures.
- Dialogue, exchange of information, and coordination are needed between disaster risk reduction, development and emergency management actors.
- The selection of appropriate drought risk reduction (prevention, mitigation and preparedness) measures requires many considerations, such as integrated environmental and natural resource management, social and economic development, land use planning opportunities, and climate change adaptations.
- A combination of top-down and bottom-up approaches is required for the development and implementation of effective mitigation and preparedness measures.
- Institutional capacity, coordinated mechanisms, identification of local needs and indigenous knowledge are required to implement effective mitigation and preparedness strategies.
- Monitoring and early warning are key elements of disaster risk reduction and must be closely linked to other risk reduction actions.
- Drought risk reduction (prevention, mitigation and preparedness) requires a long-term commitment of resources.

BOX 3.3 | A 10-step drought preparedness plan

1. Appoint drought task force
2. Define objectives of drought preparedness plan
3. Seek stakeholder participation
4. Inventorize resources and groups at risk
5. Prepare draft plan
6. Fill scientific and institutional gaps
7. Integrate science and policy
8. Publicize plan and build awareness
9. Education and training
10. Evaluate and revise drought preparedness plan

Source: WMO and GWP 2014

3.3 CLIMATE CHANGE AND INCREASED UNCERTAINTY

For many years, meteorologists and hydrologists have assumed that statistics could describe the variation in hydrological parameters. Means and standard deviations were more or less stable and lengths of dry spells and magnitude of flood peaks could be forecasted. However, an additional uncertainty has been introduced with climate change. Means and standard deviations are "drifting" and no longer stable, because of the effects of global warming. Droughts could become worse than expected and appear with higher frequencies. This means that drought preparedness will have to take into account not only earlier observed severity but also increased aggravation of the drought situation, and build on flexibility.

CLIMATE CHANGE

"Climate is what we expect, weather is what we get."

MARK TWAIN

3.4 MONITORING, EVALUATION AND INDICATORS

Monitoring and evaluation of all parts of the drought risk management framework are necessary. Monitoring and evaluation activities produce information for both gaining an understanding of the baseline situation and for tracking and improving progress towards drought risk reduction.

First of all it allows the gathering of information to establish the initial status of drought risk reduction activities, which allows the current situation to be assessed and priority actions to be identified. Furthermore, the documentation of the baseline situation is necessary to evaluate impacts of any intervention and make comparisons.

Once drought risk reduction activities are implemented, it is also important to know what impacts they are having. For this reason, monitoring of changes and the evaluation of the effectiveness of interventions is important so that strategies for reducing risk can be improved where possible.

The measurement of a status and changes is often approximated through the use of indicators. For each part of the drought risk management process, indicators should be developed.

The status of various drought risk elements such as the vulnerability of people to drought, or the strength of the drought policy or the reliability of water sources, could all be potentially simplified and summarized in indicators. Such indicators provide a means of measuring and can be monitored and used to track progression of a situation and focus efforts. However, in simplifying the situation, the indicator may represent an average situation across an area, whereas there may be important information about different vulnerabilities within that area – some areas may be much more vulnerable than others. Thus, it is important that the scale of the indicator be considered. The selection of indicators also implies the selection of the particular processes deemed most important and can lead to other important factors not

LIMITATIONS OF INDICATORS

"Everything that can be counted does not necessarily count; everything that counts cannot necessarily be counted."

ALBERT EINSTEIN

COMPLEXITY OF WATER PROBLEMS

"Anyone who can solve the problems of water will be worthy of two Nobel Prizes – one for peace and one for science."

JOHN F. KENNEDY

being represented. To ensure that users are aware of this limitation, it is important that all such assumptions are made explicit.

It is clear that a lot of important information about drought risk cannot be easily simplified and summarized in indicators. It is important that the limitations and the dangers of using indicators are acknowledged and that other forms of knowledge are not ignored. Indicators should be based on common sense and kept simple to allow as many people as possible to be involved and understand them. Furthermore, it should be emphasized that indicators are designed to aid decision-making, not to replace it. Due to their limitations, it is important that decision-making is not limited to following the direct outcome of indicator assessments but that a sensible holistic view is taken. Selecting indicators should be done in such a way that they represent the root causes of a particular issue. Otherwise there is a danger of "treating the symptoms rather than the sickness".

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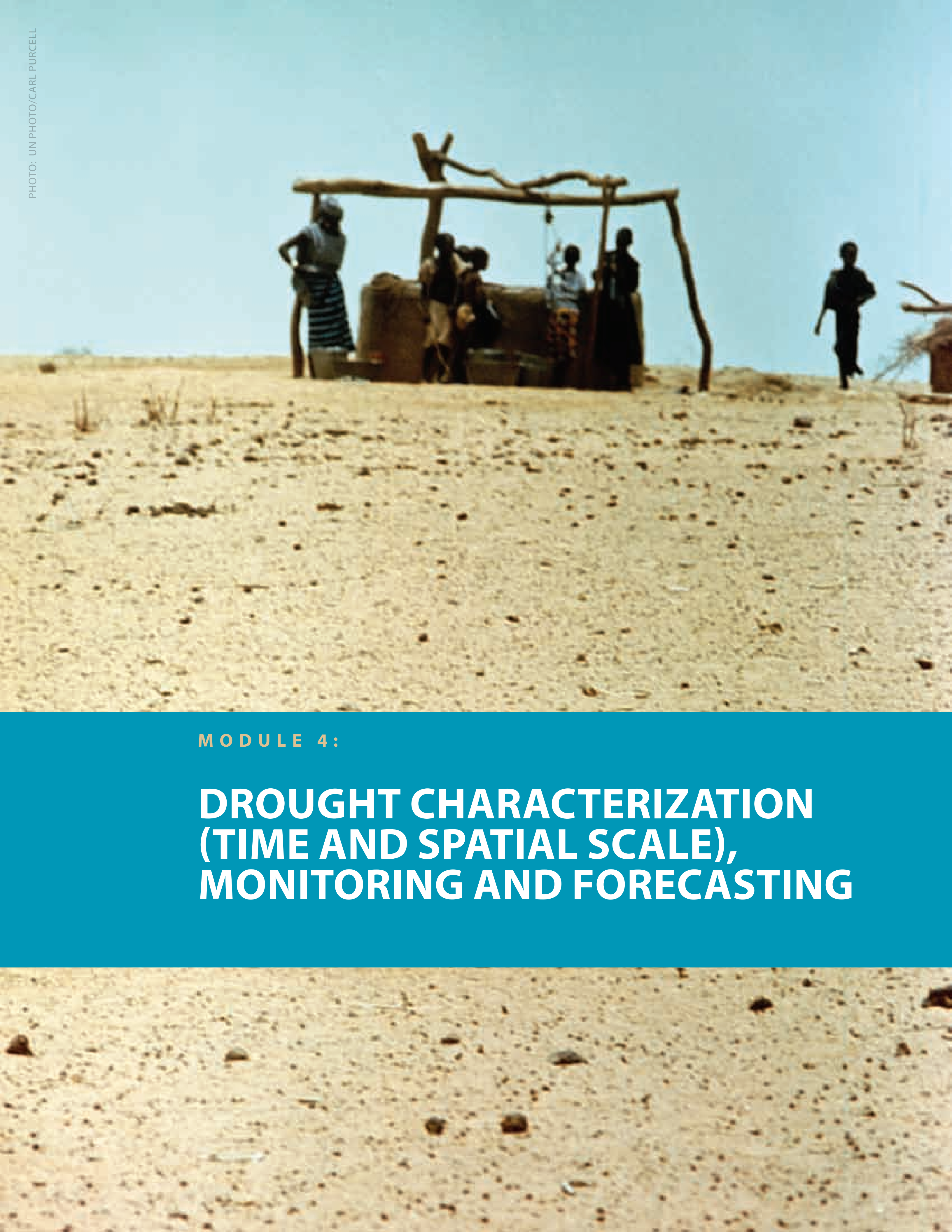


PHOTO: UN PHOTO/CARL PURCELL

MODULE 4:

DROUGHT CHARACTERIZATION (TIME AND SPATIAL SCALE), MONITORING AND FORECASTING

GOAL

The purpose of this module is to show how water managers could get answers about drought in order to make decisions. Water managers will be given tools, methodologies, and software that they can use to get or built answers about drought. This can be done by first learning the techniques to identify and estimate the different drought characteristics using state of art land and surface phenology[2] and remote sensing-based estimations, and then learning how to derive drought severity from these parameters using prepared datasets.

LEARNING OBJECTIVES

At the end of this module, participants will be able to:

- Understand what is a drought (linking to Module 1 – types of drought);
- Understand the interaction between drought status and the water balance;
- Understand how water balance components can be measured from ground and space;
- Understand how droughts can be characterized using different data;
- Identify the risk associated with the drought phenomena.

4.1 INTRODUCTION

Drought is a global problem that will reoccur and continue to grow in future. Impacts of droughts range from significant socio-economic impacts to environmental impacts leading to reduced water levels, reduced agricultural yields, increased fire hazards, and damage to wildlife. As drought is a slow hazard, it is difficult to predict the temporal start and end. This prediction is further complicated by the fact that droughts depend on a lot of variables. Hence studying droughts incorporates the investigation of land surface parameters, not all of which can be determined accurately (Mishra and Singh, 2010a). Drought characteristics such as intensity and frequency will vary from one climate regime to another and therefore need to be investigated thoroughly.

Due to its nature, drought is commonly defined both operationally as well as conceptually, and cannot be viewed in solitude, as only a physical phenomenon. Defining drought as a concept operationally allows for a concrete understanding of the onset, severity and duration of the drought, enabling conceptual definitions that policy makers, resource planners, and others can use in recognizing and planning for drought. Drought can be categorized as meteorological, agricultural, hydrological and socioeconomic, where the first three deal with mechanisms of measuring drought as a physical phenomenon, while the last deals with drought in terms of supply and demand following the effect of shortage of rain fall (Wilhite and Glantz, 1985). Drought occurs in all parts of the world, but it is severe when it occurs in developing countries and especially in Africa. The impact of climate change on drought is severe. Climate change causes not only a rise in global temperature, but also the increase of extreme weather events (IPCC, 2007). Such extremes are intense rainfall followed by prolonged absence of precipitation. Both the rise in

2 Land surface phenology (LSP) may be defined as the seasonal pattern of variation in vegetated land surfaces observed from remote sensing. LSP dynamics reflect the response of vegetated surfaces of the earth to seasonal and annual changes in the climate and hydrologic cycle.

temperature and the long absence of precipitation are major factors for causing droughts. Therefore, this global change needs to be incorporated in forecasting future droughts.

4.1.1 DROUGHT ASSESSMENT

Assessing and analysing drought is very important in water resource planning and management. Droughts are assessed under meteorological, agricultural, hydrological, and socio-economic aspects (Nagarajan, 2010). Drought assessment depends on the factors that caused the drought and the impacts of the drought.

Traditional methods of drought assessment and monitoring depend on rainfall data, and are regionally limited, inaccurate and difficult to obtain in near-real time. In contrast, satellite data are consistently available in near real time and can be used to identify the start of drought, its duration and magnitude prior to harvests (Ataklti, 2012).

4.1.2 DROUGHT CLASSIFICATION

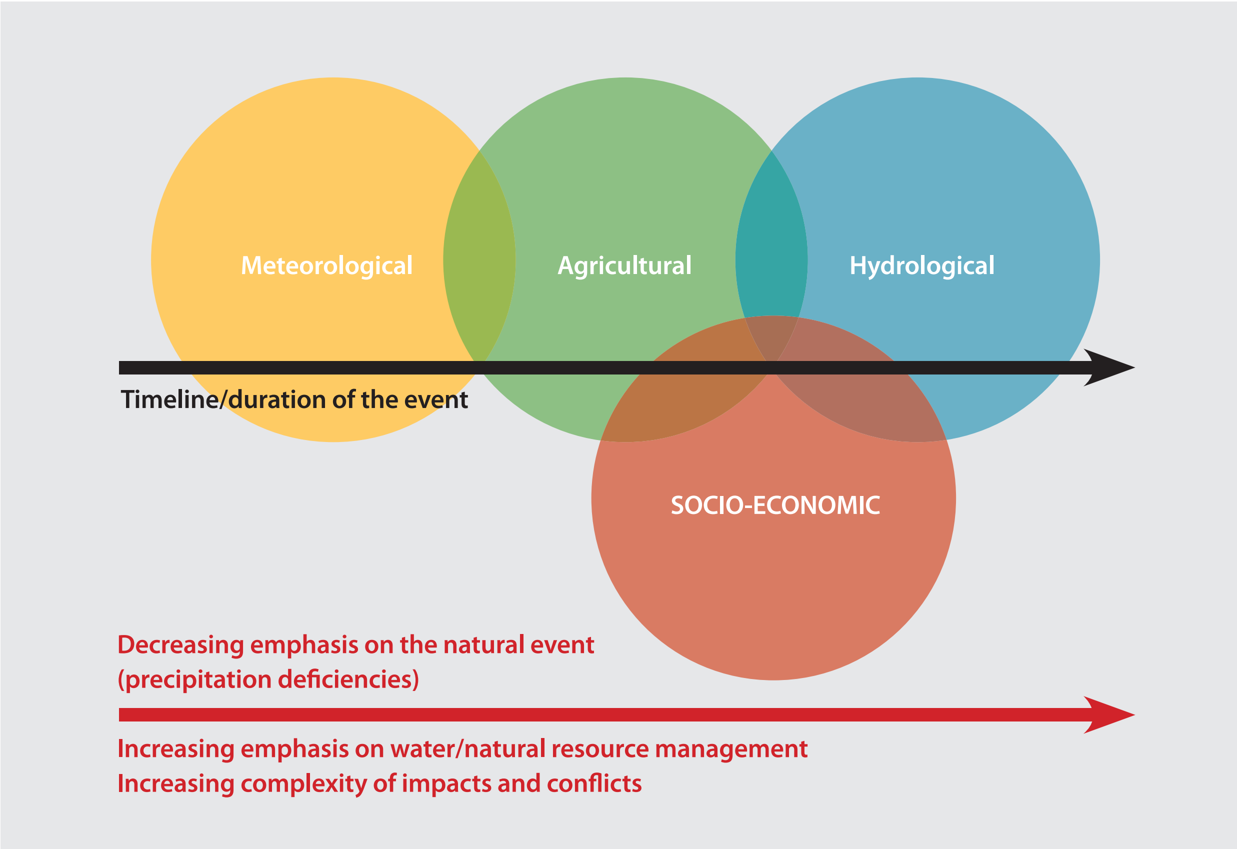
While drought is generally defined as the absence of water, different droughts can be identified depending on which specific hydrological component is absent: meteorological drought, agricultural drought and hydrological drought. An additional type, the socio-economic drought, is also recognized. which associates different droughts with the supply and demand of economic goods.

- **Meteorological drought** is defined as a lack of precipitation over a region for a period of time. Precipitation has been commonly used for meteorological drought analysis (Anderson et al., 2007; Edossa et al., 2010; Salinger, 2005;). It should be noted that meteorological drought can also occur if precipitation amounts remain stable, but evapotranspiration increases. Especially in a changing climate, this needs to be considered.
- **Agricultural drought** is defined by a period with declining soil moisture and consequent crop failure, without drawing reference to surface water. A decline in soil moisture depends on several factors affecting both meteorological and hydrological droughts, including differences between potential evapotranspiration and actual evapotranspiration. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant and stage of growth, and the physical and biological properties of soil (Allen et al., 2005a; Beyazgul et al., 2000). Numerous drought indices have been used to analyse agricultural droughts, which are determined by a combination of temperature, evapotranspiration, precipitation and soil moisture,.
- **Hydrological drought** is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. Hydrologic drought analyses depend heavily on streamflow data.
- **Socio-economic drought** occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply. It is therefore less of a physical drought definition, as it also takes into account the risks that specific stakeholders have to specific deficits of water. As such, this particular type of drought can only be monitored when all the risks on the above droughts have been characterized.

This classification is cascading from minor to major impacts, as illustrated in Figure 4.1.

FIGURE 4.1 | Natural and social dimensions of drought

Source: Stefanski, nd, citing Wilhite, 2006.



4.2 WATER BALANCE

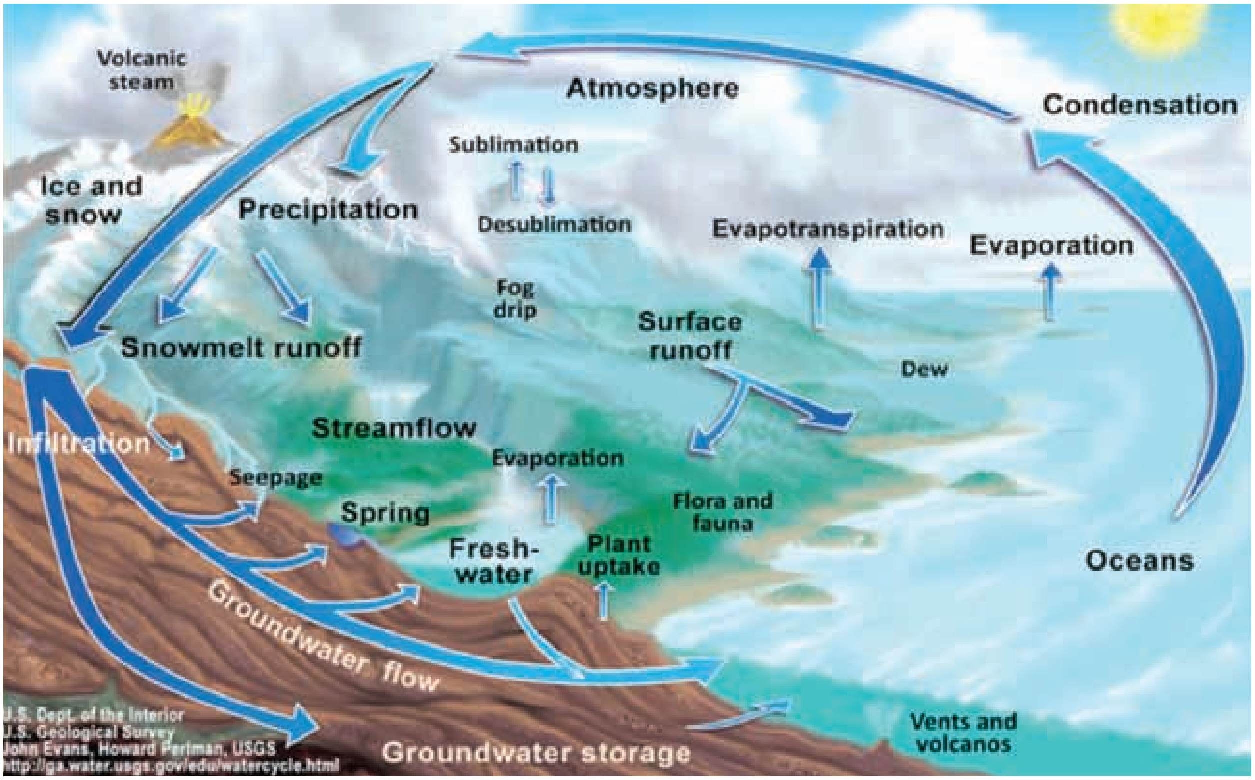
If drought is considered to be only a lack of precipitation, the drought problem can never be fully solved, as only the meteorological drought is investigated. In reality, drought is a problem caused by multiple-variables, and varies in both space and time. In order to characterize drought, one should not look only at one part of the water cycle but at all the components. This water cycle is illustrated in Figure 4.2.

Here, the sun is the driving force behind the water cycle as it heats water in the oceans. This causes evaporation of the water into air (vapour). In addition, the land surface also loses water to the atmosphere in the form of evapotranspiration (which is the combined transpiration by plants and the evaporation by the soil). Due to heating of the atmosphere, this air rises, taking the vapour up into the atmosphere. The vapour rises into the air, where cooler temperatures cause it to condense into clouds.

Air currents move clouds around the globe, and cloud particles collide, grow, and 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, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff and groundwater seepage accumulate and are stored as freshwater in lakes.

FIGURE 4.2 | The global water cycle

Source: United States Geological Survey (usgs.gov).



Not all runoff flows into rivers; much of it soaks into the ground as infiltration. Some of the water infiltrates into the ground and replenishes 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 evapotranspiration from the leaves. Over time, though, all of this water keeps moving, some to re-enter the ocean.

In drought monitoring, it is superfluous to investigate the complete water cycle over the whole earth when the area of interest is much smaller. Instead, a local water balance can be written such that all the components within an area are covered. (Syed et al, 2008). Inflow can be assumed to be the runoff from the neighbouring pixels. Regional drought can thus be investigated using the local values of each of these water balance components. Diverse types of droughts exist due to the different temporal variations present in each of these water cycle components. 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 water balance components is needed in order to understand drought and its impact.

4.2.1 PRECIPITATION

Precipitation is the dominant source of fresh water in most areas. Precipitation arises from water vapour in the air and as such is mostly dependent on the evaporation of the sea (and consequently the sea surface temperature), even though evapotranspiration from the surface also plays a huge role.

As water continually moves between oceans, atmosphere, cryosphere and land, clouds play an important role in the water cycle of the Earth. The properties and motion of the coherent cloud features are primarily determined by large-scale atmospheric circulations, which are pertinent manifestations of the weather systems. The amount of water moved through the hydrologic cycle every year is equivalent to the amount of water uniformly distributed over the surface of Earth with a depth of one meter. 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 takes place.

4.2.2 SOIL MOISTURE

The amount of water stored in the soil can be divided into two parts: soil moisture and ground water. Soil moisture is the water stored within the top level of the soil. It is fundamentally important that the rate of actual evaporation (Seneviratne et al., 2006; Seneviratne and Stöckli, 2008; Seneviratne et al., 2010), ground water recharge (Rodell et al., 2004) and runoff are measured and monitored. Consequently looking into drought is of vital importance. Both the amount of soil moisture and the water-holding capacity of the soil are important. The water-holding capacity of the soil, which is different depending on the soil type, will affect possible changes in soil moisture deficits: the lower the capacity, the greater the sensitivity to prolonged absence of precipitation.

4.2.3 EVAPOTRANSPIRATION

Evapotranspiration (ET) is the largest sink of the water balance (Kite, 2000; Thornthwaite and Mather, 1951). It represents the combination of water loss to the atmosphere through evaporation of water bodies and soil on the one hand, and the transpiration of leaf water content by the vegetation on the other hand. 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 the vegetation is a combined biological and physical process, called biophysical (Shenbin, 2006; Cammalleri et al., 2012). Therefore, the combined process of ET is dependent not only on the meteorological parameters, but also on processes within the canopy, like carbon assimilation and growth patterns.

A difference must be made between actual ET and the potential ET (Allen et al., 2005b). Potential ET is the hypothetical maximum amount of water lost by the soil/vegetation for specific meteorological conditions in case that there is no water stress, while actual ET is the real water loss calculated for those same conditions. The combination of these two estimations is of incredible value for determining the water stress level and consequently drought at the surface (Allen et al., 1998).

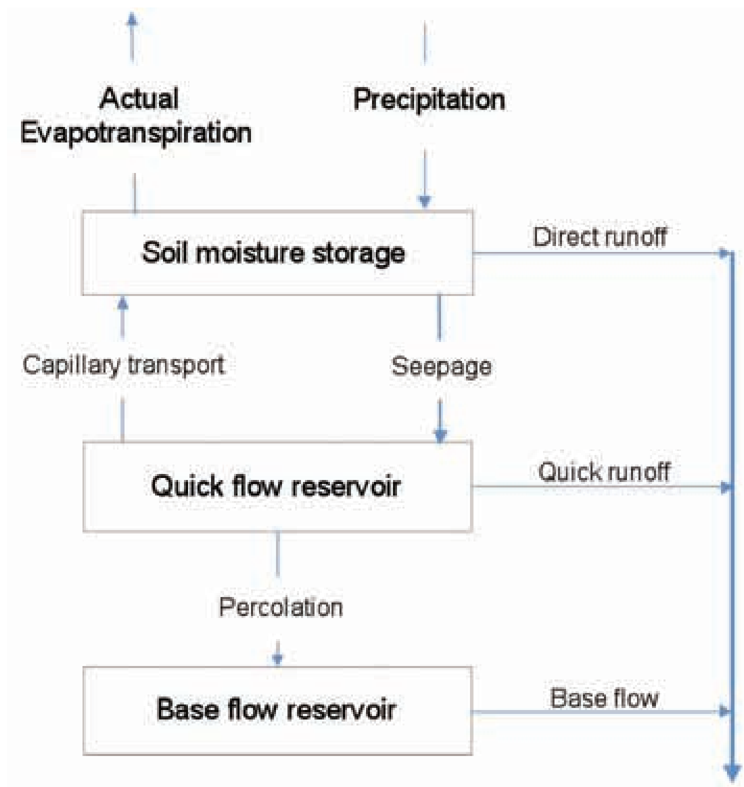
4.2.4 GROUND WATER, RUNOFF AND INFLOW

Inflow, ground water and runoff can all be considered as leftover parts of the water balance. They are very difficult to determine, as they depend on the water available by precipitation, the amount of water lost through precipitation, the amount of water that is stored in the soil through soil moisture and the roughness of the surface. This last parameter characterizes the flow speed of the runoff and consequently also the duration of the runoff over a specific area. Therefore, it influences the amount of water that is evaporated and percolated in the soil, as illustrated in Figure 4.3.

Precipitation is divided into direct runoff and infiltration. Direct runoff occurs if the simulated soil moisture storage exceeds the maximum storage capacity. The remaining precipitation infiltrates in the soil moisture reservoir and seeps through the soil layer to the quick runoff reservoir. The quick runoff routine accounts for percolation to the base flow reservoir, capillary transport to the soil moisture reservoir and quick runoff.

FIGURE 4.3 | Estimating runoff from the water balance according to the HBV model

Source: Note: Hydrologiska Byråns Vattenbalansavdelning (HBV) model is a rainfall-runoff model, which includes conceptual numerical descriptions of hydrological processes at the catchment scale. In different model versions HBV has been applied different countries and climatic conditions all over the world.



4.3 OBSERVING HYDROLOGICAL PARAMETERS FROM SPACE

4.3.1 GROUND-BASED MEASUREMENTS

There is a large variety of ground-based measurements that can be used for the different components of the water balance:

- Relying primarily on tipping buckets and radar for measurements. While tipping buckets are accurate instruments, rain events are widely distributed over the land, and a large number of tipping buckets is required to capture fully 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.

- 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. Though conventional methods have shown relatively accurate ET for homogenous area, their uses are limited for larger heterogeneous area. Hence, more instruments need to be put up for larger areas (Kite and Droogers, 2000).
- Soil moisture measurements that include theta probes, ground radar measurements and gravimetric measurements. For the first two measurements, additional information such as the soil conductivity is necessary in order to estimate soil moisture. This is not needed for the gravimetric measurements, in which a sample of the soil is taken to the lab, weighted, dried and then weighted again. For all measurements, however, multiple points need to be investigated and the number of soil moisture networks are limited.
- For runoff, one determines the river flow at the end of the catchment. This can be done using flow meters and water levels.
- Ground water level (change). Common methods of measuring the ground water are 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 ground water at large scales is challenging due to the limited number of ground water monitoring stations.

While quantitative estimation of these components, with high spatial and temporal resolution, is vital 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 lands are still unrepresented because it is costly to establish a single fully fledged hydro-meteorological station together with the associated infrastructure. In addition, hydro-meteorological equipment is unique in design, expensive, and prone to periodic break-down, due to the effects of the environment. Therefore, remote sensing is needed to cover larger scales.

4.3.2 REMOTE SENSING TECHNIQUES

Satellite remote sensing has become a vital technique in water management. Satellite sensors provide the potential of observing large areas at once with a single sensor. In addition, these observations are made several times per week, with data available within 2/3 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 like evapotranspiration.

Remote sensing uses observations of radiation to determine the state of the atmosphere/sea or land surface. Hence, only land surface parameters that have a significant impact on the reflection or emission of radiation can be detected from 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 difference is made between optical and microwave measurements.

- **Optical remote sensing** looks into the sun radiation reflected from the earth surface and the thermal radiation emitted from the earth surface. The wavelength of this radiation is between 400 nm and 15 and needs to be corrected first for the absorption/reflection of the atmosphere. The emitted radiation is a direct measure of the temperature of the cloud/land surface, while the reflected radiation provides direct information about the size of land surface.
- **Microwave remote sensing** measures satellite emitted radiation refracted back by the atmosphere/earth surface or radiation emitted by the earth surface. The wavelength of this radiation is in between 0.1 cm and 10 cm and therefore is unimpeded by cloud cover during day and night. As such, the amount of radiation received by the sensor cannot be identified as a reflection from a specific object, but instead is a measure of the dielectric constant of the soil/atmosphere.

The advantage of optical remote sensing over passive remote sensing is that the resolution is several times higher. On the other hand, optical remote sensing observations of the Earth are only made if there are no clouds, while for microwave remote sensing this does not pose a problem. Finally, the resolution of the observation differs also between optical and microwave remote sensing, with optical remote sensing having resolutions between 15 m and 3 km, and microwave remote sensing having resolutions between 12.5 km and 50 km.

Both passive and active remote sensing are used to observe radiation. From this radiation, the land cover characteristics need to be determined. In general, two methods exist for computing land surface parameters from remote sensing observations: statistical methods, and the full radiative transfer inversion. In statistical methods, the observations of reflected radiation are combined into vegetation indices, such as the Normalized Difference Vegetation Index or NVDI (Kustas et al., 1993). Using ground observations, a statistical relationship is created between the desired land surface parameter and such a vegetation type. Full radiative transfer inversion entails the estimation of land surface variables derived from detailed radiative transfer models (RTM). Firstly, an initial guess is made about the land surface variables, and the RTM is used to simulate the reflected radiation. Afterwards, the simulated radiation and the observed radiation (by remote sensing sensors) are compared. On basis of this comparison, a new guess is made and the RTM is rerun. This continues until the radiation simulated by the RTM is the same as the radiation observed from space.

BOX 4.1 | Additional information about satellite trajectories

As the satellite moves around the Earth, it does not observe a specific location each day and also the observations do not have the same view angle. The amount of days in between satellite overpasses is called revisit time, which is usually around 2/3 days. Only after a specific time does the satellite view again a specific area with the same view angle. This is called repeat cycle and is usually around 16 to 28 days.

4.3.3 REMOTE SENSING OBSERVABLES

Precipitation: Precipitation can be measured by both optical and microwave measurements. Precipitation from *optical remote sensing* is estimated using the cloud (top) temperature, which is correlated to precipitation amounts. (Roebeling and Holleman, 2009) The Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infra Red Imager (SEVIRI) are effective at detecting back-scattered radiation from cloud tops and have been used in several studies. Measurement of precipitation from microwave remote sensing has recently gained popularity in this field, with the potential to improve precipitation estimates from the surface and from space. Microwave retrievals over the ocean are thought to rival radar retrievals for accuracy, but retrievals over land have more uncertainty due to the effect of microwave reflections from the land surface (Morrissey and Greene, 1998).

Soil Moisture: Satellite remote sensing was seen as a potential tool to provide spatial and temporal continuous soil moisture measurements, dating back a number of years. These traits have motivated much research, particularly in the microwave domain of the electromagnetic spectrum. Using a map of different soil types, the dielectic constant observed from microwave remote sensing can be converted into an estimation of soil moisture. The depth of measurement in microwave remote sensing depends on the wavelength of the observation and can vary between 2.5 cm and 15 cm (Dente et al., 2012a; Dente et al., 2012b).

Evapotranspiration: Evapotranspiration cannot be directly measured from space. Instead, evapotranspiration is estimated using algorithms that model the different processes. These models are based on land surface parameters, such as land surface temperature and Leaf Area Index, in combination with meteorological conditions like air temperature, humidity and wind speed.

Note that the ground water change is also measured using remote sensing by detailed analysis of the earth gravity. However, this is not addressed here because the footprint of these measurements is about 100km x 100km and as such is not valuable for drought monitoring.

4.3.4 REMOTE SENSING PROCESSING CHAIN

In satellite remote sensing, the sensor is at the top of the atmosphere. Because processing power on the satellite is limited due to the amount of energy available, data is not processed at satellite level. Instead, the estimation of the different land surface/sea surface/atmosphere parameters is performed at the ground level using the processing chain described here. Some large scale products freely available on the internet are listed in Table 4.1.

- L1a data: The data gets transmitted downwards to receiving stations by high-speed microwave interlinks. At this stage the format of the imagery is highly compressed and uncalibrated and is called Level 1a (L1a). This data is usually not made available.
- L1b data: At the receiving station, the data is stored and afterwards geocorrected and calibrated to provide measured radiances at the top of the atmosphere (TOA). This data is called L1b data. This data is still stored in the coordinate system of the satellite, called swath. This data is made available for download, and is mostly used by universities.

TABLE 4.1 | Freely available large scale products for use in drought monitoring

Variable	Dataset	S. Res	T. Res.	Download site
Precipitation	TRMM	5 km	3 hours	ftp:/disc2.nascom.nasa.gov
	CMORPH	8 km	30 min	ftp://ftp.cpc.ncep.noaa.gov
	MSG	3 km	30 min	geonetcastamericas.noaa.gov
	ECMWF			
Soil moisture	AMSRE		1 day	esa-soilmoisture-cci.org
	WACMOS	12.5 km	1 day	
Evapotranspiration	MODIS	1 km	1 day	ftp://ftp.ntsg.umt.edu/pub/MODIS/Mirror/MOD16
	WACMOS	1 km	1 day	wacmos.itc.nl
	LANDSAF	3 km	30 min	landsaf.meteo.pt
Land surface parameters (LAI/NDVI/LST)	MODIS	1 km	Daily	ftp.e4ftl01.cr.usgs.gov
	MSG	3 km	30 min	landsaf.meteo.pt

- L2 data: The data is then corrected for the atmosphere and the angles of the sun and sensor to produce (in the case of optical remote sensing) bottom of atmosphere (BOA) reflectances/brightness temperatures. In the case of microwave data, atmospheric correction only consists of filtering data for precipitation events. This atmospherically corrected data is called L2 data.
- L3 data: From these L2 reflectances/brightness temperatures, the specific land surface parameters are calculated using a variety of algorithms. Simple algorithms (for example NDVI) calculate the ratio of specific bands, while other more complex methods estimate land surface parameters through inversion of complicated radiative transfer models. Finally, this imagery is reprojected to a specific grid. This means that all the data for different dates can be overlaid with each other. This is called L3 data. For some of the land surface parameters, the observations of different consecutive days are combined to lower the uncertainty in the products and to circumvent gaps due to cloud cover. However, this does not mean that this data is gap free. If either no cloud free days were found, or there was an error within the processing chain, gaps can be present. Note that the NASA actually names its L3 products as L2 products.

- L4 data: This processing chain is to produce gap free data. For this complicated data, assimilation techniques are used that try to 'interpolate' between the data to reduce gaps. These assimilation techniques might also use ground measured data for gap filling.
- L5 data: This last processing chain merges different products to create a completely new product, e.g. a combination of leaf area index and land surface temperature to produce evapotranspiration. For this, a dedicated remote sensing algorithm needs to be employed.

While evapotranspiration is considered a level 5 product, it still contains gaps in the data. This is because the land surface temperature input data for the remote sensing algorithm still has data gaps. Land surface temperature is one of the most difficult variables to convert into a level 5 product. The land surface temperature continuously changes based on the incoming radiation and the processes on the ground and in the atmosphere. Hence, filling in a gap due to cloud cover demands the knowledge of what the effect of this cloud is having on the temperature. A large international project (GlobTemperature) is currently underway to start making the first gap free land surface temperature.

4.3.5 COMBINING INDIGENOUS KNOWLEDGE WITH REMOTE SENSING

While remote sensing provides us with a viable tool for estimating land surface parameters and hydrological components, it does not claim to provide absolute truth. The use of remote sensing is limited due to the following shortcomings:

- Satellites only observe radiation. Therefore the objective of the remote sensing algorithms is to link this radiation to land surface parameters, and use models to link the land surface parameters to the hydrological components.
- These models first need to be calibrated using ground measurements and validated over different areas. The accuracy of the remote sensing product can therefore never be higher than the accuracy of the instruments with which the calibration/validation is performed. For example, estimating evapotranspiration from ground measurements has an uncertainty of about 20 percent. Remote sensing models are restricted to this minimum of 20 percent uncertainty, but usually have uncertainties that are higher due to model errors and uncertainties within the atmospheric correction.
- Optical remote sensing provides data only in the case of satellite overpass and only when there are no clouds over the area. In addition, atmospheric correction needs to be applied to correct for the absorption and reflection of the atmosphere.
- There is a trade-off between model complexity and the number of required inputs. A model that is very complex requires a significant amount of input information and significant computing time, while a simple model uses only a limited amount of data, but provides less accuracy than the complex models. For each application, the requirements need to be identified and model-complexity adjusted.

In short, remote sensing data provides a fast and simple method for creating large sets of information over a spatially and temporally large area. However, this information needs to be combined with ground measurements to provide ground truth information. For simple models (step 2), this can be done by calibrating/validating these specific models to each area.

For more complex models that are able to distinguish between different processes, the merging of the two information sets (remote sensing and ground measurements) is by data assimilation (step 4).

4.4 DROUGHT INDICES

Drought indices are tools used to identify the characteristics of drought such as the onset, severities and the spatial extent. Drought indices provide a basis for drought assessment. The characteristics of a good drought index are:

- The index should respond to a specific temporal domain;
- The index should be able to respond to all seasons (summer or winter); and
- The index should be spatially comparable irrespective of climatic zones.

However a single drought index cannot characterize the complete extent of the drought types. Therefore, several different drought indices have been introduced for different types of droughts. Therefore, like drought, drought indices do not have a universally accepted definition. Use of drought indices depends on the study of interest, like meteorological, hydrological or agricultural domains and also on the data available. Some of the drought indices are as follows:

- **Percent of Normal**: is one of the simplest rainfall measurements for a location or a single season. Percent of normal is calculated by dividing actual precipitation by normal precipitation and multiplying by 100. Normal precipitation for a location is considered to be 100 percent. Percent of normal is suited for the weather forecast.
- **Standardized Precipitation Index (SPI)**: SPI is more straightforward as it depends only on precipitation data from a minimum of 30 years (the longer the better). The long-term precipitation record is normalized using a probability distribution so that the mean SPI for a location and desired period is zero. SPI is computed for different time scales ranging from 3, 6, 12, 24, and 48 months. Negative SPI values indicate dry condition and positive values indicate wet conditions. SPI is helpful in early warning of drought 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.
- **Palmer Drought Severity Index(PDSI)**: PDSI was developed to measure both the intensity and duration of long-term drought. It is calculated based on the precipitation, temperature, and soil moisture data and therefore, responds to abnormally dry and wet conditions. The disadvantages of PDSI are that the values may lag for emerging droughts and that it is best suited for homogeneous regions.
- **Crop Moisture Index(CMI)**: CMI is used to monitor short-term soil moisture condition (Palmer, 1968), based on mean temperature and precipitation for each week, and is suited especially for agricultural droughts. Similar to PDSI, CMI also responds to change in weather conditions. CMI can only be used during the crop growing season and not for long-term drought.
- **Evapotranspiration Deficit Index (ETDI)**: is calculated using the water stress ratio. The water stress is calculated using the actual and reference ET. Water stress values ranges from 0 to 1, where 1 indicates no ET and 0 indicating ET occurring at same rate as the reference ET
- **Soil Moisture Deficit Index (SMDI)**: is calculated similar to the ETDI, but rather than water stress ratio, the soil moisture anomalies are captured. A long time series of data is required in the calculation of each of these indices. This long-time series of, for example, precipitation is necessary to characterize the normal situation of the land. The intensity of the drought is then characterized by the deviation of this parameter from its 30 year value.

4.4.1 PRECIPITATION DROUGHT INDICES

Drought occurs due to shortage of water at land surface, mainly due to a lack of precipitation. In order to start the monitoring of drought, precipitation needs to be investigated. Although several indices have been used in literature, only two will be discussed here due to simplicity and their frequent use in current day practices:

FIGURE 4.4 | Daily rainfall

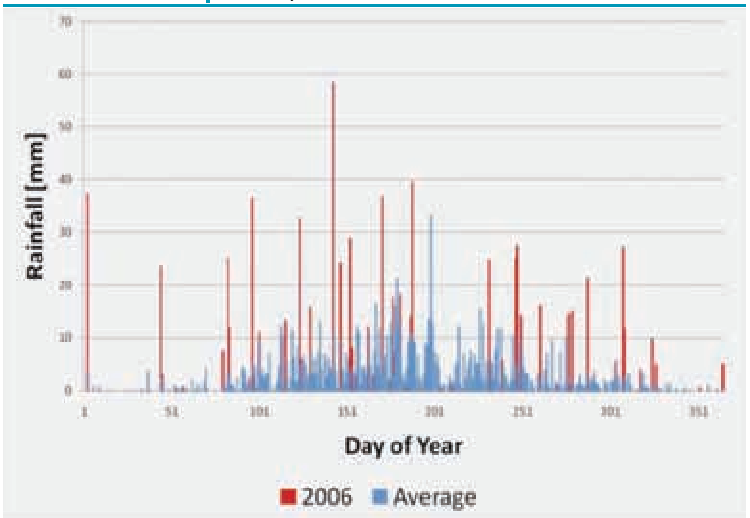
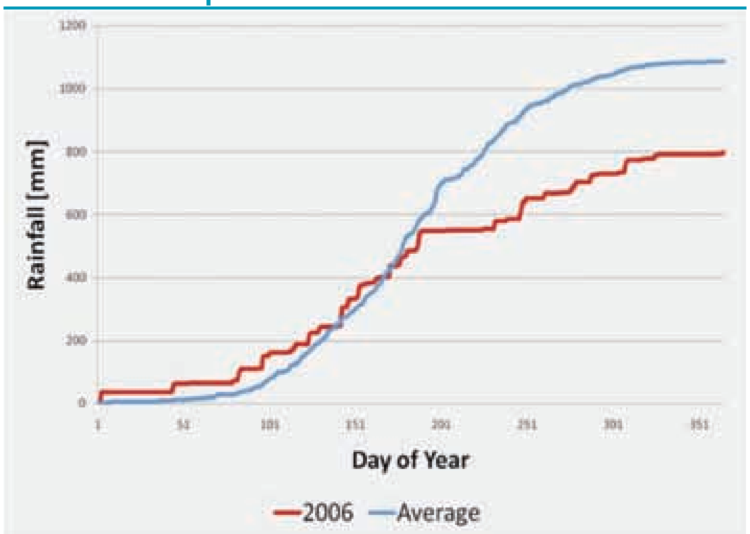


FIGURE 4.5 | Accumulative rainfall



Precipitation anomaly

As rainfall is very intermittent (see Figure 4.4) precipitation, a particular day cannot be compared to that particular day in previous years. Instead, first the data needs to be averaged over a particular period (3 or 6 months). Afterwards, this can be compared to the 3 or 6 months average of the previous years. In this way, the precipitation anomaly is defined:

$$\Delta P = \left(P_i - \overline{P}\right)$$

where P_i is the average precipitation during a particular period and $\overline{P}$ the multiyear average precipitation at the same period but during previous years. In order to provide a reasonable estimate of the normal precipitation in this period, the multiyear average ($\overline{P}$), should be calculated over at least 30 years.

The use of the precipitation anomaly, however, is limited due to the fact that it is not comparable between different locations. The precipitation anomaly does not take into account the natural variability of the precipitation in a specific area. This is solved by the introduction of the standardized precipitation index.

Standardized precipitation index

The standardized precipitation index (SPI) is based on the same principle as the precipitation anomaly, using 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, the droughts over different study areas can be compared. The SPI is calculated using the following formula:

$$SPI = \frac{\left(P_i - \overline{P}\right)}{\sigma}$$

where, P_i is the monthly precipitation observation, $\overline{P}$ is the mean monthly precipitation, and σ is the standard deviation of this mean. Negative SPI value indicated dryness and positive indicates wetness, as categorized in Table 4.2.

While precipitation is able to predict meteorological drought, it does not take into account the state of the land surface. Therefore, for agricultural drought, using the precipitation anomaly or the standardized precipitation index is not sufficient. One way to solve this problem is to use soil moisture (in parallel with SPI).

TABLE 4.2 | SPI Value Categories

2.0 and above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Source: World Meteorological Organization, 2012: Table 1

4.4.2 SOIL MOISTURE DROUGHT INDEX

In the development of Soil Moisture Deficit Index (SMDI) and ETDI (see later), the following demands were set (Narasimhan and Srinivasan, 2005a):

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

The SMDI is therefore defined as a weighted average between the previous SMDI value and the current soil moisture deficit:

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

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

$$SD_{i,j} = \frac{SWS_j - MSW_{i,j}}{MSW_j - \min SW_j} * 100 \quad \text{If } (SW_{i,j} \le MSW_j)$$

$$SD_{i,j} = \frac{SW_j - MSW_{i,j}}{\max SW_j - MSW_j} * 100 \quad \text{If } (SW_{i,j} > MSW_j)$$

where MSW_j is the long-term median available soil water in the soil profile (mm), $\max WS_j$ is the long-term maximum soil water, and $\max WS_j$ 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 the evapotranspiration.

4.4.3 EVAPOTRANSPIRATION DROUGHT INDICES

Evapotranspiration from remote sensing is an emerging product. Therefore, not a lot of drought indices have been created to use this new information fully. Increased evapotranspiration can be one of the main causes of drought, while at the same time a decrease in evapotranspiration provides a clear indication that the land surface is undergoing water stress. It is therefore of vital importance to look also into the evapotranspiration for drought monitoring, in addition to soil moisture and precipitation. Two drought indices based on evapotranspiration are listed below:

- The water requirement satisfaction index.
- The evapotranspiration deficit index.

Water requirement satisfaction index

Water requirement satisfaction index (WRSI) is an operational monitoring measure which indicates performance of a crop based on the availability of water during a growing season (Allen et al., 1998). It is calculated as the ratio of seasonal actual crop evapotranspiration (AET) to the crop water requirement (WR).

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

where WRSI is crop water requirement satisfaction index (%), AET is the seasonal actual crop evapotranspiration (mm d-1), and WR is the seasonal water requirement (mm d-1). The water requirement (WR) is the same as the potential crop evapotranspiration estimated after the FAO reference evapotranspiration has adjusted with appropriate crop coefficient (KC) value which is the water use pattern of a crop. WR = PET * KC.

In order 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 (EOS) time. The threshold used to determine SOS is based on 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. EOS can be estimated by adding the length of 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 modelling period (Brown, 2008).

Evapotranspiration deficit index

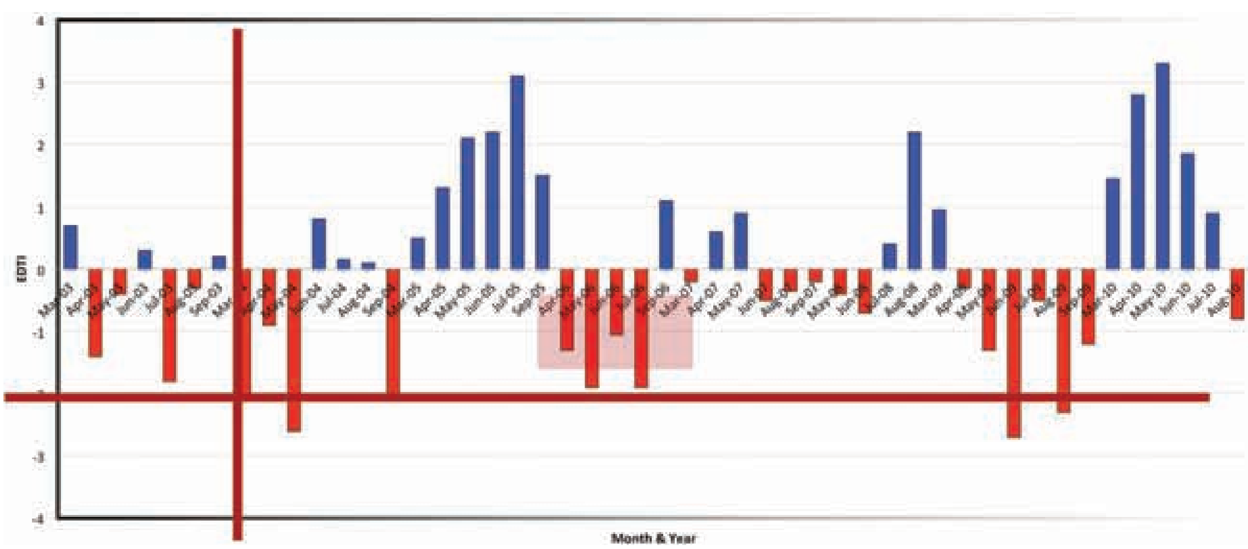
The problem with the WRSI is that it does not correct for seasonal differences, or that it takes into account previous stages of the land. This problem is circumvented by the evapotranspiration deficit index by considering the previous drought index state. It follows the same methodology as the Soil Moisture Deficit Index.

4.5 HAZARD IDENTIFICATION ON BASIS OF PAST EVENTS

In the previous section, the drought status was classified based on the different drought indicators. Before using this information to perform a hazard status and risk analysis, the drought characteristics need to be identified from these indicators. Several drought characteristics are defined, including onset, intensity, duration and frequency.

- **Drought onset.** The start of the drought is of vital importance for the prediction of food production. When drought sets in during the initial stages of the crop development, this greatly reduces the crop growth and the food productivity of the specific crop.
- **Drought intensity.** Drought intensity is necessary to identify how fast the status of the drought, e.g. meteorological, will migrate into more severe agricultural drought. This then provides an indicator of how fast the system is moving in a specific direction. However, depending on resilience (as described later), the migration of status might be avoided.
- **Drought duration.** In most cases, drought starts to get attention when it is prolonged. At this stage, it is important to know how the management system has behaved and what consequences this might have had. This directly creates input for the effectiveness of the drought early warning system and the drought mitigation management.
- **Drought frequency.** While not of direct interest when drought is identified at a specific location, the drought frequency has a great effect on the construction of drought mitigation practices and early warning system development. For example, considering a high frequency of drought occurrence results into an increased risk in the future.

FIGURE 4.6 | Identification of drought characteristics



When all of the above characteristics have been determined, the severity of the drought can now objectively be classified. In terms of disaster management, several stages can be identified leading up to a disaster. These stages are threat, hazard, and disaster.

- **Threat**. Disasters vary in the amount of warning communities receive before they occur. For example, earthquakes in general have limited (if at all) warning before they hit, while warnings for hurricanes and flooding usually are available several hours before they hit. Drought hazard is a creeping phenomenon that develops over time, and thus its impacts are diffuse and spread slowly, in contrast to other rapid onset natural hazards such as floods, earthquakes and landslides. In order to provide accurate warnings in drought monitoring, drought indices levels need to be carefully identified on the basis of previous events.
- **Hazard** is generally defined as a potentially damaging phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption and environmental degradation (UNISDR, 2009). The point at which an ongoing drought transforms from a threat to a hazard is when specific boundaries are exceeded. This can be estimated by thresholding the different drought indices. These thresholds can be dependent on duration, but also frequency.
- **Disaster** is defined as a serious disruption of the functioning of a community or a society that involves widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UNISDR, 2009). While the initial direct or physical effects of drought disaster on the water-dependent sectors may be similar regardless of the type of economy, the long-term consequences of each event will depend on specific local circumstances.

In drought management we can use these different stages to minimise the risk and impact of the drought.

4.5.1 RISK ANALYSIS

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 lives, reduced health status, livelihoods, assets and ecosystem services in connection with drought, which could occur to a particular community or a society over a specified time period in the future (UNISDR, 2009).

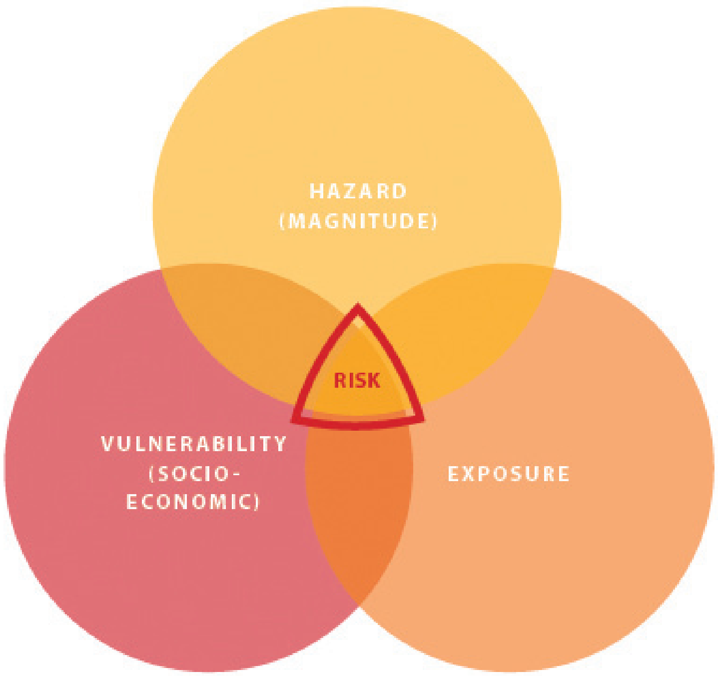
The level of drought disaster risk is often measured by the combination of (a) the degree of exposure to a drought hazard and (b) the level of vulnerability that a community (sector or system) faces. This concept is expressed in the following formula:

RISK = HAZARD x VULNERABILITY

where Vulnerability refers to the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard, as in the case of drought (UNISDR, 2009). 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, a large number of individuals subjected to exposure to a moderate drought hazard could be considered at the same risk level as a smaller number of people who live with a 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.

FIGURE 4.7 | Risk equation



In some cases, the risk equation is expanded with an exposure term (see Figure 4.7). This is because while drought may be present in a specific country/region, not all the people are in the same location as the drought. Using remote sensing data, both the hazard status and the exposure are captured in the same map, and exposure can be left out of the picture.

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

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. Nonetheless, it is still possible to prevent drought disasters, mitigate their impacts and reduce their 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 that is potentially exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and effective manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009). This ability is determined by the degree to which the social system is capable of increasing its capacity for learning from past disasters, and translating the lessons into improved future protection and risk reduction measures However, the drought risk of a given community is decreased when resilience is increased. Such a relative relationship modifies the above mentioned formula as follows:

Risk = HAZARD x Vulnerability / Resilience

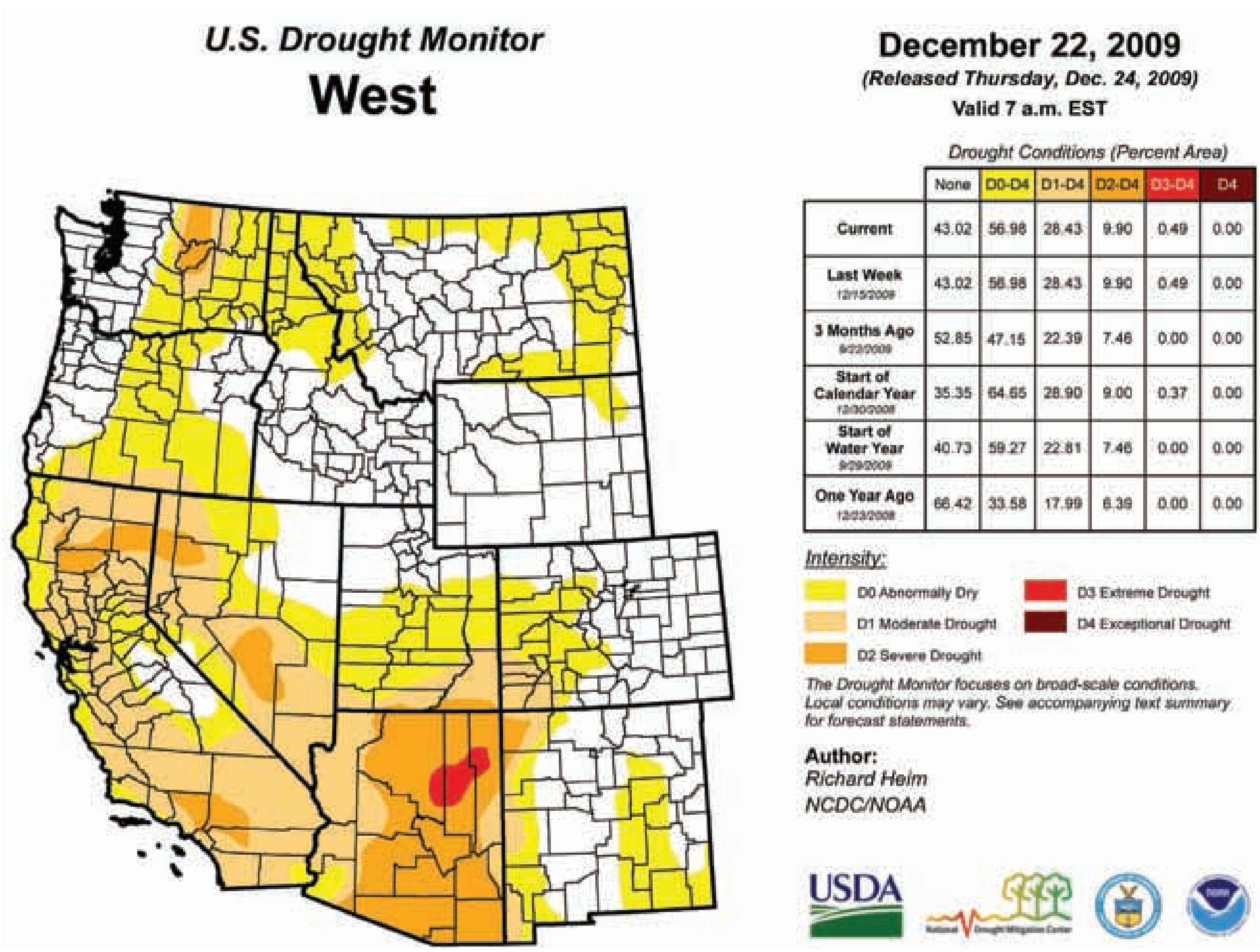
Considering that communities have little control over exposure to hazards other than relocating, the focus of development actors should be directed on finding ways to reduce the degree of vulnerability and increase the level of resilience.

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, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters (UNISDR, 2009). Coping capacity is often understood to be intrinsic to an affected community. One type of coping is the creation of a drought forecast system together with an integrated drought management system. However, to create such a system one needs to comprehend the possible causes of the drought.

4.5.2 TOWARDS DROUGHT FORECASTING

Forecasting drought assists in building resilience towards the drought events and lowers the risk, and therefore mitigates the effects of drought through warning the riskholders in time. In order to prepare for hydrological drought, an adequate hydrological model should be chosen that can simulate both local as well as continental hydrology and forecast the hydrology in the area from several months to several decades. In this way, interlinkages can be found between meteorological conditions and drought conditions which are not necessarily in the same area. An increase in sea surface temperature due to El Niño/La Niña–Southern Oscillation can have a profound impact on the rainfall intensity/frequency in Australia and Indonesia.

FIGURE 4.8 | US National Drought Monitor



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	43.02	56.98	28.43	9.90	0.49	0.00
Last Week	43.02	56.98	28.43	9.90	0.49	0.00
3 Months Ago	52.85	47.15	22.39	7.46	0.00	0.00
Start of Calendar Year	35.35	64.65	28.90	9.00	0.37	0.00
Start of Water Year	40.73	59.27	22.81	7.46	0.00	0.00
One Year Ago	66.42	33.58	17.99	6.39	0.00	0.00

There are several existing large-scale models that can perform this task. Given the complexity of each, this summary only discusses the two models currently used in the two largest drought prediction monitors.

1. **Variable Infiltration Capacity (VIC).** VIC is used in the American Drought Monitor (droughtmonitor.unl.edu) for predictive purposes (see Figure 4.8). VIC is a hybrid of physically-based and conceptual components. It uses daily precipitation and temperature as input and computes incoming shortwave radiation and long-wave radiation as a function of daily precipitation and daily minimum and maximum temperature. For the other computations it uses physically-based formulations for the calculation of the sensible and latent heat fluxes; a conceptual baseflow model to simulate runoff generation from the deepest soil layer; and a conceptual scheme to represent the spatial variability in infiltration capacity and hence production of runoff. Total daily runoff and evaporation are simulated for each grid cell independently. The runoff from each of the individual cells is then combined using a routing scheme (only for the stream), to produce daily and then accumulated monthly flows at selected calibration points.
2. **HTESSEL:** HTESSEL is part of the integrated forecast system at the European Centre for Medium Range Weather Forecast, with operational applications ranging from the short-range to monthly and seasonal forecasts. HTESSEL computes the land surface response to atmospheric forcing, and estimates the surface water and energy fluxes and the temporal evolution of soil temperature, moisture content and snowpack conditions. It has a flexible spatial resolution, depending on the input resolution, and it has been applied globally with a resolution of 0.5°. The model runs with a time step of one hour forced with sub-daily (6 hourly or less) near surface meteorology (air temperature, wind speed, specific humidity and surface pressure) and surface fluxes (solid and liquid precipitation and downward solar and thermal radiation). A detailed description of HTESSEL can be found online.

4.6 SUMMARY

This module identified the different types of drought. Depending on the severity of the drought, it is classified as meteorological, agricultural, hydrological and socio-economic. In principle, meteorological drought starts if precipitation is absent for a long time in comparison to other years. However, an increase in precipitation (originated by climate change) might also cause the onset of meteorological drought. As such, the characterization of meteorological drought is mainly performed by investigation into precipitation patterns. Agricultural and hydrological drought are in fact caused by prolonged meteorological drought that causes reservoirs in the top layer (soil moisture) and deeper in the ground (ground water) to be depleted. Agricultural drought can be characterized by monitoring soil moisture patterns, but also evapotranspiration, as this variable is highly linked with soil moisture. Hydrological drought should be determined by characterizing all variables within the water balance to identify the complete water shortage.

While the first three drought types can be considered pure physical phenomena, socio-economic drought is the result of the combination of both physical effects of drought and their impact on socio economic stakeholders. As such, the characterization of this kind of drought can only be performed when a risk analysis has been performed for each of the types of drought.

Considering the above definitions of drought, monitoring of these water balance components is of vital importance. As drought does not restrict itself to human-made boundaries, large scale investigations should always considered. It has been shown that this can be performed using remote sensing observations. While remote sensing (actively and passively) only observes radiation, a process chain was shown that can be used to convert these measurements into real hydrological variables. Different large scale products were shown that are downloadable from the internet.

Finally, it was shown how drought can be characterized by calculation of different drought indices. These drought indices should eventually be combined to provide a clear monitor for monitoring the drought characteristics such as duration, intensity and frequency. These characteristics are then introduced into an risk analysis to provide requirements on early warning systems and drought impact mitigation services.

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MODULE 5:

STRATEGIC PLANNING UNDER INTEGRATED WATER RESOURCES MANAGEMENT FOR DROUGHT RISK MANAGEMENT

GOAL

To outline the methodology to build tactical interventions to drought risk, taking into account a participatory process, within sustainable development approach and integrated water resources management and focused on the most important factors in order to optimize economic investments and human efforts.

LEARNING OBJECTIVES

At the end of this module, participants are expected to:

- Understand that management must start before droughts occurs;
- Be aware of some of the various management options available;
- Understand how to screen options and select the best set of them through the use of indicators; and
- Know how to build a strategic plan for drought risk management.

5.1 INTRODUCTION

Drought as an extra-ordinary water deficit has three stages: before, during and post event occurrence, and each of these stages has particular attributes, each needing a specific management plan. The objective of drought risk management, as it has already been outlined in Module 3, is to prioritize interventions needed for reducing underlying factors of drought risk.

Failure to fully consider potential and weak integration of the several approaches to drought risk management, such a sustainable land management, water resources management, food security etc. stands out as a weak point in drought management.

Drought does, but ought not to, lead to disaster. Disaster only occurs when there is a serious disruption of the functioning of a community or a society, which involves widespread human, material, economic or environmental losses and impacts, and which exceeds the ability of the affected community or society to cope using its own resources.

Potential disaster losses; economic losses, loss of lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period, are defined as "disaster risk". Therefore, drought risk management is defined as the systematic process of using administrative directives, organizations and operational skills and capacities to implement strategies, policies and measures for improved coping capacities in order to lessen, i.e. prevent mitigate and prepare for, the adverse impacts of drought and the possibility of disaster.

Similarly, drought risk reduction is the practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including reduced exposure to drought (prevention), lessened vulnerability of people and poverty (mitigation), wise management of land and the environment, and improved preparedness for adverse events. Drought mitigation, then, is the lessening or limitation of the adverse impacts of drought and related disasters (UNISDR, 2009a).

Drought risk management at the local level, like a river-basin scale, is potentially more integrated, and likely to yield better results because local approaches link in a much better way the vulnerability factors to livelihood strategies and management of natural resources. Moreover, there is broad agreement that greater traction for drought risk management occurs at lower levels when efforts are optimized, strengthening cooperation among the stakeholders where they share clear strategic roles, responsibility and contributions towards a successful management of commonly experienced issues.

The most successful drought risk management practice is to stimulate community-based action. With this concept in mind, a number of key concepts are relevant:

- Need for integrated development approach centred on sustainable development axis (economic, social and environmental);
- The importance of indigenous knowledge about coping with drought;
- The importance of a community-lead participatory approach and use of community organisations (e.g. farmers' groups and water user associations), especially in relation to sustainable local natural resources management; and
- Need for a stronger focus on diversification of livelihoods, including crop and livestock varieties and other income-generating activities.

On the other hand, opportunities exist where replicable good practice can fill the gaps in key areas.

The specific topics to be considered for a better drought risk management are:

- Raising awareness on the value of indigenous knowledge;
- Promoting a multifaceted approach to deal with drivers of drought risk (to mitigate the root causes and impacts of drought);
- Expanding awareness about the economic impacts of drought and whether these influence political decision-making processes;
- Investigating the integration of non-climatic indicators of drought into early warning systems. If some non-climatic indicators are integrated under the existence of an early warning system, they could render it more pragmatic and a very useful communication tool;
- Innovative approaches to drought risk reduction and adaptation to climate change; and
- Coordination and communication of drought awareness and knowledge within government and among the civil society.

Some of the most important threats from drought includes: forest fire; decline in crop yields and thus increased food insecurity; livestock losses; forced sale of household assets; forced sale of land; increased crime; depletion of water for human use (e.g. drinking, cooking and cleaning); decline in health (e.g. through malnutrition or lack of safe drinking water); displacement/migration; civil conflicts; famine; depletion in water for use in business/industry and national economic impact (UNDP, 2012). In consequence, the drought phenomena could have a number of different and interconnected social, economic and environmental impacts that would require better understanding and preparedness.

5.2 STRATEGIC PLANNING UNDER INTEGRATED WATER RESOURCES MANAGEMENT FOR DROUGHT RISK MANAGEMENT

There is wide appreciation of the fact that a multifaceted approach to drought risk management is required. The approach must recognize the wide scope of drought and thus the implications for coherent strategies to manage it across sectors, levels and disciplines (UNDP, 2012).

The strategic planning process under IWRM approach for drought risk management consists of the development and implementation of a flexible set of strategies that holistically considers the most important areas negatively affected by a drought as well as their links to other management sectors. Hence, strategic planning gives us clarity about what we actually want to achieve and how to go about achieving it, rather than a set of actions for day to day operations, as this last set is a part of a specific project management. Herein, a heuristic approach is proposed to develop a method that is practical, relatively simple, transparent, participatory, easy to communicate and understand for decision-makers and the public in general, that enables the sustainable watershed tactical planning for drought risk management in a short period of time.

5.3 CRITICAL SUCCESS FACTORS FOR DROUGHT

In order to build the set of Critical Success Factors (CSF) Matrixes for Drought, we have to consider the set of critical problems associated with this phenomenon, taking into account the three axis of sustainable development (i.e. social, environmental and economic) and the fourth one which is the available Information, Science and Technology as a base for the decision-making process. Moreover, each one of these dimensions should be regarded under the relevant institutional and legal frameworks. This analysis should include the risk associated with drought for any region or group exposed to the natural hazard and the vulnerability of the society to the event, under the definition of vulnerability as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. The planners in drought-prone regions should conduct risk assessments both to better understand the drought hazard and to identify the main factors and processes concerning who and what is most at risk to drought, and why. The present document suggests retaining the proposed issues as main elements of a drought risk reduction in line with the priorities of the Hyogo Framework.[3] This framework outlines five priorities to build resilience of nations and communities to natural hazards: 1) policy and governance; 2) drought risk identification and early warning; 3) awareness and education; 4) reducing underlying factors of drought risk, and 5) mitigation and preparedness, as well as crosscutting issues (UNISDR, 2009a).

The team that will build the Tactical Strategic Planning for drought risk management must represent all the stakeholders of the community involved in the drought event. This team must include governments,

3 The new international framework for disaster risk reduction - Sendai Framework for Disaster Risk Reduction 2015-2030 to replace HFA was adopted in March 2015. It contains seven targets and four priorities for action; Understanding disaster risk, strengthening disaster risk governance to manage disaster risk, Investing in disaster risk reduction for resilience and Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction. See www.wcdrr.org/uploads/Sendai_Framework_for_Disaster_Risk_Reduction_2015-2030.pdf

technicians, scientists, and civil society and should work taking into account a set of principles for each of the five priorities identified by Hyogo Framework. The principles of these five elements are listed below.

1) **Guiding principles for the first element:**
POLICY AND GOVERNANCE

- Political commitment, high-level engagement, strong institutional setting, clear responsibilities both at central and local levels and appropriate governance are essential for integrating drought risk issues into a sustainable development and disaster risk reduction process;
- A bottom-up approach with effective decentralization and active community participation for drought risk management in planning, decision making and implementation, is essential to move from policy to practice;
- Capacity building and knowledge development are usually required to help build political commitment, competent institutions and an informed constituency;
- Drought risk reduction policies should establish a clear set of principles or operating guidelines to govern the management of drought and its impacts, including the development of a preparedness plan that lays out a strategy to achieve these objectives;
- Drought –related policies and plans should emphasize risk reduction rather than relying solely on drought relief;
- Drought monitoring, risk assessment and other appropriate risk reduction measures are principal components of drought policies and plans;
- Institutional mechanisms should be developed and enforced to ensure that risk reduction strategies are carried out;
- Sound development of long-term investment in risk reduction measures is essential to reduce the effects of drought.

2) **Guiding principles for the second element:**
DROUGHT RISK IDENTIFICATION, RISK MONITORING AND EARLY WARNING

- Drought risk is the combination of the natural hazard and the human, social, economic and environmental vulnerability of a community or country, and managing risk requires understanding these two components and related factors in space and time;
- Increasing individual, community, institutional and national capacities is essential to reduce vulnerability and drought impacts;
- Impact assessment plays an important role in drought risk management, in particular, identifying most vulnerable groups and sectors during drought;
- Drought monitoring and early warning systems play an important role in risk identification, assessment and management;
- Changing climate and the associated changing nature of drought poses a serious risk to the environment, hence to sustainable development and society.

3) **Guiding principles for the third element:**
DROUGHT AWARENESS, KNOWLEDGE MANAGEMENT AND EDUCATION

- The effects of drought can be substantially reduced if people are well informed and motivated toward a culture of disaster prevention and resilience;
- Effective information management and exchange requires strengthening dialogue and networks among disaster researchers, practitioners, and stakeholders in order to foster consistent knowledge collection and meaningful message dissemination;
- Public awareness programmes should be designed and implemented with a clear understanding of local perspectives and needs and strong community involvement;
- Education and training are essential for all people in order to reduce local drought risk.

4) **Guiding principles for the fourth element:**
REDUCING UNDERLYING FACTORS OF DROUGHT RISK

- Mechanisms should be in place to systematically bring together practitioners in disaster risk reduction and key institutions involved in environmental management;
- Areas of overlap and synergy should be identified between existing environmental programmes and disaster risk reduction activities;
- A mechanism for carrying out joint assessments should be institutionalized to integrate disaster risk reduction and environmental protection parameters;
- Specific attention should be given to socio-economic high-risk factors such as age, disabilities, social disparities and gender. By focusing on protection of the most vulnerable groups, the impacts of disasters can be reduced;
- Safety nets such as insurance mechanisms for properties as well as microcredit and financing for ensuring minimum livelihood means can accelerate post-drought recovery process.

5) **Guiding principles for the fifth element:**
ENHANCING MITIGATION MEASURES AND PREPAREDNESS FOR DROUGHT

- Prevention, mitigation and preparedness are central components of disaster risk reduction, and are more important than relying solely on ad-hoc emergency response measures;
- Dialogue, exchange of information, and coordination are needed between disaster risk reduction, development and emergency management actors;
- The selection of appropriate drought risk reduction measures requires many considerations, such as integrated environmental and natural resource management, social and economic development, land use planning opportunities, and climate change adaptations;
- A combination of top-down and bottom-up approaches is required for development and implementation of effective mitigation and preparedness measures;
- Institutional capacity, coordinated mechanisms, identification of local needs and indigenous knowledge are required to implement effective mitigation and preparedness strategies;
- Monitoring and early warning are key elements of disaster risk reduction and must be closely linked to other risk reduction actions;
- Drought risk reduction (prevention, mitigation and preparedness) requires a long-term commitment of resources.

The Planning and Coordination Strategic Area (PCSA) can be used to consider the analysis of the drought risk management under four main dimensions: 1) social, 2) environmental, 3) economic, and 4) information-science and technology. The PCSA is defined as the conceptual model used to prioritise CSFs for drought, determine the specific goals in order to mitigate droughts, evaluate the progress of the strategic planning process and evaluate the success of the strategic planning for drought preparedness.

5.4 METHODOLOGY TO PRIORITIZE THE CRITICAL SUCCESS FACTORS FOR DROUGHT

Periodic recurrence of drought disasters in many parts of the world, particularly in Africa and Asia, highlights the importance of reviewing and reforming drought management comprehensively: from short-term emergency response to efforts to build longer-term resilience, from narrowly-scoped sectoral to comprehensive broad-based support, and from dominant scientific bases to open participatory process (UNDP, 2012). To promote these changes, raising awareness and sharing experiences about effective approaches as well as scaling up those approaches and specially highlighting cross-sectoral relationships, are commonly regarded as essential first steps. The methodology proposed takes into account the set of challenges mentioned above in order to promote synergy among the stakeholders concerned with the drought phenomena through a Tactical Strategic Planning Process. This methodology encourages a strengthened partnership and coordinating activities through the whole decision-making and implementation process among the stakeholders.

As part of the strategic planning process, a SLOT analysis help to identify strengths, limitations, opportunities and threats for each of the four PCSAs before proceeding to the formulation of a strategy. SLOT analysis refers to the analysis of CSFs and includes the following five stages:

1) statement of the organization mission and goals;
2) analysis of internal CSFs (strengths and limitations);
3) analysis of external CSFs (opportunities and threats);
4) definition and selection of strategies; and
5) implementation of selected strategies. The last step also involves the design of the organisational structure and control systems necessary to implement the chosen strategies.

It is important to stress that, by definition, strengths and limitations are considered to be CSFs over which the organization has, in some measure, control. Also, by definition, opportunities and threats are considered CSFs over which the organization has essentially no control (see Table 5.1).

SLOT analysis helps in strategic planning in the following ways: a) it is a source of information for strategic planning; b) identifies socio-ecosystem strengths; c) identifies its limitations; d) maximizes its response taking into account the opportunities; e) helps to overcome drought threats; f) helps in setting goals for strategic planning; g) helps to increase knowledge, over space and time, about CSFs for drought risk management.

TABLE 5.1 | Critical success factors for drought risk management under the SWOT analysis

Classification of critical success factors for drought risk management	Description
Strengths (Internal CSF)	Strengths are the qualities that enable us to accomplish the organization's missions and goals for drought risk management. These are the basis on which resilience against drought has been a continuous success and could be continued or sustained.
Limitations (Internal CSF)	Limitations are the qualities that prevent us from accomplishing the organization's mission and achieving the resilience of the socio-ecosystem against drought.
Opportunities (External CSF)	Opportunities arise when the organization can benefit from conditions in order to increase resilience and control against drought. They could arise from acquisition of knowledge, advances in science and technology, or monitoring key parameters, and in consequence enhance strengths and minimize limitations and threats.
Threats (External CSF)	Threats arise when external conditions, without possible organizational control, make the socio-ecosystem vulnerable against drought phenomena.

The heuristic and explicit teamwork knowledge-based process to prioritize CSFs for drought risk management is achieved through the following steps (Diaz-Delgado et al., 2009). The authors of this module will provide you with software to develop this planning procedure.

First step: This step should identify the set of CSFs for drought risk management; at least 3 but no more than 7 for each category (strengths; limitations; opportunities; and threats) and for each of the planning and coordination strategic area, or PCSA (social; environment; economy; and information-science and technology).

Second step: This step consists of drawing a conceptual map of the PCSA taking into account all the CSFs identified in the first step for each PCSA and connecting the CSF by a word reflecting its relationship.

Third step: As a product of the first step, we have four CSF matrixes, and now we have to prioritize the principal CSFs that will be tackled with the strategic planning process. To do so, we will build a contrast matrix for each PCSA and contrast every CSF against each other. At every contrast we analyse, through a participatory team work process, whether the CSF placed on the row is more important than the CSF placed on the column and we fill the answer case with a 1 (one) if the CSF on row is more important, otherwise with a 0 (zero). The product of this step will be a triangular symmetric matrix.

Fourth step: For each PCSA matrix obtained, we have to add the total of ones in each row, and the total of zeros placed above the diagonal in each column. Finally, we have to add the two results obtained for each CSF.

Fifth step: This step serves to select the three principal CSFs for each PCSA, taking into account the CSF with a greater sum obtained at the fourth step. These 12 CSF (3 for each PCSA) will be the basis for the next phase of the Strategic Planning Process.

5.5 PERFORMANCE INDICATOR AND PERFORMANCE INDEX

An indicator is an observable variable which serves to analyse a complex or a non-observable reality. An index would be a synthetic indicator built by aggregation of basic indicators and following the next ordered procedure: a) Conceptual analysis to be represented; b) Identification and selection of variables reflecting the relevant dimensions; c) Definition of scales and procedures for measuring the values of each variable which gives place to the indicators; d) Analysis of the aggregation procedure; and e) Proposal of a final index (Boulanger, 2004; Diaz-Delgado et al, 2009). This means that the construction of an indicator implies the assumption of a "reality" for which a measure has been sought, as a level or degree of presence of a determined quality or set of quality descriptors. Indicators can be used to analyse, describe, classify or monitor the behaviour of the phenomena under analysis. Here it is important to stress that indicators play a double role, as scientific builders and as political instruments. Indicators will have influence to the extent that they reflect socially shared meanings and policy objectives, as well as a sound technical methodology. As a consequence, stakeholder participation in the definition of indicators from the moment of their conception should favour a good implementation.

Indicators chosen to represent and explain the phenomena must be measurable and meaningful. The main characteristics of good indicators are:

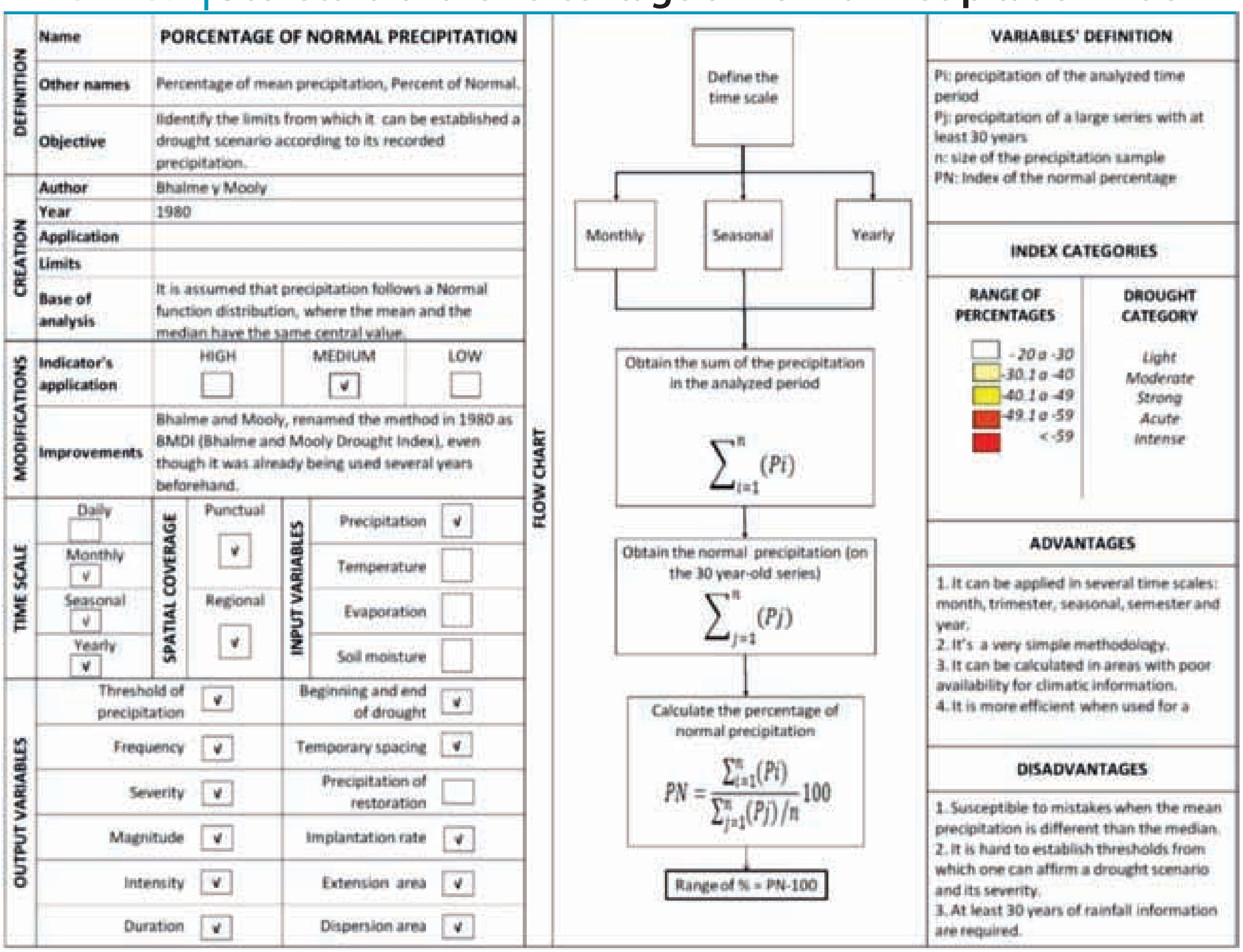
- To be representative – the indicator must be representative of the characteristic it is supposed to measure.
- To be scientifically valid – the indicator must be scientifically supported and a scalar of the performance outcome it is supposed to measure.
- To show trends in time and space.
- To give an early warning of future events.
- To be sensitive to changes in the processes they are aimed to reflect.
- To be accessible – the indicator must be accessible and easily available at the desired level of accuracy.
- To be selective – the indicator must be able to distinguish different levels of performance appropriately and fairly.
- To be objective – the measurements taken with the indicator must be identical no matter who takes them.
- To have reliability – the measurements must be reliable in the sense that they are scalars of the indicator and are unaffected by possible confounding variables.

The performance indicators chosen have to assess conditions and trends in relation to the goals and targets established. Hence, it is important to highlight the difference between descriptive indicators and performance indicators. The key characteristics for distinguishing these two types of indicators are: a) Descriptive indicators show trends in degradation or improvement of a situation; b) Performance indicators show not only trends but distance to some threshold or goal associated with time schedule, set by environmental policy or plan; and c) The target may be as specified in a certain policy, plan or a reference value such as a standard guideline. When combined with targets for future performance, this set of performance indicators can show how effectively current strategies are helping to improve the system conditions, and how far there is yet to go.

5.6 EXAMPLE OF A SCORECARD FOR A PERFORMANCE INDICATOR OR PERFORMANCE INDEX

The scorecard is a technical fact sheet which contains, in a structured way, the conceptual elements and essential methodologies used to build the specific Performance Indicator. It also presents the technical support of the information needed to construct it and how to interpret the results obtained after its calculation. Then this fact sheet allows us in an easy way to communicate the aspect of the system modelled by this Performance Indicator to the decision-maker or general audience. Figure 5.2 shows an example of scorecard for a Performance Indicator of Drought.

FIGURE 5.2 | Scorecard of the Percentage of Normal Precipitation Index



5.7 THE DRIVER-PRESSURE-STATE-IMPACT-RESPONSE FRAMEWORK FOR DROUGHT PERFORMANCE INDICATORS SYSTEM

The Driver-Pressure-State-Impact-Response (DPSIR) model is a causal framework for describing the interactions between society and the environment. Based on the Pressure-State-Response (PSR) model developed by OECD, DPSIR constitutes the first mechanism to keep track of drought risk management progress. The framework starts from a simple set of questions (see Table 5.2 for questions and Table 5.3 for indicator descriptions). At the end of this process, we are able to identify a set of Performance Indicators for each PCSA.

TABLE 5.2 | Set of questions to consider under a DPSIR framework

Questions to answer	Type of indicators	What the indicators must show
What are drought-related human needs, and how are these different from the norm?	Performance Indicators of **DRIVERS**	Overall levels of consumption and production patterns of social, demographic and economic developments that drive human needs
Why is it happening?	Performance Indicators of **PRESSURE**	Stresses or pressures from human activities that cause environmental, social or economic changes
What is the physical and biological condition or state of the socio-ecosystem resources?	Performance Indicators of **STATE**	Description, changes or trends of the state of the environmental, social and economic resources (quantity and quality aspects)
Which impacts are occurring as a result of the changes in the quality and functioning of the socio-ecosystem?	Performance indicators of **IMPACT**	Description of the effects of changes and trends of the impacts on the environmental, social and economic resources (quantity and quality aspects)
What are we doing about it?	Performance indicators of **RESPONSE**	Societal actions adopted in response to environmental, social and economic dimensions

Source: Adapted from OECD, 1998, and Diaz-Delgado *et al*., 2009.

TABLE 5.3 | Description of performance indicators types for the DPSIR model

Performance indicators of **DRIVER**	**EXAMPLES** • Food • Health • Water • Security • Shelter • Culture
These indicators identify the major driving forces affecting levels of consumption and production patterns. Driving forces can originate and act globally, regionally or locally. The two most important social factors influencing anthropogenic activities included in the productive system are stakeholder interest and human lifestyle. Both the productive structure and the social system are regulated by the legislative framework; therefore, the driver analysis under the DPSIR model provides insight into methods of modifying the interaction of the socio-economic and ecological systems for drought risk reduction.	
Performance indicators of **PRESSURE**	**EXAMPLES** • Water demand/intensity of water use • Emissions of greenhouse gases • Land use changes • Other
These indicators describe pressures from human activities exerted on each one of the PCSA, including natural resources. They are also related to production and consumption patterns. These indicators should include direct and indirect pressures over the socio-ecosystem. Pressure indicators can be very useful for measuring policy effectiveness since they are thoroughly descriptive. These kinds of indicators are particularly useful in formulating policy targets (over space and time) and in evaluating policy or plan performances that automatically become performance indicators.	
Performance indicators of **STATE**	**EXAMPLES** • Water level in reservoirs • Water quality available for drinking purposes • The status of wildlife and of natural resource stocks • Other
State indicators relate to the quality conditions of each one of the Planning and Coordination Strategic Area (PCSA), taking into account the quality and quantity of their resources. Thus, they can reflect the ultimate objective of sustainable development policies. They are designed to give an overview of the situation (the state) of the environment, society, economy and its development over time. To develop a performance indicator using an indicator of state, reference to quality standards is necessary.	
Performance indicators of **IMPACT**	**EXAMPLES** • Lack of water for crops • Increased waterborne disease rate due to low water quality for drinking purposes • Increased forest fire rate • Other
Impact indicators deal with the effects, direct or indirect, that occur due to the state of conditions and the pressures acting over the socio-ecosystem. These type of performance indicators show present and possible future trends of impacts, over space and time, for each one of the PCSA which have been selected to model the phenomena in the basin or watershed.	
Performance indicators of **RESPONSE**	**EXAMPLES** • Establish a strategic plan under IWRM for drought risk management • Environment-related taxes and subsidies • Institutional arrangements addressed to cope with the drought • Other
Response indicators gauge the efforts taken by society to improve the control of adverse conditions or mitigate degradation, to preserve and conserve the socio-ecosystem resources. They show how policies are implemented by tracking the implementation of government commitments, regulatory compliance, financial incentives, treaty agreements, or voluntary behavioural changes. Moreover, we can say that these efforts and actions should be derived from each planning cycle and their performance and improvement will be evaluated every cycle ran.	

5.8 METHODOLOGY TO PRIORITIZE PERFORMANCE INDICATORS AND OBTAIN THEIR SPECIFIC WEIGHT FOR THE SOCIO-ECOSYSTEM

Up to now we have already defined the set of the principal twelve CSFs for addressing a Drought Risk Management Strategic Planning Process. However, we are interested in developing the Tactical Phase of the Strategic Planning Process because this stage corresponds to the main positive effects that must be achieved in the shortest period of time. The Pareto Law (also known as the 80–20 rule) states that roughly 80 percent of the effects come from 20 percent of the causes, and this holds true in relation to the CSFs for drought risk management acting over the socio-ecosystem. To solve this problem, we have to model the set of three CSFs for each PCSA through a set of indicators under the DPSIR system already presented. Then each PCSA will be modelled by at least four, but no more than eight, DPSIR indicators in order to obtain a final set of 32 DPSIR indicators which represent the model of the main CSFs for drought risk management of the socio-ecosystem under analysis.

Now we have to deal with the identification process to obtain the specific weight of each performance indicator over the socio-ecosystem, in order to build tactical strategies taking into account the most weighted performance indicators in order to maximize efforts and investments to improve resilience of the system against drought phenomena. The methodology to prioritize Performance Indicators and obtain their specific weight for drought risk management in the socio-ecosystem is presented in the following steps (Diaz-Delgado et al., 2009).

First step: We will build a contrast matrix for each PCSA and contrast every performance indicator to each of the four PCSAs. At every contrast performance indicator we analyse, through participatory team work, whether when the value of the Performance Indicator placed on the row is improved, it also improves the value of the Performance Indicator placed on the column, and if yes we fill the answer case with a number "one", otherwise with a number "zero".

Second step: For each Performance Indicator, we have to add the total of number "1" in each row and this value represents the number of connections of each Performance Indicator with the other Performance Indicators in the socio-ecosystem.

Third step: We will now organize the set of Performance indicators in a hierarchical order taking into account the number of connections obtained in the previous step. The Performance Indicator with the highest connection number will be the first in the list and so on.

Fourth step: This step consists of assigning the specific weight of each Performance Indicator according with the list obtained at the previous step. Then we will assign the specific weight as follows:

- "1" to the first subset of eight Performance Indicators;
- "0.5" to the second subset of eight Performance Indicators;
- "0.25" to the third subset of eight Performance indicators; and
- "0.125" to the fourth subset of eight Performance indicators.

Fifth step: Additionally, with the specific weights of Performance Indicators obtained at the previous step, we can calculate the specific weight of each PCSA. In other words, we can measure the influence of each PCSA for drought risk management over the socio-ecosystem. This weight is obtained only by adding the specific weight of Performance Indicators which are involved at each PCSA.

5.9 DROUGHT RISK MANAGEMENT STRATEGY

The long-term strategy of a society for drought risk management seeks to increase the resilience of the socio-ecosystem against drought through its configuration of resources (environment, social, and economic dimensions) within a challenging reality, to support the needs of a sustainable development and to fulfil the stakeholders' expectations.

Strategy and tactics are about means and ends: they bridge the gap between our vision of the future and our day to day decisions. Tactics and strategy are also relative terms. What is seen as strategic from one point of view can be seen as tactical from another; they adapt to the changing circumstances and with variations in the perspective of what means are required to reach a desired outcome. However, in the present framework of building a tactical strategic plan for drought risk management, we will consider a strategy as where we should be in terms of performance indicator targets, in space and time, through the set of programs included in each strategy, considering a program as a set of projects to get the targets. Then, it is considered that at the end of this stage we will have a set of strategies, at least one, but no more than three, for each PCSA taking into account their set of Performance Indicators and their correspondent cause-effects analysis in order to define each specific strategy.

5.10 METHODOLOGY TO PRIORITIZE STRATEGIES TO INCREASE DROUGHT RESILIENCE IN THE SOCIO-ECOSYSTEM

By now we should have a set of strategies defined by the work team at the previous stage. In order to prioritize the strategies for increasing drought resilience in the socio-ecosystem, we have to analyse which, and how many, Performance Indicators are considered for each strategy. Then, based on the number of Performance Indicators and their specific weight, we can obtain the specific weight of each strategy simply by adding the specific weight of Performance Indicators involved with each one of them. After we get the specific weight of each strategy, we are able to order them into a hierarchical statement. In other words, through this way we will establish the most important ordered strategies which maximize the positive results over the socio-ecosystem. This procedure allows us to define priorities and the investments required to implement the Tactical Strategic Plan for Drought Risk Management.

Finally, in order to get a complete Plan, the next steps consist of determining, for each tactical strategy, their set of specific projects including their respective set of actions, institutional coordination arrangements, responsibility matrix, and definitions of economic and financial needs.

5.11 SUMMARY

- There are several management options to prepare for drought and to manage water during drought, but we have to optimize the plan in order to give the best answer for the socio-ecosystem with the minimum investment.
- The indicators system is the information tool which makes possible the process of monitoring key variables needed to make decisions and improve the resilience of the socio-ecosystem against drought phenomena.
- Emphasis should be on drought mitigation and preparedness through non-structural measures.
- Early warning and drought management planning can reduce the socioeconomic impacts and improve resilience of the socio-ecosystem.

SESSION | Exercise: develop, guided by the facilitator, a tactical strategic planning process for drought risk management using the SPPSM-Drought software

Duration: 45 minutes

Activity: Facilitator will work with the participants, in a participatory process, building a tactical strategic plan under IWRM for drought risk management.

This activity will consider the following aspects and the use of the Strategic Participatory Planning Support Module for Drought (SPPSM-Drought V-1.0):

- The SLOT model to build the Planning and Coordination Strategic Areas (PCSAs)
- The Driver-Pressure-State-Impact-Response model (DPSIR)
- Analysis of the PCSA-Social dimension
- Definition of three main Strategies for increase drought resilience of the socio-ecosystem taking into account the PCSA-Social

Facilitator: Facilitator should demonstrate how we can put in practice a strategic plan under IWRM for Drought Risk Management on a participatory basis.

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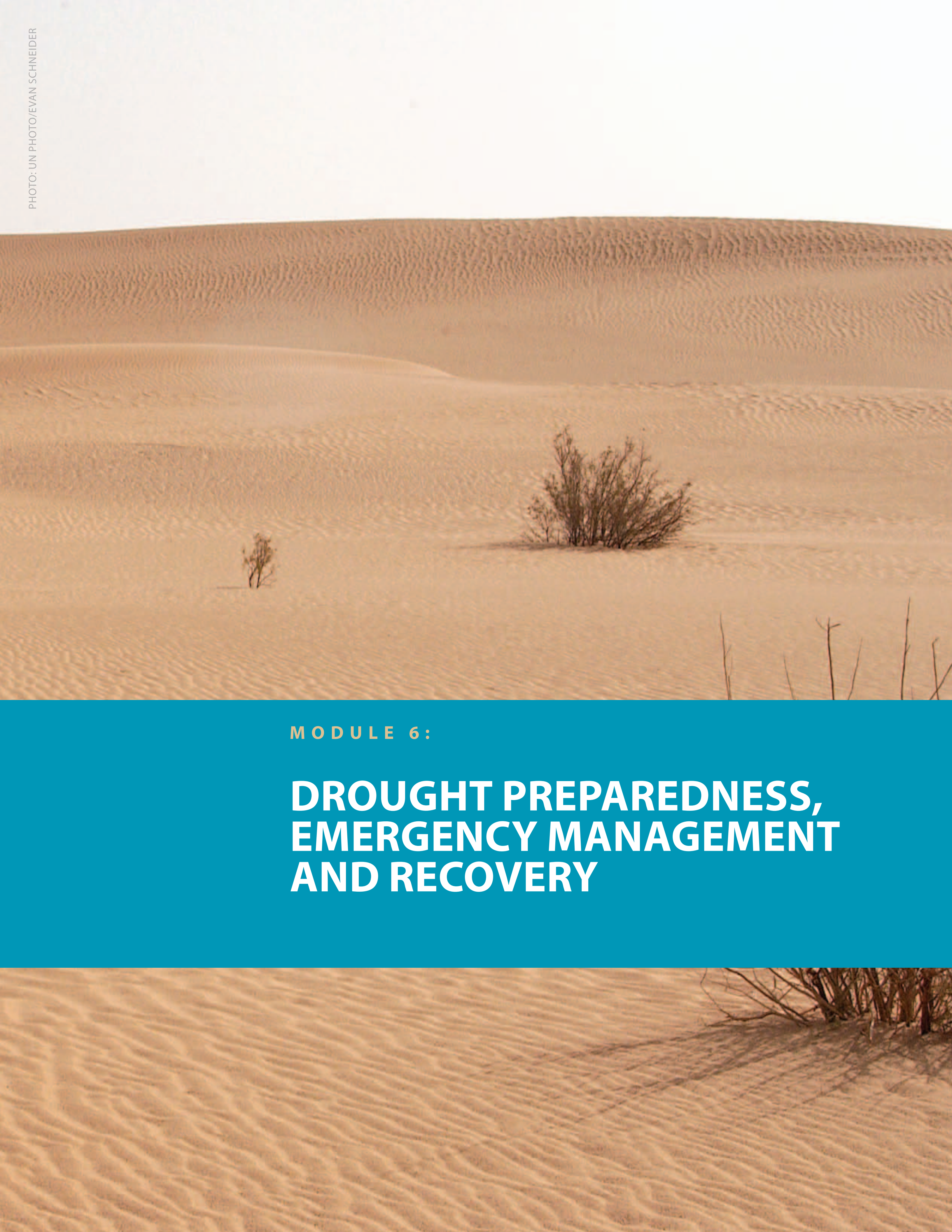


PHOTO: UN PHOTO/EVAN SCHNEIDER

MODULE 6:

DROUGHT PREPAREDNESS, EMERGENCY MANAGEMENT AND RECOVERY

GOAL

To introduce a proactive planning approach to minimize the impacts of drought on people and resources. This module outlines both long-term and short-term measures to prepare for, respond to, and mitigate the effects of drought.

LEARNING OBJECTIVES

At the end of this module, participants will able to:

- Work through a step-by-step process for planning and coordination of drought emergency;
- Identify long and short-term actions that can be taken to minimize drought emergency impacts before and after a drought occurs;
- Identify catalyst measures for the creation and implementation of local drought contingency planning, monitoring, and impact assessment and response and recovery efforts;
- Define actions by phases for emergency management and assignment of responsibilities to local, state, and private sector entities that are involved with drought management, lead or supporting roles in managing the drought response activities.

6.1 INTRODUCTION

Hyogo Framework of Action (HFA) 5:

Strengthen disaster preparedness for effective response at all levels

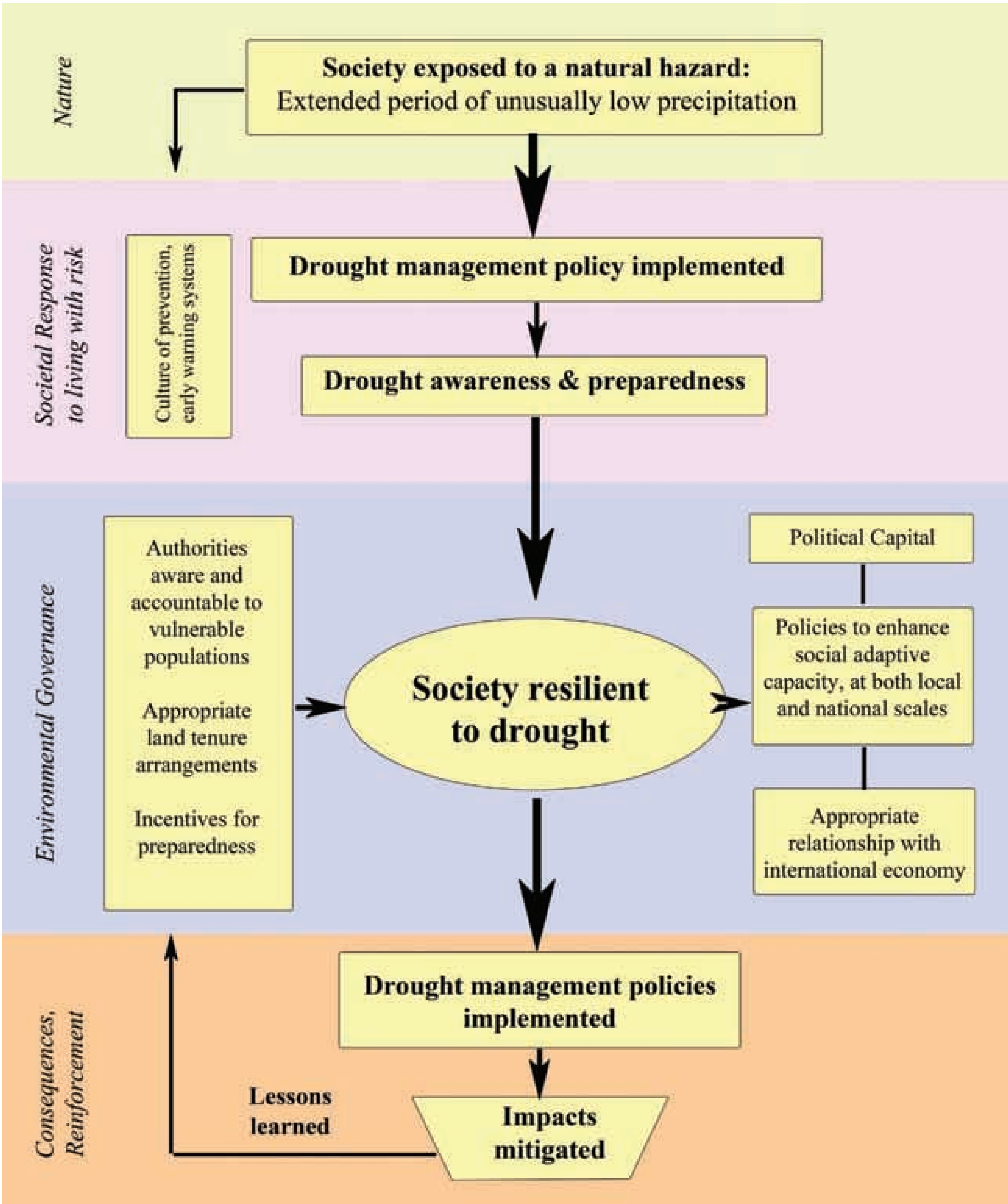
Drought is a normal part of climate; an extreme climatic event, often described as a natural hazard. Drought by itself does not trigger an emergency. Whether it becomes an emergency depends on its impact on people local, and that, in turn, depends upon their vulnerability to such a 'shock'.

Understanding people's vulnerability to drought is complex, yet essential for designing drought preparedness, mitigation and response/relief programmes (see Module 3). This module represent an important link and complement to drought hazard monitoring (see Module 4) and drought risk management planning and implementation (see Module 5). This module, therefore, is concerned with the operational domain. It outlines needs to be met and the manner of executing responsibilities for risk, emergency and recovery management responsibilities.

This involves support for institutional dialogue and coordination, stakeholder engagement, review, updating contingency plan and mechanisms for funding emergency

FIGURE 6.1 | Building resilient society

Source: UNISDR, 2009.



6.2 DROUGHT MANAGEMENT PLANNING

Droughts are defined by their impacts, depending on the severity and duration of drought coupled with society vulnerability. Vulnerability to impacts can be reduced by making preparedness the cornerstone of national drought policy (US National Drought Policy Commission, 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.

SESSION | Contributing factors

Think of factors that contribute to drought risk in your areas and the corresponding measures for preparedness and emergency. How effective are they?

A passive attitude to drought risk creates a tendency simply to react when crises strike. Whereas some element of reactivity is not entirely avoidable, it could be minimized, as it is not good process of resource management. Drought management must anticipate the inevitable – that droughts will come and go – and therefore develop an approach that seeks to minimize the effects of drought when it inevitably occurs.

Drought management planning, therefore, is necessary to meet goals such as:

- To prevent disasters (particularly drought-induced famines) by targeting their basic causes;
- To build resources and managerial and institutional capacity well in advance of disasters, so that the magnitude of destruction that is likely to result from disasters can be mitigated; and
- To put the necessary logistics (for response as well as recovery) in place to be able to alleviate suffering during and immediately after disasters.

FIGURE 6.2 | Disaster management cycle

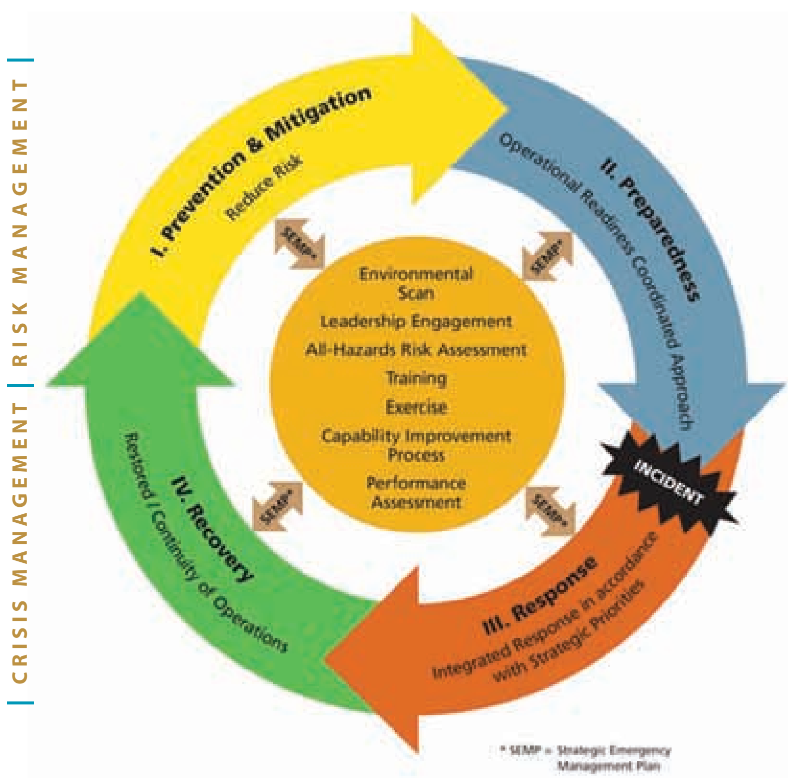
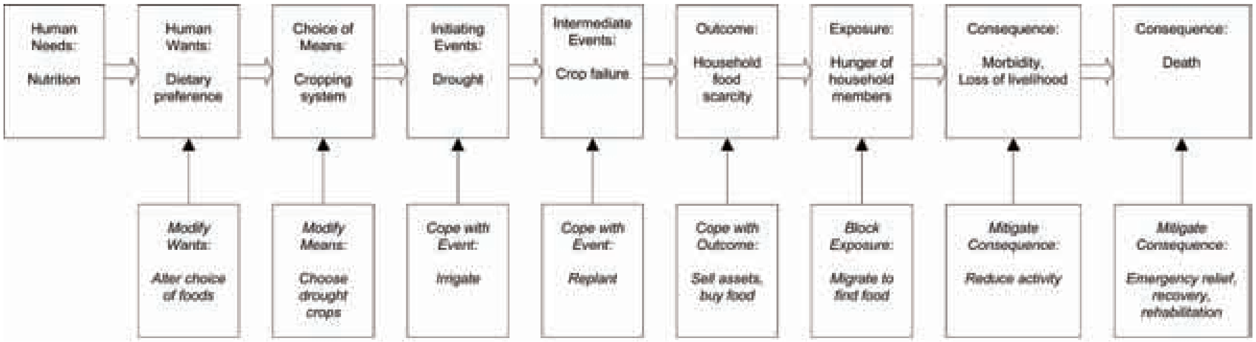


FIGURE 6.3 | Causal chain of hazard and response development

Source: Adapted from SEI Oxford, nd.



Disaster risk management, including for drought, can be envisaged in four stages:

1. **Mitigation** – which includes all actions taken to reduce or eliminate the effects of emergency or disaster;
2. **Preparedness** – actions taken prior to an emergency or disaster to ensure an effective response if and when disaster finally happens. Preparedness is a mitigation action;
3. **Response** – actions taken to respond during drought emergency; and
4. **Recovery** – actions taken to recuperate form the impacts of disaster and reinstate capacity.

6.3 DROUGHT AND WATER MANAGEMENT

Drought is a major issue for water management and environmental protection. Unsustainable water management, including inefficient water use planning and water pollution, as well as predicted climate change effects, could result in severe impacts on nature and society. Therefore, measures are to be taken in each drought phase in order to prevent deterioration of water status and to mitigate negative drought effects.

Table 6.1 lists some common drought vulnerabilities associated with water resources.

FIGURE 6.4 | Drought conditions and impacts

Source: Government of India, 2009

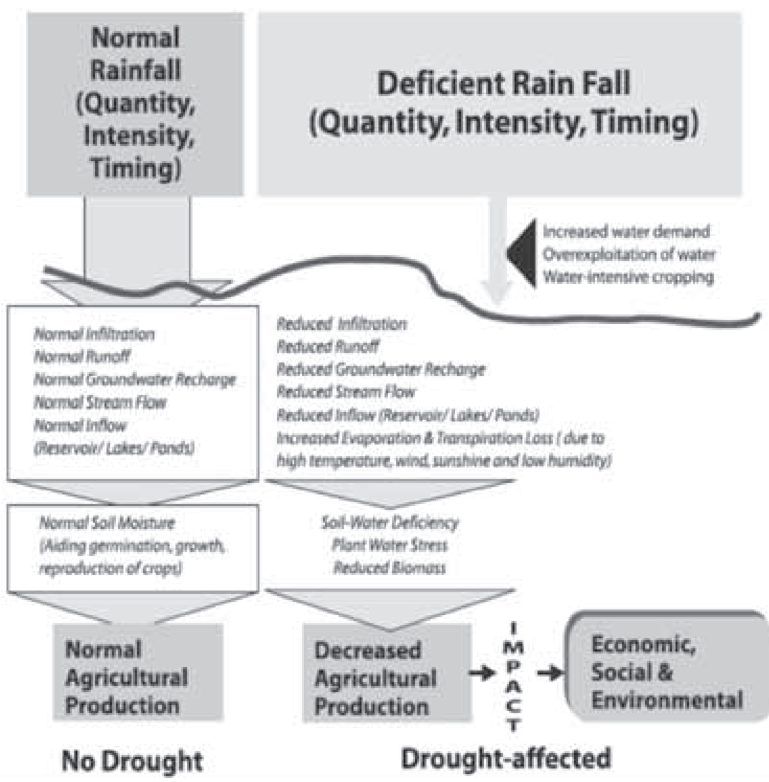


TABLE 6.1 | Water vulnerability continuum

	Higher vulnerability	Lower vulnerability
Meteorological drought	Wide precipitation variation	Stable precipitation pattern
	Lack of data/Single source data	Good long-term data/multiple sources of data
	Passive drought "acceptance"	Advance warning
	Longer duration	Shorter duration
	Higher severity shortage	Lower severity shortage
	Sudden change in supply	Gradual changes in supply
Supply/demand balance or "institutional drought"	Single water source or low supply reliability	Multiple water sources or high supply reliability
	Low priority water rights or low contractual rights	Senior water rights or high contractual rights
	Water supply at risk from contamination	Protected water supply
	Imported water supply	Local supply and locally controlled
	Subject to other natural disasters	Low likelihood of other natural disasters
Water use patterns	High growth area/high additional demand	Stable or decreasing water demand
	High percent water use efficiency = in-built demand management response	Low percent water use efficiency improvement "slack" in system = requires more demand management response in drought
	Landscape/irrigation practices dependent on precipitation	"Climate appropriate" plants or non-irrigated agriculture

6.4 DROUGHT IMPACTS RANKING

The list of "current" impacts should be ranked according to the most important impacts. To be effective and equitable, the ranking should take into consideration concerns such as cost, areal extent, trends over time, public opinion, fairness, and the ability of the affected area to recover. Module 5 provides a methodology for analysing drought impacts and prioritizing action

In choosing the highest priority impacts, it may be helpful to ask some of the following questions:

- Which impacts are important to the affected individual's or group's way of life?
- If impacts are not distributed evenly, should hard-hit groups receive greater attention?
- Is there a trend of particular impacts becoming more of a problem than others?

6.5 SOCIAL-ECONOMIC VULNERABILITY ASSESSMENT

BOX 6.1 | Gathering information

One of the first steps required to implement a system based on risk reduction is an information system that could answer questions like:

- Where do disasters take place?
- Why do they take place there?
- Who gets affected?
- What makes them vulnerable to these disasters?

Vulnerability assessment provides a framework for identifying the underlying cause of drought impacts. It bridges the gap between impact assessment and policy formulation by directing policy attention to the underlying causes of vulnerability rather than to its result, the negative impacts, which follow triggering events such as drought.

For example, the direct impact of a lack of precipitation may be reduced crop yields. The underlying cause of this vulnerability, however, may be that the farmers did not make proper choice of seeds or that there was insufficient early warning information to facilitate farmers' decision.

6.6 LONG AND SHORT-TERM ACTION IDENTIFICATION

Once drought impact priorities have been set and the corresponding underlying causes of vulnerability have been exposed, it is time to identify actions that are appropriate for reducing drought risk.

In accordance with the overall goal of drought mitigation rather than drought response, the emphasis should be on identifying mitigation actions before potential response actions.

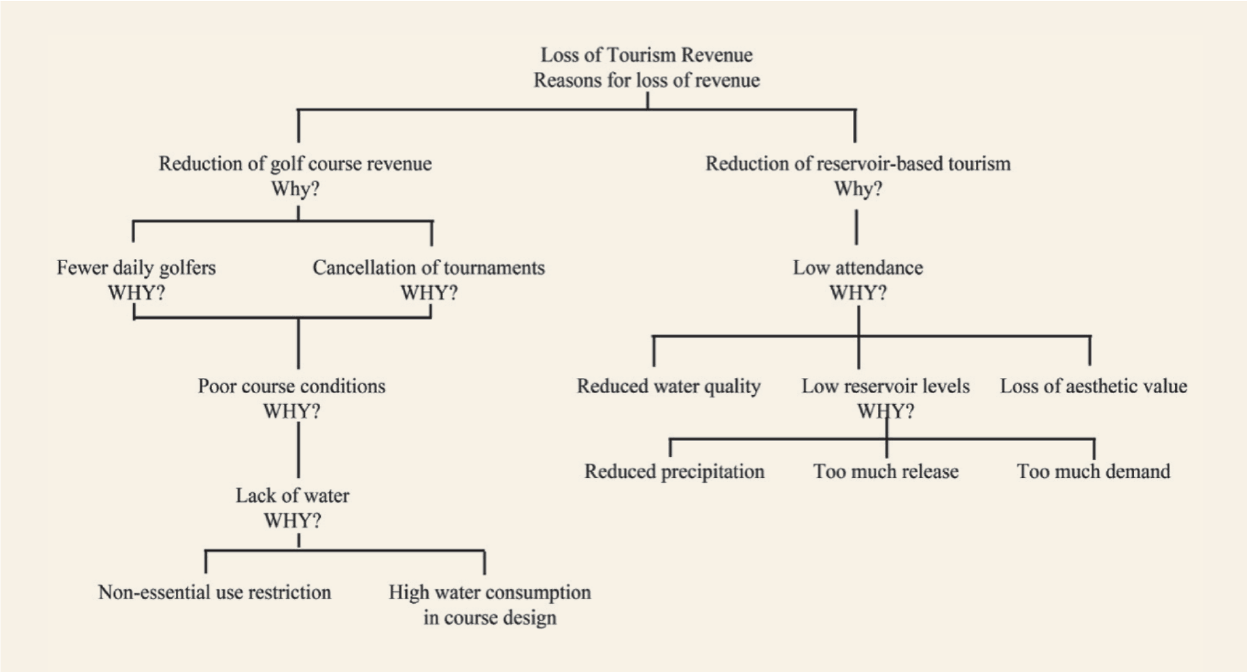
Again, it may be useful to develop some kind of decision-making matrix (see Table 6.2). This matrix expands on the impact tree example of income loss from crop failure (Figure 6.5). Keep in mind that impacts are the face of drought; therefore, the matrix starts with *impact* as well as the described *root* causes of the impact.

From this point, begin to investigate what actions could be taken to address each of these basal causes. The following sequence of questions may be helpful in identifying potential actions:

- First, can the basal cause be mitigated (can it be modified before a drought)? If yes, then how?
- Second, can the basal cause be responded to (can it be modified during or after a drought)? If so, then how?
- Is there some basal cause, or aspect of the basal cause, that cannot be modified and must be accepted as a drought-related risk for your activity or area?

FIGURE 6.5 | Drought impact tree analysis

Source: Knutson et al, 1998.



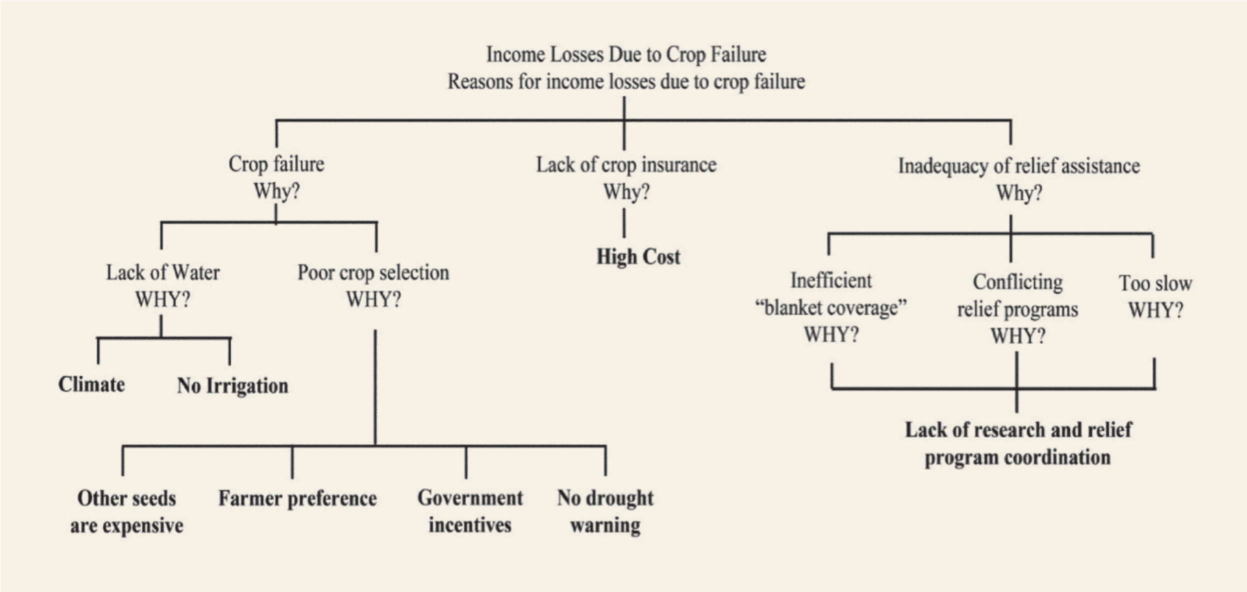


TABLE 6.2 | Drought risk action identification matrix

Impact of Drought	Underlying Causes of Vulnerability (Basal Causes of the Why Questions)	Possible Actions	Mitigation (M), Response (R), or Accepted Risk (AR)	Feasible?	Effective for impact reduction?	Benefit/ Cost?	Equitable?	To Do?
Income loss from crop failure	Variable climate	Weather modification	M					
		Weather monitoring	M					
	No irrigation	Haul water during a drought	R					
		Provide government assistance for projects	M					
	Expensive seeds	Subsidize seed sales	M					
	Farmer preferences to plant specific seeds	Conduct workshops	M					
		Conduct research	M					
		Enhance communication	M					
	Government incentives to plant specific crops	Lobby for new incentives	M					
	No drought warning	Provide weather monitoring	M					
		Identify "triggers"	M					
	High cost of crop insurance	Government subsidies	R					
	Lack of research as to the efficiency of drought relief efforts	Identify target groups and conflicting relief program criteria and goals	M					
	Lack of drought relief program coordination	Streamline relief application and funding	M					

Source: Knutson et al, 1998.

6.7 DROUGHT MITIGATION

Drought mitigation or prevention covers pre-disaster measures and activities designed to increase the level of readiness or improve operational capabilities for responding to a drought emergency. They are policy/regulatory and physical measures to pre-empt disasters, ensuring that they are prevented and/or their effects are mitigated. Not only do prevention/mitigation measures reduce the impact of hazards, but also reduce the susceptibility and increase the resilience of the community vulnerable to hazards.

Prevention measures include land use planning, agro-forestry, water-harvesting and food security programs to forestall potential famine.

Mitigation assumes that community and property are vulnerable to hazards, and that preparedness will be necessary to address occurrences of hazardous events. It thus entails measures such as drought monitoring, establishing emergency relief centre, formulation of emergency plans in advance of disasters, and training persons and vulnerable communities to be able to undertake rescue and recovery as and when disasters eventuate.

Managerial and technical steps taken to minimize losses just before, during and after a disaster come within the envelope of preparedness. Measures that are relevant to water resources management include:

1. Drought hazard and impacts assessment;
2. Legislation and public policy;
3. Water conservation and demand reduction;
4. Increasing or augmenting water supply;
5. Public education and participation; and
6. Conflict resolution.

6.7.1 DROUGHT HAZARD AND IMPACTS ASSESSMENT

- Improve the accuracy of seasonal runoff water, availability and uses forecasts
- Strengthen data collection and monitoring networks
- Develop or improve early warning systems
- Establish alert procedures for water quality problems
- Develop criteria for drought management action triggers
- Evaluate and develop new water sources for drought-prone areas
- Monitor vulnerable public water suppliers
- Evaluate use of ground water in emergency
- Study public willingness and capacity to pay more for more reliable water supplies during emergency
- Study and improve effectiveness of soil and moisture conservation measures
- Investigate and improve business and farming diversification
- Evaluate capacities to withstand losses associated with drought such as incomes, assets, credit flexibility and decision-making processes, subsidy, loan, and welfare program applicability and the effect of government programs and policies

6.7.1 Drought hazard and impacts assessment (continued)

- Research drought impacts on various social groups
- Inventory and monitor natural resources within the relevant areas

6.7.2 LEGISLATION AND PUBLIC POLICY

- Prepare position papers for legislature on public policy issues
- Examine regulations governing water rights for possible modification during shortages
- Pass regulations to protect water flows
- Pass regulations to protect and manage groundwater
- Pass regulations providing guaranteed low-interest loans to farmers
- Impose water use efficiency and limitation measures
- Develop water plan
- Technical support for developing contingency plans by all large water users

6.7.3 WATER CONSERVATION AND DEMAND REDUCTION

- Establish stronger economic incentives for private investment in water conservation
- Encourage and support voluntary water conservation
- Require water users to decrease reliance on ground water and implement conservation measures
- Improve water use and conveyance efficiencies
- Implement water metering and leak detection programs
- Reduce consumptive use by changing the type of water application system or using water meters
- Institute conjunctive use of surface and ground water
- Conduct water-conservation education of the public and of school children, including special emphasis during times of water shortage
- Line canals or install piping to control seepage
- Use sprinkler and drip irrigation systems
- Soil-moisture monitoring
- Promote innovative technologies such as irrigation system improvements, waterless urinals, and monitoring technologies

6.7.4 INCREASING AND AUGMENTING WATER SUPPLY

- Issue emergency permits for water use
- Provide pumps and pipes for distribution
- Rehabilitate reservoirs and increase water storage
- Undertake water supply vulnerability assessments
- Inventory and review reservoir operation plans
- Implement water quality management and wastewater reuse

6.7.5 PUBLIC EDUCATION AND PARTICIPATION

- Establish a public advisory committee
- Include public participation in drought planning
- Organize drought information meetings for the public and the media
- Implement water conservation awareness programs
- Organize workshops on special drought-related topics
- Establish a drought information centre
- Develop training materials in several languages

6.7.6 CONFLICT RESOLUTION

- Resolve emerging water use conflicts
- Suspend water use permits in watersheds with low water levels
- Work with community-based organizations to promote public participation in conservation programs

6.8 DROUGHT PREPAREDNESS

Contingency planning for drought involves a wide range of areas, from investment in infrastructure such as operations centres, communications systems and provision for emergency health care to the strengthening of social and institutional measures such as national and local preparedness plans, trained staff and community based first aid.

Potential measures for drought contingency planning for water resources are to:

- Adopt an emergency water allocation strategy to be implemented during severe drought
- Evaluate worst-case drought scenarios for possible further actions
- Establish natural hazard mitigation committees
- Provide technical assistance to water users
- Advise people on potential sources of water
- Provide additional training to natural resource personnel
- Adopting water conservation measures
- Drought information centre and distribute real-time weather data
- Develop capacity for design and implementation of water rationing programs
- Develop software to monitor emergency flows

> **"Even with effective disaster risk reduction measures in place, there will remain some residual elements of risk that are difficult to remove either because it is technically too costly or technically too unfeasible to eliminate."**
>
> WORD TO ACTION, GUIDE FOR IMPLEMENTING HYOGO FRAMEWORK, UNISDR

- Establish special plans to protect vital supplies and environmental assets
- Stockpile pumps, pipes, water filters, and other equipment
- Establish and publicize livestock watering spots
- Contingent fund for water system improvements, new systems, and new wells
- Fund drought recovery program
- Provide lower intakes for water supplies
- Extend ramps and docks
- Issue emergency irrigation permits for using state waters for irrigation

6.9 RESPONDING TO DROUGHT

Response is preparedness in action, whereby actions are taken during and immediately after the impact of disaster that ensure the affected communities are evacuated from disaster zone and are provided with emergency medical assistance, food, shelter, clothing. Search and rescue operations, concerted and coordinated actions taken to alleviate the suffering of the victims and speed of responses along the lines expected are indeed the tests of the administrative machinery put in place during and immediately after disaster.

Effective response ought to be prompt, concerted, and coordinated.

BOX 6.2 | Areas of action for drought response

While specific attention is given to water management, this manual presents drought response as a wide range of actions in many sectors. Such actions include:

- Contingency crop planning
- Relief employment
- Water resources management
- Food security
- Gratuitous assistance
- Relief through tax waivers and concessions
- Cattle camps and fodder supply
- Institutional response
- Financing relief expenditure
- Information and media coordination
- Drought preparedness and response checklist

6.10 RECOVERING FROM DROUGHT

Response measures are an important part of drought preparedness but should only be one part of a more comprehensive mitigation strategy. Activities and programs that support immediate remedial measures to return drought-impacted systems from minimal capabilities to normal conditions are needed.

Recovery spans from activities pertaining to damage assessment and debris clearance to actions that support victims getting back to normal life and reintegrating into regular community functions.

Restoring normalcy also includes provision of temporary employment and regaining of lost livelihoods, psychosocial rehabilitation of traumatized community, replacement of buildings and infrastructure and lifeline facilities.

- Measures to provide early recovery from drought impacts (not long-term mitigation).
- Sometimes overlap those for drought response because drought impacts often linger long after the end of a drought.
- Post-drought evaluation, restoration, improvements and follow-up with drought-impacted communities.

6.11 DROUGHT MONITORING, INDICATORS AND EARLY WARNING SYSTEMS

6.11.1 DROUGHT MONITORING, INDICATORS AND TRIGGERS

Because of the slow onset nature of drought, it is essential that early warning systems have the capacity to detect the early emergence of rainfall deficiencies, which will normally be the best indicator of an incipient drought period. Hydro-climatic indices are applied to evaluate the status of climate and water supply conditions and potential impacts in specific sectors.

Common indicators of drought include meteorological variables such as precipitation and evaporation, as well as hydrological variables such as stream flow, ground water levels, reservoir and lake levels and soil moisture.

To be functional, drought indicators should identify the severity of drought conditions, and represent it in a probabilistic perspective. Indices have strengths and weaknesses, which need to be clearly understood as they are integrated into drought early warning systems. The background on drought indices is elaborated further in Module 4.

TABLE 6.3 | Template for Drought Indices

	Climatological Indices	Agriculture Index	Water Availability Index
Region A			
Region B			
Region C			

Drought indices may be linked to descriptive indicators, categorized as meteorological/environmental, hydrological, agricultural, and socio-economic to suggest approaching or actual drought conditions.

6.11.2 ENVIRONMENTAL INDICATORS

- **Reduction in biomass production of common grass species.** Early warning is wilting, as grass and crop roots become progressively damaged by lack of soil water
- **Leaf fall and litter in forests.** Leaf fall and litter (detritus) on the forest floor is another indicator of drought. Measurement of volume or weight of detritus would be required if this indicator is to be reliably used. Since leaf fall varies between species, measurement would need to be correlated with plant associations.
- **Damage to 'indicator' plant species.** Some types of succulent plant, such as cacti, utilize stored water in dry periods without noticeable damage. In fact, such plants can survive for weeks when uprooted, so that signs of damage (dried leaves or broken stems) may be an indication of negative water balance resulting from extended drought.

Hydrological

Reduction in ground water levels. Ground water levels at various well fields is an indicator of hydrological drought. There is a time lapse between meteorological and agricultural drought conditions and hydrological drought as indicated by ground water levels. The latter occurs later but the time lag cannot accurately be predicted in the absence of more complete rainfall data that could be correlated with rates of pumping and recharge for the drainage areas in which the well fields occur.

Recovery from meteorological and agriculture droughts occurs in advance of the replenishment of ground water to average levels. Again, the data does not exist to accurately predict the gap in time between these events.

Reduction of water levels at dams and ponds. Receding water levels at dams and ponds is another drought indicator observed. Indicator levels at selected dams could be established over a period of time by consistent monitoring of meteorological and hydrological data, including, rainfall, temperature, wind speed, evaporation and seepage.

Drying of wetlands. Drying of fresh water wetlands is an indication that ground water levels have receded to critical levels.

Agricultural

Weight loss in livestock. Livestock gain water from drinking water, foraging plants and water molecules produced in the breakdown of food. They lose water through urine, faeces and water evaporated through the skin and lungs. Weight loss and visible ribs are symptomatic of reduced muscle density. Some diseases become more common in animals during drought than in normal times.

Crops. Indicators may include:

- Negative water balance, as evidenced by the wilting and ultimately death of plants in extended droughts.
- Unusually high incidences of disease as plants are unable to obtain needed moisture and nutrients from the soil.

Socio-economic

Socio-economic indicators include changes in water use practices by households and businesses:

- Storage of water in existing or temporary storage facilities as a result of water rationing.
- Reduction of water used for landscaping of household and hotel gardens.
- Regular trucking of water to meet water deficit due to rationing.
- Higher incidence of respiratory ailments due to excessive dust in a very dry landscape.

6.11.3 PHASES FOR DROUGHT RESPONSE

Drought management or actions are to be implemented according to various stages of drought. The stages are decided according to drought intensity, such as:

- Level 1 – Advisory;
- Level 2 – Watch;
- Level 3 – Warning;
- Level 4 – Emergency; and
- Level 5 – Disaster.

TABLE 6.4 | Drought severity classification and related ranges

DROUGHT SEVERITY CLASSIFICATION		RANGES					
DPC STAGE	DESCRIPTION	POSSIBLE IMPACTS	SPI	KBDI	VT INDEX	CROP MOISTURE INDEX	PDSI
Advisory	Abnormally Dry	Going into drought: short-term dryness slowing planting and growing crops or pastures; fire risk above average. Coming out of drought: lingering water deficits; pastures or crops not fully recovered	0 to -.99	300-399	36-45	-1.0 to -1.9	-1.0 to -1.9
Watch	First-Stage Drought	Damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, water shortages developing or imminent, voluntary water use restrictions requested	-1.0 to –1.49	400-550	26-35	-2.0 to -2.9	-2.0 to -2.9
Warning	Severe Drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed	-1.5 to -1.99	551-650	16-25	-3.0 to -3.9	-3.0 to -3.9
Emergency	Extreme Drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions	-2.0 or less	650-700	6-15	-4.0 to -4.9	-4.0 to -4.9
Disaster	Exceptional Drought	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells, creating water emergencies	-2.0 or less	>700	1-5	-5.0 or less	-5.0 or less

Source: TWDB Regional climatic and Hydrologic Indicators (Modified from US Drought Monitor, 2000)

TABLE 6.5 | Water availability assessment values

DROUGHT SEVERITY CLASSIFICATION		RANGES					
DPC STAGE	DESCRIPTION	POSSIBLE IMPACTS	SPI	KBDI	VT INDEX	CROP MOISTURE INDEX	PDSI
Advisory	Abnormally Dry	Going into drought: short-term dryness slowing planting and growing crops or pastures; fire risk above average. Coming out of drought: lingering water deficits; pastures or crops not fully recovered	0 to -.99	300-399	36-45	-1.0 to -1.9	-1.0 to -1.9
Watch	First-Stage Drought	Damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, water shortages developing or imminent, voluntary water use restrictions requested	-1.0 to –1.49	400-550	26-35	-2.0 to -2.9	-2.0 to -2.9
Warning	Severe Drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed	-1.5 to -1.99	551-650	16-25	-3.0 to -3.9	-3.0 to -3.9
Emergency	Extreme Drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions	-2.0 or less	650-700	6-15	-4.0 to -4.9	-4.0 to -4.9
Disaster	Exceptional Drought	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells, creating water emergencies	-2.0 or less	>700	1-5	-5.0 or less	-5.0 or less

Source: TWDB Regional climatic and Hydrologic Indicators (Modified from US Drought Monitor, 2000)

6.11.4 DROUGHT RISK COMMUNICATION

A drought early warning system (EWS) must encompass not only the mechanisms and procedures for the collection and analysis of information in a timely manner, but also issues such as:

- Dissemination of that information through locally appropriate channels to potential end users;
- Training end users about the value of this information to decision-making;
- Once an emerging drought period is identified or forecast, there should be continuous information flow on expected onset and timing, intensity, cessation, duration, spatial extent and changes in spatial coverage through time, and the estimation of economic, social, and environmental impacts; and
- Forecasts include certain level of uncertainty and this should be clearly communicated.

Meteorological institutions play a critical role in EWS by making available well-functioning early warning systems. Such systems should, with a multi-hazard approach, deliver accurate reliable and understandable warnings in a timely fashion to authorities, emergency operations and the population at risk to enable preventative actions to reduce the impacts of potential disasters.

Assignment of responsibilities

Agreeing on triggers for response is not likely to create an automatic warning-response system – this is not a panacea – but it will be one important tool to press for early response.

It is one thing to be aware of the impending event and a different thing to trigger the right action 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.

It is expected that there will be a range of triggers for different sorts of response. So, for example, at an early stage the trigger might be for advocacy, but as the situation deteriorates, it might be for a livelihood response, and subsequently for a food/nutrition response.

What should the process be?

- Once the EWS has flagged a potential problem, this should immediately activate a process of further investigation.
- Detailed monitoring can be used to design interventions and operationalize emergency plans. These plans need to be clear on who should do what and when, but currently there is no shared understanding of this.
- Mobilize a common approach to using triggers, so that decision-makers know exactly what they ought to be doing as the situation deteriorates and the consequences if they fail to act on those triggers. All actors need to work together to develop a system of triggers.

FIGURE 6.6 | Disaster management coordination

SESSION | Exercise: role play

Give group EWS information and let them decide how they use it. They are to decide on the format and presentation of information, who to contact and for what purpose.

SESSION | Exercise: define drought risk management activities within an IWRM cycle

Complete at the end of the training course.

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DROUGHT RISK REDUCTION IN INTEGRATED WATER RESOURCES MANAGEMENT

TRAINING MANUAL

International Network for Capacity Development in
Sustainable Water Management (Cap-Net UNDP)

For more information: www.cap-net.org