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Euro-Mediterranean Regional Programme for Local Water Management (MEDA Water)
Mediterranean Drought Preparedness and Mitigation Planning (MEDROPLAN)

Drought Management Guidelines

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Executive summary: background, objectives and contents of the guidelines

Responding to social and policy questions

Droughts occur very frequently in the Mediterranean countries, with severe economic and social consequences also connected to the vulnerability of the water supply systems, the agricultural systems and of society in general. Such vulnerability is due to situations of permanent water scarcity, quality deterioration and increasing water demands deriving from population growth, tourist development and irrigation needs. Thus, a policy for drought management is required based on actions aimed to improve drought preparedness and to mitigate impacts of ongoing droughts.

The experiences in the development of agriculture, land and water management plans highlight valuable results in coping with drought risk in many regions. Most of the successful experiences emphasize risk-based management as a critical approach to mitigate the impacts associated with drought in societies with different vulnerabilities. Based on these experiences and the current legislation, management, technology and methods for evaluating risk, the present Drought Management Guidelines for Mediterranean countries, developed within the MEDROPLAN project (Mediterranean Drought Preparedness and Mitigation Planning) provide an effective and systematic approach to develop drought management plans linking science and policy and that can be applied to other regions.

The MEDROPLAN Guidelines are the result of a project funded through the Euro-Mediterranean Regional Programme for Local Water Management (MEDA Water) of the European Commission with the collaboration of scientists and stakeholders from Cyprus, Greece, Italy, Morocco, Spain and Tunisia.

The guidelines are designed to contribute to key social and policy questions:

- How can water management be improved, and how best can people benefit from such changes? The present contribution argues that there are options to minimize the risk of drought impacts by promoting drought preparedness and management plans.
- How can research help to develop innovative institutional arrangements and decision-support tools? The Guidelines provide a framework and a systematic approach to link academic knowledge to operational and policy aspects of drought risk management.

The Guidelines have been developed starting from the premises of moving from a reactive to a proactive approach to fighting drought, placing emphasis on the institutional and legal framework and on stakeholder participation, and establishing a wide range of methodologies to cope with drought.

Structure of the Guidelines and intended users

The outputs derived from the MEDROPLAN project are structured into three main elements:

- The Drought Management Guidelines, which are a summary of all the components developed within the framework of the project. The Guidelines are designed to appeal to a broad audience, with special reference to policy makers. Each component includes information that can be understood by a non-technical user and academic, technical and operational issues are also included, therefore linking scientific and policy communities. The document has been published in 6 languages (Arabic, English, French, Greek, Italian and Spanish) and is followed by examples in English and French of drought management experiences in the 6 countries participating in the MEDROPLAN consortium: Cyprus, Greece, Italy, Morocco, Spain and Tunisia.
- The Technical Annex to the Drought Management Guidelines, which is published as a special issue of the CIHEAM journal "Options Méditerranéennes". The Technical Annex contains a deeper development of the issues dealt with in the Drought Management Guidelines and is aimed at specialists and experts in drought.
- The MEDROPLAN website that contains all the information contained in the two documents mentioned previously also provides a tutorial that guides the user to find and select the relevant information in the different aspects of developing a drought management plan, and provides examples of application of the proposed methods and models. A CD version of the MEDROPLAN website with all the above mentioned information is included in a sleeve inside the back cover of the Drought Management Guidelines.

A tool to complement integrated water resources management

The integrated drought planning concept of the guidelines includes five components: The planning framework, the organizational, methodological, operational and public review components. A compendium of examples of application to different case studies from Mediterranean countries is likewise included.

The planning framework defines the local, regional and national purpose for developing drought planning and highlights the dynamic process that responds to changing pressures in the environment and society.

The organizational component assists the user of the guidelines to collect and provide the most comprehensive information about the institutions and organizations relevant to drought and water scarcity management and about how society responds to drought and therefore to establish the linkages among the stakeholders. A very important outcome of this component should be a proposal of the creation, if it does not already exist, and functioning of a drought committee that should become an essential figure in the management of drought plans.

A methodological component is needed to encourage objective technical studies that evaluate drought risk and vulnerability and support the controversial declaration of drought and its different levels of alert. The complexity of these topics suggests a wide range of possible evaluation methods, a combination of which is usually more rewarding than the application of a single method. Most methodologies include aspects of drought characterization, evaluation of possible impacts, risk analysis and evaluation of vulnerability.

The operational component identifies both the long and short term activities and actions to prevent and mitigate drought impacts, as well as the procedure to implement them. The activities and actions are essential for the creation of specific drought planning and response efforts.

Finally the public review component is essential since it provides the reviewing and revision of the drought plan developed by applying the guidelines.

Stakeholder participation and awareness building in each step

Analysis of the social and hydrological contexts of Mediterranean countries has pointed out the complex institutional framework and has highlighted the importance of stakeholder involvement and awareness building for successful drought management. Designing effective risk-based strategies that mitigate the effects of drought in agriculture and water supply systems, ultimately depends on the role of organizations, institutions, and civil stakeholders involved in drought in each case.

The Guidelines are developed in the context of current drought vulnerability, legislation, management, and technologies. The design of the Guidelines intends to be broad enough to incorporate new criteria for establishing priorities as societies change or as scientific and technological aspects of drought management improve.

Drought management plans are always in progress and all components need to be considered dynamic. As technologies evolve, new programmes are developed, and institutional responsibilities change these plans have to be revised.

1. Overview and use of the Guidelines

1.1. Responding to drought management challenges

What is the purpose of the Guidelines?

The purpose of the MEDROPLAN Guidelines is to provide Mediterranean countries with a framework for an effective and systematic approach to prevent and/or minimize the impacts of drought on people.

The Guidelines are intended to complement the ongoing regional and country water basin planning efforts and the ongoing agricultural policy initiatives.

The MEDROPLAN Guidelines are the result of more than three years of research and they should be considered as an integrated framework for drought planning. In particular, they aim to develop and promote criteria and methodologies based on the concepts of drought risk management and mitigation of corresponding impacts.

The Guidelines are intended to support countries in coping with the most severe impacts of such a natural disaster by means of more advanced water resources planning either at national, regional or basin level, as well as through agricultural policy initiatives. Also, the role of both long and short term measures that are to be used to prevent and mitigate the effects of drought are discussed in detail.

What is the structure and who is the intended user of the Guidelines?

The outputs derived from the MEDROPLAN project are structured into three main elements:

- The Drought Management Guidelines, which are a summary of all the components developed within the framework of the project. The Guidelines are designed to appeal to a broad audience, with special reference to policy makers. Each component of the Guidelines includes information that can be understood by a non-technical user. The Guidelines link academic, and technical issues with operational aspects, therefore linking scientific and policy communities. The document has been published in 6 languages (Arabic, English, French, Greek, Italian and Spanish) and is followed by examples in English and French of drought management experiences in the 6 countries participating in the MEDROPLAN consortium: Cyprus, Greece, Italy, Morocco, Spain and Tunisia.

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Drought management plans must make information available to the largest possible audience; therefore the goal of the MEDROPLAN Guidelines is to reach the full range of stakeholders related to drought in the Mediterranean, and is especially oriented to the support of policy making.

In order to achieve this goal, the Guidelines are written with the user in mind and try to avoid the use of very specific scientific or technical language that may be difficult to be understood by a non specialist.

How are the Guidelines to be used?

The Guidelines provide a complete framework to cope with drought through the design and application of pro-active drought management plans. Nevertheless, each country and each basin has its own characteristics and the drought plans should be adapted to them. So the Guidelines are not prescriptive and have to be taken as a reference, and the tools proposed have to be chosen and adapted to the planning reality.

The Guidelines are designed to appeal to a broad audience. Each component of the Guidelines includes information that can be understood by a non-technical user. The Technical Annexes complement the Guidelines and include more in-depth scientific information and developments in drought management, being addressed to a more specialized public (scientists, water managers, experts, etc.) that may be interested in studying some aspects of the Guidelines or whole components of them in greater depth. The website and the tutorial contain all the previous documentation and are intended to reach a wider public and to help readers find their way through all the information.

Are the Guidelines a final product?

The Guidelines reflect the current situation of the Mediterranean countries involved in the MEDROPLAN project with respect to drought vulnerability, water resources legislations and management and available technologies. Nonetheless, the design of the Guidelines intends to be broad enough to incorporate new criteria for establishing priorities as societies change or as scientific and technological aspects of drought management improve.

Can the Guidelines be used in situations different than the Case Studies?

The experiences in the development and implementation of drought management plans highlight the success and challenges of coping with drought for societies with different vulnerabilities and emphasize risk-based drought management as a critical approach to mitigate the impacts associated to drought-induced water shortages. Based on these experiences and the current methods for evaluating risk, the Guidelines synthesize drought management operational actions that can be applied to other regions.

The Guidelines respond to the growing need of drought preparedness planning, monitoring, and mitigation which has worldwide application.

The methodologies and lessons learned are focused on a specific, drought-prone region so the applications have more significance. The Mediterranean region exemplifies many other drought-prone regions with rapidly expanding populations that are placing increased pressure on already limited water supplies.

1.2. Components of the Guidelines

The objective of the Guidelines is to provide a methodological framework with examples that may be followed to develop drought management plans in a range of situations. The Guidelines include the following components (Figure 1):

- The planning framework
- Organizational component

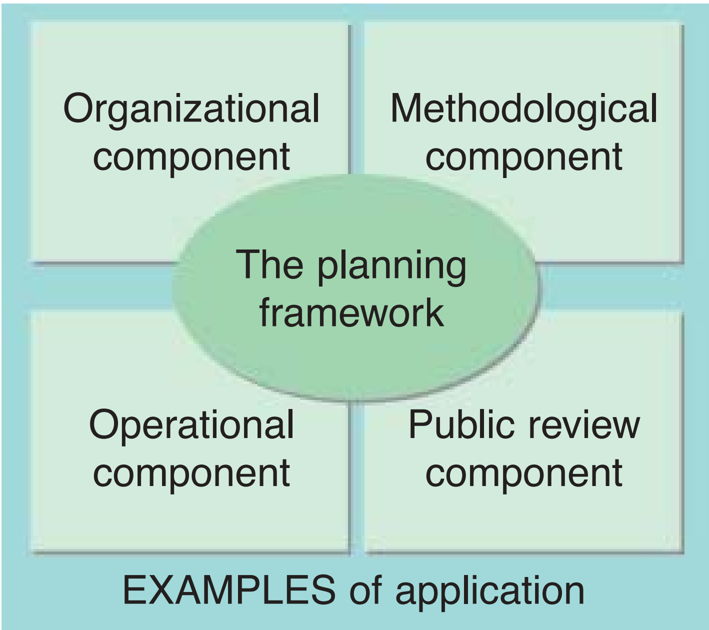


Figure 1. Components of the Guidelines

• Methodological component

• Operational component

• Public review component

Besides, the Guidelines include examples of the application of the drought management framework to specific situations in order to show how the various components and methodologies can be developed and applied to drought management plans.

The **planning framework** defines the local, regional and national purpose for developing drought planning. The planning framework guides the user of the Guidelines to define the planning purpose and process, establishes a common language among stakeholders, and highlights the importance of using a common set of terms and concepts for developing a drought management plan that can be discussed among a full range of stakeholders.

The **organizational component** assists the user of the Guidelines in understanding the institutional and legal framework within which the drought plan will be designed and implemented, as well as to define an efficient organizational structure to implement the plan in an efficient manner. It also emphasizes the geographical unit of planning, with respect to which planning tools to prevent and mitigate drought-induced water shortage have to be chosen. The organizational component assists the user of the guidelines in compiling and providing the most comprehensive information about how society responds to drought, coordinating with the various institutions, providing public information and defining the actors responsible for drought declaration.

The **methodological component** presents a scientific approach to risk evaluation through the following steps:

- Compile and provide the most comprehensive technical and scientific approaches to drought characterization, and development of indicators of risk in water resources and agricultural systems.
- Define the methods used for risk management in the context of the Mediterranean region.
- Define the academic methods for evaluating social vulnerability based on indicators that include the capacity to anticipate, cope with and respond to drought.
- Encourage technical studies to strengthen the use of indices and the declaration of drought.

The **operational component** identifies both the long and short term actions that can be implemented to prevent and mitigate drought impacts. The activities and actions are essential for the creation of specific drought planning and response efforts. The operational component includes five aspects:

- Preparedness and early warning (permanent measures).
- Establishing priorities to be respected during water shortages due to droughts.
- Thresholds defined by drought indices and indicators (physical and social).
- Defining the actions.
- Evaluating the process to implement the actions.

The **public review component** presents a methodology to revise the application of the previous components when developing a drought plan. Our approach suggests a public multi-stakeholder dialogue and includes a protocol for developing dialogue workshops, guided interviews, and questionnaires aiming to collect feedbacks. Dissemination of information is also essential in this component. Apart from the initial public review, it is important to make periodic revisions of the drought plan, especially after drought episodes, in order to make the necessary adjustments in the light of the results of the application of the plan and of changes in society, technology and the environment.

Why examples of application in the Guidelines?

The examples of application help to better understand the drought management framework of the Guidelines. They explain how the Guidelines can be applied to different environmental and socio-economic realities taking into account that:

- Every drought has unique problems and impacts therefore it is difficult to present a plan that details and addresses all of them.
- The social and economic structure of every basin or water unit is different and examples are used to show the range of possible application of the Guidelines.
- There is already valuable information and knowledge of drought management in agricultural and water supply systems and the examples enhance the exchange of experiences.
- The Guidelines are not prescriptive, they simply ofter a range of options based on real case studies.

What is the content of the examples of application?

The examples of application developed in the partner countries (Cyprus, Greece, Italy, Morocco, Spain and Tunisia) include the description of effective measures taken in the past and proposals for the future. These examples provide the context for developing demand-driven guidelines that may be applied to other regions. Figure 2 shows the MEDROPLAN partner countries.

Figure 2. The six Mediterranean countries involved in the MEDROPLAN project, where the examples of application of drought planning are provided

2. The planning framework

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 2: Defining the planning purpose, framework, and concepts
Chapter 3: Diagnostic of the situation

2.1. Defining the planning purpose and process

Why is it necessary to define a purpose?

Drought has a wide range of effects in different sectors, social groups, or the environment. Whether the drought plan addresses the full range of possible risks or focuses on a few, it is necessary to establish the final purpose from the onset. The purpose determines the choice of methodologies for developing the plan.

Are drought plans static products?

Drought management plans are always in progress. As technologies evolve, new programmes are developed and institutional responsibilities change, these plans have to be revised and updated; therefore all components need to be considered dynamic (Figure 3).

Figure 3. Development and revision of a drought management plan based on the MEDROPLAN guidelines

The proposed Guidelines for drought planning are the result of more than three years of research and they should be considered as an integrating framework, which takes into account almost every aspect of mitigating drought for the time being. However it is true, that from time to time they should be reviewed, edited and updated if necessary.

2.2. Defining a common language among stakeholders

Why is a multi-stakeholder dialogue necessary from the onset?

- To increase the quality and acceptance of drought management plans
- To increase acceptance of or trust in the science that is the basis of the planning
- To provide essential information and insights about drought preparedness since the relevant wisdom is not limited to scientific specialists and public officials.

What are the challenges for involving stakeholders?

- To identify incentives and means for engaging stakeholders
- To represent stakeholder decision-making in realistic terms
- To ensure that complex models are transparent and provide insight to individual users.

Why is it necessary to start with concepts?

Drought, aridity, water shortage, water scarcity and desertification are common and overlapping processes in Mediterranean countries (Figure 4) and are often misinterpreted and misused. Starting with clear and agreed definitions and concepts contributes to the development of clear methods and to the correct interpretation of the results when developing drought management plans. Some of the most important concepts and definitions are included in Annex 1 of this document.

- **Drought:** Natural casual (random) temporary condition of consistent reduction in precipitation and water availability with respect to normal values, spanning along a significant period of time and covering a wide region.
- **Aridity:** Natural permanent climatic condition with very low average annual or seasonal precipitation.
- **Water shortage:** Man-induced temporary water imbalance. Water shortage in a water supply system represents a water deficit with respect to the demand, which can occur due to a drought or other man-induced causes (e.g. low water quality, ill services).
- **Water scarcity** indicates a permanent condition of imbalance between water resources and water demands in a region (or in a water supply system) characterized by an arid climate and/or a fast increasing of water demand, associated to growth of population, extension of irrigated agriculture, etc.

- **Desertification:** the degradation of land in arid, semi-arid and other areas with a dry season; caused primarily by over-exploitation and inappropriate land use interacting with climatic variance.

	Natural	Man induced
Temporary	• Drought	• Water shortage
Permanent	• Aridity	• Water scarcity • Desertification

Figure 4. Basic concepts related to water availability

Box 1. Types of drought

According to the different component of the natural hydrologic cycle affected by a drought event, it is possible to distinguish between: meteorological, agricultural or hydrological drought (see Figure 5).

In particular, a **meteorological drought** indicates a condition of reduction of precipitation with respect to normal values, consequent to precipitation variability probably caused by earth processes (such as geophysical and oceanographic interactions), interactions with the biosphere and maybe by sunlight energy fluctuations.

As a direct consequence of meteorological drought, a soil moisture deficit occurs (**agricultural drought**), depending on the importance of the meteorological drought transformed by the water storage effect. The soil water storage causes a delay in the water deficit occurrence and modifies its entity in relation to the initial humidity conditions and to the evapo-transpiration process. Agricultural drought particularly affects agriculture and livestock systems in rainfed conditions.

Subsequently, when the previous deficit affects surface water bodies (rivers) and **groundwater** bodies (aquifers), a **hydrological drought**, as a surface and/or groundwater flow decreasing with respect to the normal values, occurs.

Finally, drought can have effects on water supply systems leading to water shortages. The latter is sometimes defined as **operational drought**, and in relation with the environmental, economic and social system features it can have economic and intangible impacts. Both the water availability reduction and its impacts depend, besides the importance of the drought event, on the efficiency of the mitigation measures adopted in water supply and socio-economic systems.

Sometimes, the definition of **socio-economic drought** is also used to indicate impacts of water shortage on the population and the economy. Hereafter, the latter will be examined in terms of economic, environmental and social impacts produced by a drought.

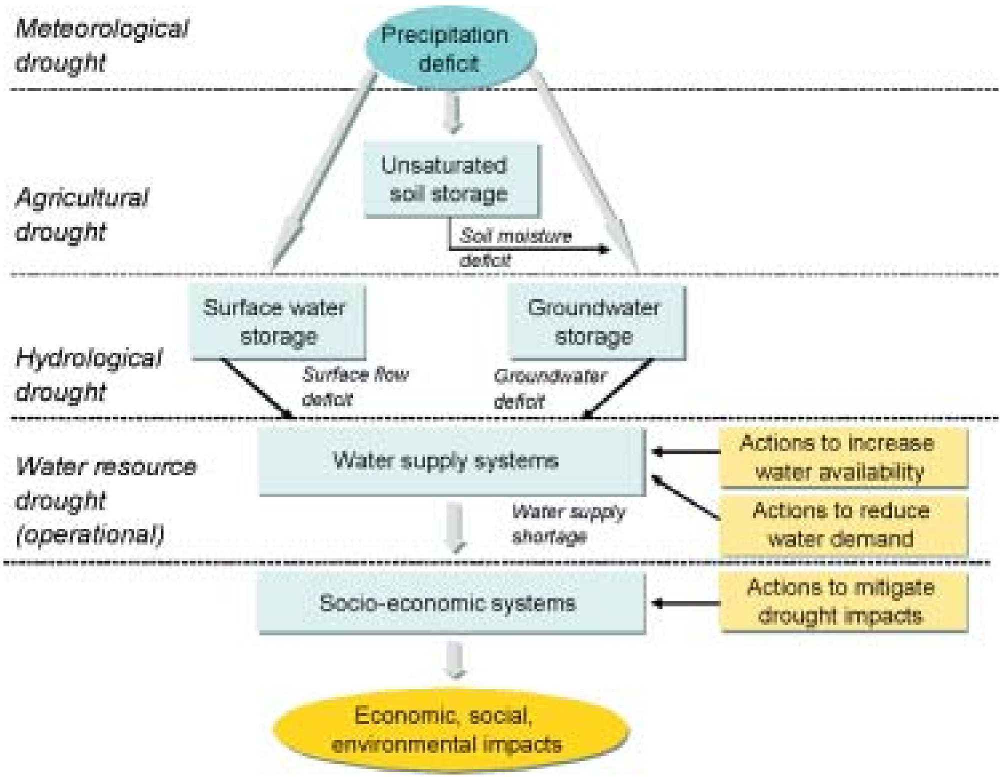


Figure 5. Drought phenomenon and role of drought mitigation measures

2.3. Defining the drought management approaches

Management before or during a drought period?

A **reactive approach** is based on the implementation of measures and actions after a drought event has started and is perceived. This approach is taken in emergency situations and often results in inefficient technical and economic solutions since actions are taken with little time to evaluate optimal actions and stakeholder participation is very limited.

A **proactive or preventive approach** includes all the measures designed in advance, with appropriate planning tools and stakeholder participation. The proactive approach is based both on short term and long term measures and includes monitoring systems for a timely warning of drought conditions. It can be considered an approach to "manage risk". A proactive approach consists of planning the necessary measures to prevent or minimize drought impacts in advance. Such an approach includes preparedness of planning tools which enable the consequences of a possible water emergency to be avoided or reduced, as well as the implementation of such plans when a drought occurs. The proactive approach foresees a continuous monitoring of hydrometeorological variables and of the status of water reserves in order to identify possible water crisis situations and to apply the necessary measures before a real water emergency occurs. Nevertheless, if it is not possible to avoid a water crisis that appears as a natural public calamity (after a government declaration), the Drought Contingency Plan is implemented until the establishment of normal conditions. It is evident that a proactive approach, even if more complex, is more efficient than the traditional approach, since it allows drought mitigation measures (both long term and short term) to be defined in advance, improving the quality of the interventions.

Table 1 summarizes the characteristics of the reactive and the proactive approaches.

Table 1. Characteristics of the approaches to drought management

Approaches to drought management	Characteristics	Limitations
Reactive approach	Based on the implementation of actions after a drought event has occurred and is perceived. Taken in emergency situations but not based on a contingency plan.	Often results in inefficient technical and economic solutions since actions are taken with little time for evaluating optimal actions. Limited stakeholder participation
Proactive or preventive approach	Actions designed in advance, with appropriate planning tools. Includes stakeholder participation. Provides both short and long term measures and includes early warning systems. Includes a contingency plan for emergency situations.	The ineffective coordination and cooperation between institutions and the lack of policy to support and revise the proactive plan may lead to an inadequate planning.

Which institutional aspects are necessary for an efficient drought management?

The implementation of a proactive approach implies drafting plans in which the mitigation measures are clearly defined together with the instructions for their implementation. At this end, a clear assignment of competences among the different institutions involved appears to be a key issue; therefore a legislative act which defines the responsibilities is necessary in each country. Such an act could be part of a national water resources policy and/or strategy to fight desertification (within the U.N. convention).

No single management action, legislation or policy can respond to all the aspects and achieve all goals for effective drought management. Multiple collaborative efforts are needed to integrate the multidimensional effects of drought on society.

Other important aspects to take into account are:

- Stakeholders' participation;
- Management and changes in water rights legislation allowing water exchange during droughts;
- Definition of standards of efficiency to foster water saving and sanctions for those who do not respect them.

3. Organizational component

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 4: Institutional and legal framework for drought management
Chapter 5: New tools for social intervention in water disputes
Chapter 6: Stakeholder dialogue for improved local water governance

3.1. Overview

The management of drought in a defined area requires integrative approaches and integrated management, based not only on the natural features, but also on socio-economic conditions of the area. The relations among Organizations and Institutions are the basis for understanding current drought management plans and for improving future actions that mitigate the effect of drought on agriculture, water supply systems and the economy. Understanding the national institutional regime is a key factor for establishing effective and integrated drought management plans that incorporate monitoring, public participation, and contingency planning.

Why is an organizational component needed?

An organizational component is needed to:

- Compile and provide the most comprehensive information about how society responds to drought and establish the linkages among the stakeholders
- Coordinate with various institutions to avoid conflict, duplication, and expedite the administrative and legal process
- Provide responsible and timely public information
- Define the actors responsible for drought declaration

Who is affected and who is responsible?

The geographical location and the social structure determine drought planning; three essential elements define the organizational component:

- Where? (The geographical unit)
- Who is affected? (The stakeholders)
- Who is responsible for the planning? (The legal and institutional framework)

The organizational component provides a common methodology for analysing the organizations and institutions relevant to water scarcity and drought management. The common methodology is adequate to provide information that will contribute to compare among and across countries and to promote the cooperation between the existing institutions, organizations, networks, and other stakeholders in the Mediterranean countries.

3.2. The geographical unit

The geographical unit, or spatial extent of the drought plan, defines the bio-physical risks to be considered, the stakeholders affected and their responses, and the organizations and institutions responsible for planning.

When water resources are managed at the basin level, there is an opportunity to respond directly to the needs and problems of the natural hydrological system with policy decisions. For example, Basin Authorities in Spain can establish priorities of users or rights holders according to each situation, can approve works and projects needed to solve emergent scarcity problems, and can create Water Exchanging Centres, through which rights holders can offer or demand use rights in periods of droughts or severe water shortage situations.

The human dimension of drought management in the Mediterranean might not stop at the regions' boundaries. There is a potential for more pronounced water conflicts with neighbouring

regions (e.g. transboundary issues in shared surface waters and aquifers) and demographic shifts due to the collapse of agricultural activities in some areas.

Different geographical units can be considered, in relation to the measures to be implemented and the legal framework of each country, especially with respect to the system adopted to attribute subsidies to cover damages due to natural calamities and the planning tools for water resources. For instance, with reference to the Italian system of financial aid to the population affected by droughts, considered as natural calamities, the geographical units involved are the provinces (for damage warning) and the regions (for the request of calamity declaration to the national government and to receive subsidies).

Within a proactive approach, which implies the identification of long and short term measures, the geographical units may be the following:

- Hydrographic district, according to the European Directive 2000/60 ("Confederación Hidrográfica" in Spain, River Basin in Italy and Greece), for which a planning tool for water resources use, also including specific criteria to manage drought risk, is required;
- Territories with interconnected water supply systems, for which preventive measures to avoid water emergency situations have to be defined (within a plan to prevent water emergencies) into the water supply management actions;
- Regions, provinces or municipalities (according to the different legislations) for which a Drought Contingency Plan has to be prepared.

3.3. The stakeholders

Each geographical unit should have its own stakeholders system that has to be carefully diagnosed. Table 2 shows an example of stakeholder diagnosis in Mediterranean regions, stressing the relation of stakeholders with drought.

Table 2. Stakeholder identification and participation in drought management

Stakeholder	Participation	Expectations	Adaptive capacity
1. Rainfed farmers.	Individuals or collective organizations. Research and development of insurance products.	Improve adaptation practices (before or during drought) in livestock and crops to minimize or avoid drought effects.	Low investment capacity for new technologies. Insurance options. Alternative sources of livestock feeding.
2. Irrigated area farmers.	Individuals or irrigators' associations. Basin plan design.	Same as above. Maintain water supply guarantee.	Same as above. Increasing experience in water efficiency technologies.
3. Urban water consumers and water utilities.	Individuals or consumers' associations. Basin plan design.	Avoid water shortages, increase supply guarantee levels and increase water quality standards.	High potential of saving water.
4. Tourism companies.	Individuals or tourist companies associations. Basin plan design.	Avoid water shortages and bad quality that limits sector development.	High water saving potential
5. Industrial companies.	Individuals or employers' organizations. Basin plan design.	Avoid water shortages and bad quality that limits sector development.	High potential for improving water sustainability
6. Water Basin Authorities.	State Government Agencies. Include public participation boards and mechanisms.	Development of water policies based on risk analysis.	Coordinators of stakeholder dialogue; potential leaders to implement non-conventional water resources. Pro-active and reactive actions included in river basin plans.
7. Local Water Authorities and Water Suppliers.	Local Government Agencies or private companies. Includes assembly of users.	Development of water policies based on risk analysis	Potential for improving water use efficiency and capacity to adopt prompt actions
8. Meteorological and Hydrographical Institutions.	Government Agencies	Use of data to analyse risk	Capacity to develop early warning systems
9. Ministries of Agriculture, Environment, Water, Tourism, Industry.	Government Agencies. Participate in drought committees.	Implementation of mitigation policies.	Coordination and capacity to revise legislation

Stakeholder	Participation	Expectations	Adaptive capacity
10. Agricultural Insurance companies.	Private-public Agencies.	Develop adequate insurance products.	Revision of insurance products, new insurance products.
11. Rural lending institutions or banks.	Government Agencies or private companies.	Forecasting extraordinary financial resources.	Revision of financial products, new financial products.
12. Research and education institutions.	Private-public institutions.	Develop adequate academic knowledge on risk analysis, adaptation and technology.	Improvement of international academic knowledge.
13. International Cooperation Organizations.	Inter-governmental. Networking. Facilitate international agreements.	Transfer of technology and knowledge.	Improvement of international knowledge and networks.
14. NGO´s.	Non-governmental. Potential to engage civil society.	Environmental and social improvements.	High influence in public opinion.

3.4. The legal and institutional framework

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 4: Institutional and legal framework for drought management

Designing effective risk-based strategies that mitigate the effects of drought in agriculture and water supply systems ultimately depends on the role of organizations, institutions, and civil stakeholders involved in drought in each case.

Objectives of the analysis

The objective is to identify, analyse, and promote cooperation among and between international, national, and local organizations and institutions that work on:

- The collection, processing, storing of meteorological, hydrological, biological, and socio-economic data;
- Water resources planning and operation of water supply systems;
- Drought preparedness and mitigation.

The analysis aims to provide insights into the following key questions:

- Are the set of organizations and institutions that interact within a formal or an informal network?
- Are there networks to provide communication and hierarchical flows of command?
- Are the stakeholders included in the network?
- What is the degree of influence and dependence of the stakeholders' decisions on the institutions' core themes?

Moreover, the main objectives of the analysis are: (i) that the drought plan fits or matches as far as possible the legal and institutional framework of the region where it will be implemented, to avoid contradictions and duplication of tasks and to be as operative as possible; (ii) to identify strengths and weaknesses of the framework and (if possible) propose improvements.

Methodology

Although the objectives of the Guidelines are not directly focused on the institutional analysis per se, it is important to understand the concepts and to identify and map the institutions involved, to ensure the relevance of subsequent drought management analysis. The methodology that has been followed in MEDROPLAN to map the relevant institutions in each partner country consists of five main tasks:

- Elaborate a mental model of organizations and institutions in each country and describe the institutional and legal frameworks at the different levels of interest (geographical units, country, region, local basin…).
- Collect additional information by interviews and / or other dialogue methods with selected individuals from official institutions and stakeholder organizations. The interview should include "problem analysis" (e.g., what actions did your institution take during a historical drought in a specific year?) and identification of the decision makers and the stakeholders affected by the decisions of each institution.

- Validate the model structure. Communicate back to the organizations and institutions the results of the previous two tasks and complete the analysis.
- Analysis of the strengths and weaknesses of the system organizational processes to take decisions within the institution and within the hierarchical structure of institutions.
- Discussion of the challenges and opportunities to improve drought management.

A more in-depth description of the analysis process followed in the MEDROPLAN project as well as its results can be consulted in Options Méditerranéennes, Série B, 51 (2005).

Examples of application and results are provided in each individual case study.

Expected outcome

The institutional analysis provides:

- Explicit description of legislation, institutions and organizations with competence in water policy and administration, in planning, decision making, operation of water supply systems and in drought preparedness, and emergency action with particular emphasis in municipal and irrigation water supply.
- Explicit description of the linkages and hierarchical relations among the organizations and institutions.
- Information on existing drought preparedness and management plans.
- Information on the institutional experience on the application of the existing drought preparedness and management plans.
- Description of the data collection system in the country, specifying the institutions responsible, the type of reporting and accessibility, and the primary uses of the data.
- Evaluation of the strengths and weaknesses of the legal and institutional framework and potential improvements.

According to the results of the analysis, it may be necessary to propose the design of a drought management committee, indicating its composition, competences and mode of operation, both during drought and non-drought periods. This committee would have a very relevant role both in the drought management plans and in their revision and updating when the climatic and socio-economic circumstances so advise.

Table 3 summarizes the expected outcomes in relation to the operational aspects of institutional performance.

Table 3. Expected outcomes from the institutional analysis related to operational performance

<table>
<tr><th>Aspects</th><th>Items of special interest</th><th>Key considerations for analysis</th></tr>
<tr><td>Data and information systems</td><td>Bio-physical (hydro-meteorological, agricultural, etc.)
Socio-economic</td><td>Availability
Reliability of data collection and processing</td></tr>
<tr><td>Specific drought-related action plans</td><td>Specific legal provisions for drought preparedness
Risk-sharing mechanisms (e.g., insurance)
Existence of a drought management committee
Contingency plan
Budgetary provisions
Social participation</td><td rowspan="2">Reactive capacity:
Time response after declaration of drought
Coordination
Mobilization of financial resources
Outreach
Policy implementation
Ability to anticipate costs and effects

Scope:
Sectorial levels
Geographical level
Social groups
Indirectly related sectors
Special target groups

Social learning process:
Lessons drawn from past drought experience
Research and Development
Ex-post evaluations
Preparation of remediation and alleviation plans
Participation in international initiatives/projects</td></tr>
<tr><td>Drought-related initiatives not included in specific drought plans</td><td>General legal provisions related to drought
Policy initiatives: level and financial support</td></tr>
</table>

Box 2. Institutional and legal framework for coping with drought in Europe

The European Union Water Directive 2000/60 explicitly defines planning as the main tool to guarantee protection of water bodies and indicates mitigation of flood and drought events as main objectives. However it does not take into account criteria and actions to face drought risk, references to drought are rare and ambiguous and often misleading and mitigation measures are only considered optional.

Most European countries have not issued a legal framework to face drought risk and emergency actions are managed by Civil Protection Agencies or some legislative acts referring to recovery from natural disasters. The lessons learned during recent droughts have shown the inadequacy of the legal systems, fostering towards planning of drought mitigation measures and the substitution of subsidies to cover damages in agriculture with insurances. Spain is an example of institutional support for taking these initiatives. The success in most cases is due to the management of water at the basin level, allowing coordination of policy, physical and technical aspects.

For example, in Spain there is a clear share of competences among the bodies involved, as well as a clear definition of the contents of drought mitigation plans. The Law 10/2001 applies a proactive approach to face drought risk: defines the basis to develop a system of hydrologic indicators to monitor and forecast drought events; gives responsibility to the Basin Authorities (Confederaciones Hidrográficas) to prepare their drought plans and to the municipal water agencies to prepare drought emergency plans; and assigns responsibilities for drought declaration.

3.5. Design of drought committees

In some cases it may be necessary to design drought committees that may have competences at different levels of implementation of policy and expert analysis.

Policy committee (Drought Committee)

The components of a possible policy committee may include representatives of the Organizations and Institutions relevant to drought management previously defined and relevant to the geographic unit of the study. The competences and mode of operation, both during drought and non-drought periods should be clearly defined.

Technical committee

In some cases, the diagnostic risk analysis of drought is complex, and an expert committee may assist in the evaluations outlined in the Methodological Component of the Guidelines.

An important aspect is to provide timely and accurate information on drought conditions to both governmental organizations and civil society, so that decisions can be made before a crisis situation develops.

4. Methodological component

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 7: Drought characterization
Chapter 8: Methods for drought risk analysis in agriculture
Chapter 9: Methods for assessing shortage risk in water supply systems
Chapter 10: Methods for evaluating social vulnerability
Chapter 11: Tools and models

4.1. Overview

The complexity of drought calls for complex methods of analysis

A methodological component is needed to understand the system: the drought hazard, the risks to different systems, the causes of risk, and the operational aspects to decrease risk. These aspects can be evaluated in isolation or in an integrated approach. The complexity of these topics suggests a wide range of possible evaluation methods. Each method has its own merit and they are usually supportive of each other. A combination of methods is usually most rewarding.

The results of the methodological component provide elements that support the controversial official declaration of drought and of its different levels of alert.

Defining the concepts: hazard, risk, and vulnerability

The concepts of vulnerability and risk are part of the common language and the concepts are used by most people in their daily lives. These concepts are used loosely in many different contexts, from medicine to poverty and development literature. In the context of natural hazards, the concepts are often derived from the social sciences since there is an explicit demand for increasing social protection to natural hazards. In contrast, the concept of risk in engineering is physically based on the computation of failure probabilities in a hydrological system.

Regardless of the nuance of risk definitions, the key concepts are:

- Risk relates to the consequences of a disturbance, rather than its agent;
- Risk is a relative measure and critical levels of risk must be defined by the analyst.

There is no clear definition that includes cross-sector (social and physical) concepts. Since the intended user of the guidelines is the policy maker, we provide here the definition that appears in almost all policy documents (United Nations, 2006; United Nations International Strategy for Disaster Reduction, 2006; Box 3).

Box 3. Definition of hazard, risk, and vulnerability (UNISDR)

HAZARD: A potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Each hazard is characterized by its location, intensity, frequency and probability.

VULNERABILITY: A set of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards. Positive factors, that increase the ability of people and the society they live in to cope effectively with hazards and can reduce their susceptibility are often designated as capacities.

RISK: The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Risks are always created or exist within social systems, therefore it is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.

RISK = HAZARD x VULNERABILITY

Source: The UN International Strategy for Disaster Reduction (UNISDR, 2006)

http://www.unisdr.org/

Methodology presented in the guidelines

The methodological component of the Guidelines compiles and provides comprehensive technical and scientific approaches to encourage objective technical studies. A summary of the methodological component and the linkages to the operational component is presented in Figure 6. First, methods for drought characterization and evaluation of the use of adequate indices for agricultural, hydrological and water supply systems are presented. Second, a guide to evaluate the risks of drought in a system and region is provided. This includes qualitative or semi quantitative methods based on stakeholder consultation and quantitative methods based on formal risk evaluations that are probabilistic analyses. The quantitative risk evaluation provides a means to quantify the probability of damage in each drought situation. By knowing the estimated damage in advance, stakeholders can anticipate measures to minimize the impacts of drought.

Finally, methods to evaluate vulnerability are presented. Vulnerability refers to the characteristics of a social group or sector in terms of its capacity to anticipate to, to cope with, and to recover from drought. Vulnerability represents the internal component of risk and can be described by a combination of economic, environmental, and social factors. By understanding the causes of vulnerability of the systems, stakeholders can design proactive measures to decrease the potential impacts of drought, since the solution (management) depends on the problem (vulnerability).

The management actions that are often a component of traditional risk evaluation are considered in the Operational Component of the MEDROPLAN Guidelines.

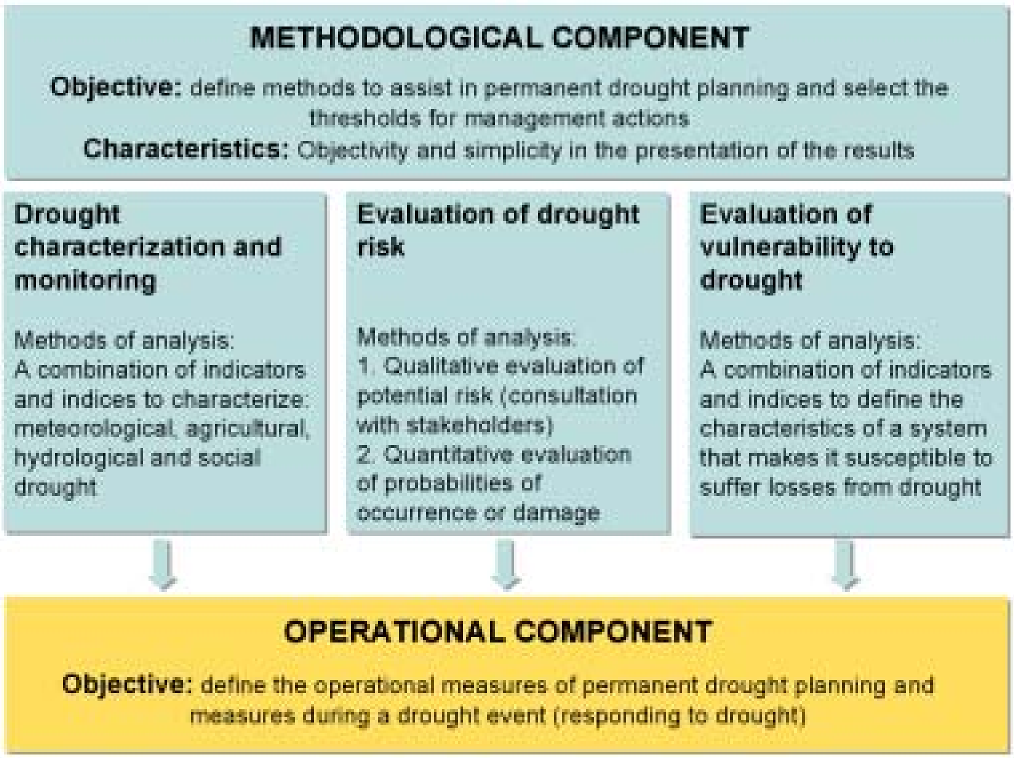


Figure 6. Summary of the methodological component and linkages to the operational component

Producing technical information that is understood by stakeholders

The proposed methodological component is based on two essential requirements: objectivity and simplicity on the presentation of the results. Objectivity is unavoidable, since drought management actions affecting users' rights will be based on the results of the analysis. The requirement for simplicity is justified by the necessity to submit the results of the analysis to discussion and approval by all stakeholders. Complex models based on sophisticated analyses are often necessary to obtain the most accurate results and predictions. Nevertheless, they are difficult to understand and it may not be appropriate to present the raw results of these models to affected users. Therefore it is necessary to simplify and synthesize the information to communicate to stakeholders. It is expected that once the drought plan is approved and put into operation, the simplicity requirement may be relaxed progressively, as users become more familiar with the methodology.

4.2. Drought characterization and monitoring

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 7: Drought characterization

Objective

The objective is to provide the methodology to be applied for the characterization of meteorological and hydrological droughts. The correct drought characterization provides decision makers with a measurement of abnormal weather variability, so that protection from possible impacts may be implemented.

Methods

Drought is a three-dimensional phenomenon that can be characterized by its severity or intensity, duration, and geographic extent. Drought characterization is complex and there are a wide range of meteorological or hydrological indices or indicators that can be used. It requires an accurate selection of drought identification methods and/or of drought indices, able to describe in a synthetic and clear manner the evolution of drought conditions in space and time. Each one has its own merit and they are often supportive of each other. A combination of indices and indicators is usually the preferred option.

Drought indices can be used to describe all types of droughts (that is, meteorological drought: deviation from the normal meteorological conditions; hydrological drought: deviation from the normal hydrological conditions; agricultural droughts: deviation from the normal soil moisture conditions for crop growth; and socioeconomic drought: deviation from the normal level of availability of water for fulfilling societal needs).

The indices for drought characterization have to comply with the following requirements: (a) that they can be calculated from data available from actual data collection systems; (b) that they have an a priori and direct relation with vulnerable social, economic and environmental systems; and (c) that they can be used for predictions and early monitoring systems.

Drought characterization should also include a previous diagnosis of the sources, scales and reliability of the data used in the analysis.

Expected outcome

The expected outcome is the characterization of the meteorological and hydrological drought periods in the historical record in each geographical unit.

The correct drought characterization provides decision makers with a measurement of the abnormality of historical weather variability and its effects on a region. Drought monitoring has the objectives to warn about a possible incoming drought, providing adequate information for an objective drought declaration and for avoiding severe water shortages, therefore this methodological component is essential for stakeholders.

The use of indices for characterization and monitoring

Drought management depends on indices to detect drought conditions, and thresholds to activate drought responses. Indices and thresholds are important to detect the onset of drought conditions, to monitor and measure drought events, and to quantify the hazard.

The appropriate drought index is selected according to the type of drought. Indices may be considered as general or specific depending on the utility for which they have been devised. It is understood that this distinction is difficult. Some of the indices, however, are more appropriate for monitoring and some for the analysis of historical drought events.

A compendium of useful drought indices

Drought indices are essential elements for drought monitoring since they summarize the complex interaction between climatic variables and related processes (e.g. soil water moisture). Use of indices allow a quantitative assessment to be made of the climatic anomalies in terms of intensity, spatial extent and frequency, and favour the exchange of information about drought conditions among decision makers as well as the public.

The availability of a large number of indices is mainly due to the difficulty in defining unequivocally a drought phenomenon. The current common orientation consists of the application of a group of different indices within a monitoring system of hydro-meteorological variables and water resources availability provided by public “monitoring centres”. The main purpose of “monitoring” centres is to support decision makers in timely recognizing drought onset.

Different indices and methods have been proposed since the ‘60s to identify and monitor drought events. Some of the indices refer to meteorological drought and are based on precipitation series, while others are oriented to describe hydrological or agricultural drought or water shortages in urban water supply systems. Table 4 presents a summary of some of the main indices that can be applied to drought characterization and monitoring.

Table 4. Drought indices and their characteristics

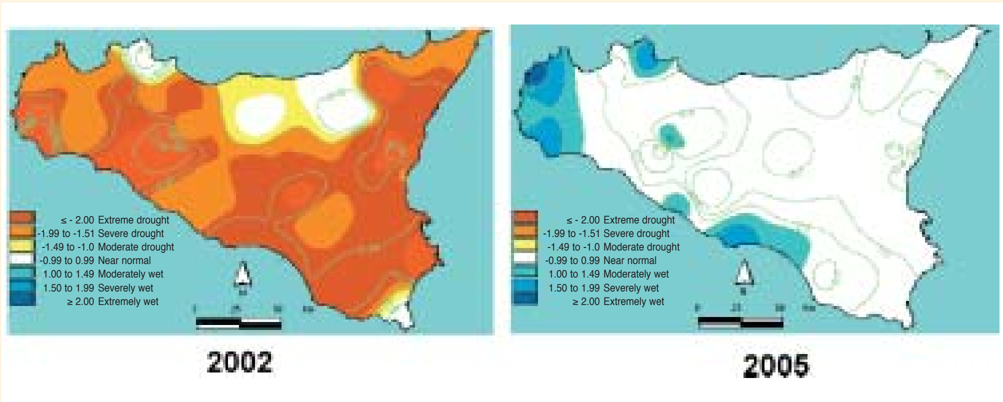
Drought Indices	Data needed	Category of use
Deciles	Precipitation	Meteorological
Standardized Precipitation Index (SPI)	Precipitation	Meteorological, used for monitoring and forecasting
Rainfall Anomaly Index	Precipitation	Meteorological, sensitive to extreme events
Reconnaissance Drought Index (RDI)	Precipitation, Potential Evapotranspiration	Meteorological
Run Analysis	Precipitation, streamflows	Meteorological and hydrological, for spatio-temporal analysis of historical events
Palmer Drought Severity Index (PDSI)	Precipitation, Temperature, Soil Moisture (Available Water Content)	Meteorological, effective in agriculture, used in historical analysis and risk analysis
Palmer Hydrological Drought Severity Index (PHDI)	Precipitation, Temperature, Soil Moisture Conditions	Hydrological, effective in monitoring
Surface Water Supply Index (SWSI)	Snowfall, Precipitation, Streamflow, Reservoirs	Hydrological, effective when snow is important
Crop Moisture Index (CMI)	Precipitation, Temperature, Soil Moisture Conditions	Agricultural
Soil Moisture Anomaly Index (SMAI)	Soil Moisture Conditions, Potential Evapotranspiration, Potential Runoff	Hydro-Agricultural
Normalized Difference Vegetation Index (NDVI)	Satellite images	Natural resources, agricultural

The most commonly applied drought indices include the Standardized Precipitation Index (SPI), the Palmer Drought Severity Index (PDSI) and Deciles due to their simplicity. It was concluded that the easiest index to use for monitoring purposes is the SPI, which is based on a single meteorological parameter (precipitation) and the RDI that also includes evapotranspiration. Recent advances in remote sensing provide products that have a large potential as drought indices. The NDVI is widely used for monitoring and forecasting crop production world-wide and by agricultural insurance companies.

Because hydrometeorological parameters are measured at certain stations and decisions should be taken in most cases at basin level, spatial integration is required in the case of applications of the methodology for water and agricultural management decisions. Spatial integration at a level of a small basin or sub-basin may be implemented by calculating the weighted mean of the parameters involved. Weight in this approach is the area represented by each station. The spatial extent of drought is estimated based on comparisons of the affected area with a threshold referred to as “critical area”. A promising method with the flexibility to use various area thresholds associated with each severity level of drought is based on plotting the percentage of affected area against each level of severity of drought.

As far as the time step is concerned characterization of drought can be based on an annual time step accompanied by other shorter time steps (e.g. six months, three months) or any other time duration tailored for the specific application. The selection of the time step applied is a crucial element in the analysis as well as the selection of the threshold for each index.

Box 4. Examples of spatial application of the SPI drought index in Sicily, Italy, during a drought year (2002) and a normal year (2005). Maps correspond to the situation in January of each year.

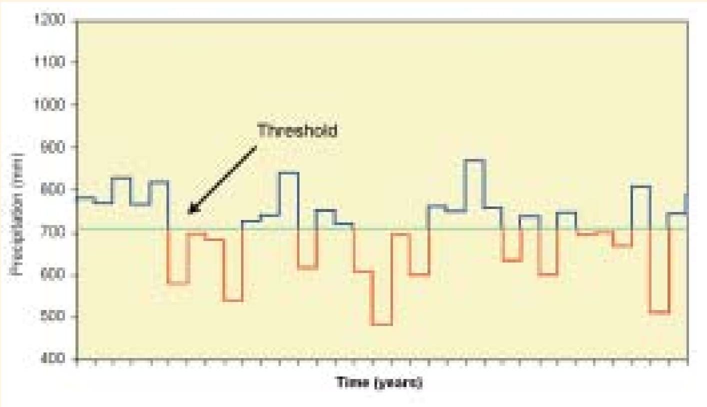


The importance of computing drought probabilities

The objective of the assessment of drought characteristics is to evaluate the severity and duration of droughts that can occur in a given area or region in probabilistic terms. Such an assessment is useful for the analysis of past droughts, and to define "design droughts" of a fixed return period, that assist in the analysis of risk.

Box 5. Statistical properties of drought

Among the different proposed methods for characterizing droughts, the run method has found widespread use, due to the objectivity in the definition of drought. Furthermore, the method allows an analytical derivation of the probability distributions of drought characteristics to be carried out, thus overcoming the limits of an inferential approach due to limited sample lengths. The run method can be applied to a hydrological series of interest, either at yearly or sub-yearly time scales (e.g. precipitation, streamflows, etc.) assuming as a threshold a value representative of the demand level. The method can also be extended to the case of regional droughts, by introducing a threshold representative of the areal extension of deficits.



Drought identification using the theory of runs (drought periods in red colour)

Key issues and conclusions

- Drought indices are not a goal, but a means to identify and analyse droughts.
- Even though computation of indices can be complex, the resulting outputs should be presented in a simple format.
- All indices are sector/system specific.
- Some of the indices include relevant meteorological and hydrological information, but do not consider water uses in the basin.
- A clear criterion to identify droughts is not universal. All indices are sector/system-specific, therefore multiple indices should be used to characterize drought.
- Recent remote sensing-based indices may have a large potential as drought indices, especially where other sources of data are limited.
- Meteorological drought indices may not correlate well with historical drought impacts, due to the effect of storage in regulated systems (e.g., over year storage). On the other hand, drought indices are very useful in rainfed conditions to forecast agricultural production.
- The optimal approach for using indices is to calibrate them with observed impacts, risk level, and vulnerability.

4.3. Evaluation of risk: Overview

Objective

The objective is to provide methods for evaluating the level of risk associated with the potential consequences of drought in different sectors and systems.

Methods

Here we present methodologies that include:

- Qualitative evaluation of potential risk (consultation with stakeholders).
- Quantitative evaluation of probabilities of occurrence or damage.

Expected outcome

- Identification and perception of historical and potential risks.
- Definition of the affected systems and selection of the variables that characterize them in relation to drought.
- Establishing the links of drought indices to risks.
- Quantitative evaluation of the probability associated with the potential damage.
- Establishing the links of drought risk to management actions.

The characterization of risk is complex and depends on the system

Since both hazard and vulnerability are dynamic and region/sector specific, it is desirable that risks are framed in a specific geographical or organizational context. Stakeholders may characterize drought risks at the most disaggregate level possible and then integrate to a level adequate for establishing general conclusions for drought management plans. An example of this is a water supply system including various interconnected reservoirs, from which urban and agricultural users are supplied. Although it is necessary to evaluate the risk for each user, a comprehensive risk for the whole system should be computed.

Drought may affect rainfed agriculture, irrigation, water supply, industrial supply and hydropower, as well as environment. For each of these sectors, the risk of each drought period may be quantified, using one or more variables. For instance, risk on rainfed or irrigated agriculture could be quantified in terms of production losses. In urban water supply, the more readily accessible variable would be the probability of failing to meet the various demands of the system (e.g., drinking water, irrigation of public parks, etc.). But secondary consequences may be, in some cases, of great importance. For example, the reduction in crop yield may result in land abandonment due to reduced crop yields and subsequent loss of farm income.

Qualitative evaluation of potential impacts: consultation with stakeholders

Although the complete definition of drought impacts is rather complicated, the main impacts can be broadly classified into three categories: economic, environmental and social. Each category comprises several impacts, according to the affected sector. In Table 5 a list of main drought impacts is reported.

Similar approaches are proven to be very effective in evaluating the risks of drought in a range of case studies. It is useful to provide as much information as possible about each impact, such as social groups affected, estimated damage, etc. Often different groups have different perceptions of drought damage; such is the case of groups that have contrasting economic or environmental priorities. A useful attribute to drought impact evaluation is the definition of the interest group and the level of agreement within the members of the group.

Table 5. Summary of the main impacts to be considered in each sector (adapted from various sources)

Sector	Impact
ECONOMIC	Decreased production in agriculture, forestry, fisheries, hydroelectric energy, tourism, industry, and financial activities that depend on these sectors Unemployment caused by production decrease Economic damage to reduced navigability of streams, rivers and canals Damage to the tourism sector due to the reduced water availability in water supply and/or water bodies Pressure on financial institutions (more risks in lending, capitals decrease etc.) Income reduction for water firms due to reduced water delivery Costs in emergency measures to improve resources and decrease demands (additional costs for water transport and removal, costs of advertising to reduce water use, etc.)
ENVIRONMENTAL	Decrease water supply and quality of surface water and groundwater Damage to ecosystems and wetlands, biodiversity and diseases (soil erosion, dust, reduced vegetation coverage etc) Increased fires Lack of feed and drinking water Increase of salt concentration (in streams, underground layers, irrigated areas) Loss in natural and artificial lakes (fish, landscapes, etc.) Damages to river and wetlands life (flora, fauna) Damage to air quality (for example polluting dust)
SOCIAL	Damage to public health and safety, by affecting air and water quality or increased fire Increase in social inequality, by affecting different socio-economic groups Tensions between public administrations and affected groups Changes in political perspectives Inconveniences due to water rationing Impacts on way of life (unemployment, reduced saving capability, difficulty in personal care, reuse of water at home, street and car washing prohibition, doubt on future, decrease of celebrations and amusements, loss of property) Inequity in drought impacts and mitigation measures distribution Abandoning of activities and emigration (in extreme cases)

Risk evaluation to quantify probabilities of damage

In the drought risk evaluation it is essential to include a quantitative analysis of the probabilities of damage in different sectors such as municipal water supply, dryland agriculture, irrigated agriculture, industry, and environment. For each sector, the analysis may include more than one variable to enhance the results. For instance, for municipal water supply, the variable of interest may be represented by water shortage, and the analysis should have the objective of probabilistically quantifying such a shortage. In the case of agriculture, especially in rainfed agriculture, the variable of interest is generally represented by yield loss. A range of approaches of probabilistic analysis of drought risk in agriculture and water supply systems is presented in the following sections.

4.4. Evaluation of risk in agriculture

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 8: Methods for drought risk analysis in agriculture

Mediterranean rainfed farming systems

Unfavourable weather conditions are the main source of risk in subsistence farming systems, especially in marginal land and social conditions. In this case, drought has a direct relationship with farmers' income and it is relatively simple to analyse risk by evaluating simple variables, such as crop yield. In contrast, farming systems in economically developed regions, are greatly affected by policy, markets, technology and financial instruments, and it is complex to determine the effect of drought in individual farmers and in the aggregated agricultural sector.

A proposed method

The objective of the method is to measure the rainfed agriculture risk to drought in a way that allows making comparisons between different places with different potential yields. The method integrates both climate (hazard) and agricultural system's characteristics (that explain vulnerability and trends of the systems) through yield functions (yield is taken as impact variable).

The sequential steps to be taken for the quantification of the overall drought risk of agricultural systems are:

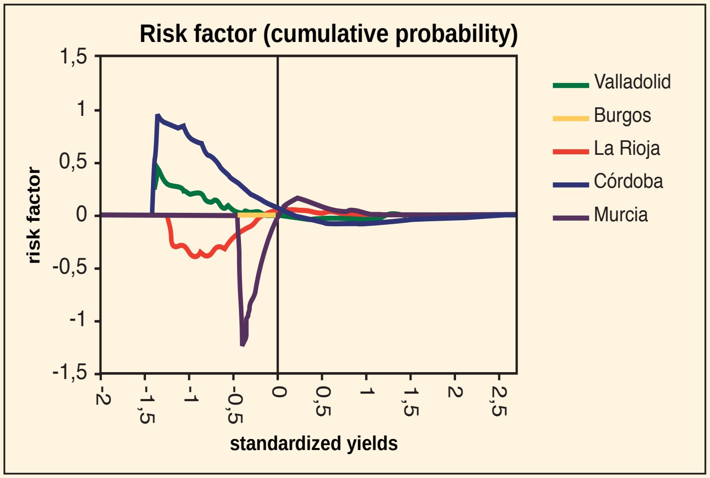
- **Step 1.** Identification of the agricultural system representative of the geographical unit and definition of the basic cost structures and revenues of the farms. For example, subsistence farmers in dryland areas, commercial irrigated farms, among others.

- **Step 2.** Definition of the variables that characterize each agricultural system. For example, crop yield, irrigation water demand, farm income.
- **Step 3.** Definition of theoretical causal relationships between the agricultural variables and drought. An empirical model may be used to find the relations between yield, climate and agriculture characteristics, using available data. A model is defined and calibrated for each region and agricultural system.
- **Step 4.** Statistical analysis of the correlations of drought indices with the selected variables that define the system. This step is essential for the selection and validation of the drought indices as thresholds of the drought risk. The indices that show a larger significant correlation with the impacted variables should be the ones to consider as potential triggers in the management plans. Monte Carlo simulation is a statistical tool that allows large samples of the yield to be obtained through the generation of synthetic data from the yield functions that were obtained in Step 3. With that large size sample, it is possible to analyse the statistical distributions of the yield function in a much finer and more precise manner and to obtain better correlations.
- **Step 5.** Definition and measure of a risk function. This function measures the probability of exceeding or not surpassing a given yield in each region of study.
- **Step 6.** Definition of an aggregated measure of sensitivity of the agricultural system to drought based on the combination of the partial impacts. Aggregation (Step 6) is always a complex task, but a simple aggregated measure may be constructed by normalizing and scaling the representative variables (or proxy variables) with respect to some common baseline.

Box 6. An example of risk evaluation in agricultural systems

Drought risk is evaluated for characteristic Mediterranean rainfed systems following the methodology described above. Models are derived for each location and crop type to estimate crop yield, taking into account the climate, technological, and management variables that describe the farming system. Therefore, this methodology can be applied to other regions. The demand component of the farming system is an essential element of the agricultural risk due to market variations and policy and can also be incorporated in the analysis.

Risk level across geographical areas is determined by applying a risk factor function (RF). The RF for each location is calculated by normalizing cumulative yield distributions functions that are previously derived by Monte Carlo simulations. A reference station is taken as a comparison basis and two yields classes are considered: below the mean and above the mean. For each location, the RF values indicate whether yields in that station are more at risk than in the reference station. In the context of agricultural yield, the areas with highest risk are the ones that have a higher probability of having low yields. Positive RF values when yields are below the mean (lower than 0) indicate that the location has more risk because there is a higher probability of attaining low yields than in the reference station. Positive RF values when yields are above the mean (higher than 0) indicate that the risk is lower because there is a higher probability of reaching yields above average than in the reference scenario.



The graph below illustrates the risk factor distribution in five Spanish locations under rainfed cereal farming systems. Yields are standardized to the average: below zero are lower than average yields and above zero are higher than average yields.

In the graph, the reference station is Burgos, with RF = 0. Cordoba and Valladolid show a higher probability of attaining yields lower than average and therefore risk is higher in these locations (RF › 0 for yields lower than the average). La Rioja shows negative values of RF for yields lower than average and therefore there is a low probability of obtaining low yields. On the other side of the graph, for yields above average, Cordoba shows again a higher level of risk because the probability of attaining high yields is lower than in the reference station (RF ‹ 0 for high yields). Murcia shows an RF close to 0 except for slightly lower than average yields where there is a much lower probability of obtaining these low yields.

4.5. Risk in water supply systems

> This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
> Chapter 9: Methods for assessing shortage risk in water supply systems

Specifying the risk concept in water supply systems

In water supply systems, drought is characterized by a high level of complexity. In general, a set of performance indices is used, attempting to capture different aspects related to concepts such as reliability, resiliency and vulnerability. Indeed, the stochastic nature of inflows, the high interconnection between the different components of the system, the presence in some cases of many conflicting demands, the uncertainty related to the actual impacts of extreme events such as droughts, make the risk assessment of a water supply system a problem that is better faced through a set of several indices and/or by analysing the probabilities of shortages of different entities.

Quantitative evaluation of risk in water supply systems may follow several methodologies as consequences of the various approaches for quantifying probabilities: (1) risk defined as the probability of an adverse event; (2) risk defined as the expected consequence or damage due to an adverse event.

Risk as the probability of an adverse event

The first category includes the concept of risk according to statistical hydrology, defined as the probability that a hydrological variable (e.g., maximum annual discharge) exceeds a given threshold at least once in a given number of years. Assuming stationarity and independence of the events, the risk can be computed.

Similarly, in reliability theory, risk is defined as the probability of failure for the system under investigation. More specifically, risk is defined as the probability that load L (e.g. the external forcing factor) exceeds resistance R (an intrinsic characteristic of the system), leading to a failure.

Risk as the expected damage

The second category (risk as expected consequence) includes the definitions according to natural disasters mitigation. In particular, risk is defined as “the expected losses due to a particular natural phenomenon as a function of natural hazard and vulnerability and element at risk” (See Box 3). In the above definition, the natural hazard represents the probability of occurrence, within a specified period of time and in a given area, of a potentially damaging natural phenomenon, whereas the vulnerability is the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss). It follows that according to the above definition, risk is measured in some physical terms, such as economic (damages), or social (lives lost).

Drought and water shortage

Risk in water supply systems is directly related with water shortage, which differs from drought because it is related to a shortage of water availability to satisfy demands. The shortage results from an imbalance between water supply and demand, which is originated by a meteorological phenomenon, but is also conditioned by other time-varying factors, such as demand development, supply infrastructures and management strategies. The result of the imbalance is water shortage, which is of concern for water managers.

Risk evaluation in water supply systems consists of identifying demands that may not be fully satisfied with available water resources, and quantifying the estimated impacts of water shortage.

It is usually not economically efficient to satisfy all the demands in a system at 100%, because the cost would be too high for too little enhancement (see Box 7 for a concrete example).

> **Box 7. Risk analysis in the water supply company of Madrid (Canal del Isabel II)**
>
> The water supply company for Madrid (Canal de Isabel II, a partner in MEDROPLAN) has an operational drought management plan. The risk level is defined by the probability of imposing a reduction in consumption or decreases in the water demand that can be satisfied with full reliability. The plan considers management criteria of the system that should adjust to each risk level scenario. The design of the plan is to guarantee that only in 4 % of the years could there be a 9 % reduction of water availability.

Defining the acceptable risk level

The acceptable risk level is conditioned by available water resources and infrastructures and depends on demand characteristics and their elasticity. In this context, the risk analysis should consider the following aspects:

- Probability of failure occurrence (probability of not satisfying the demand)

- Severity of failures (magnitude of the deficit)
- Failure duration (time span when deficits occur)
- Economic impact of failures

These factors also determine the operational rules for system management during droughts. In regulated systems, reliability and water supply capacity are linked by operational rules and risk management strategies. At the river basin or water catchment level, there are inter-dependent risk management units that implement different risk management plans. Reliabilities are defined depending on location of the risk management unit (e.g., up or downstream). Upstream units also need to consider the risk of down-stream units.

The relevant indicators that define the previous aspects of risk management are:

- Water demand / Average inflows. Provides information about the degree of development of water resources in the system. Ratios close to 1 mean frequent system failures, depending on inter-annual or seasonal variability of hydrologic series.
- Water demand / Reservoir capacity. This provides information about the quantity that the system is able to supply.
- Reservoir capacity / Average inflows. This provides information on the capacity of the system to overcome inflow irregularities (droughts).
- Annual water demand / Current reservoir storage. This represents the expected time to failure, in years, if future inflows are neglected. The variable provides information on the margin of operation of the system.

Models for water management

The distribution of resources among multiple demands in water supply systems in a drought period is a challenging task requiring careful planning. The operational rules of the system are related to resource-sharing criteria, priorities among users, utilization of complementary resources and strategic reserves, among others. In large systems, mathematical simulation and optimization models should be used to obtain quantitative results accounting for all system complexities in an uncertain context. These models provide guidance in identifying critical demands, evaluating the effect of capacity building or water conservation measures, and scheduling available actions within given constraints. All models provide a measure of demand reliability, quantified as the probability that a given demand may suffer water shortages during a given drought.

However, the availability of well-calibrated operational models is doubtful in some areas since they require a large investment in information, to evaluate resources, characterize demands, identify optimal management criteria, etc, which may not be readily available in all regions. If these models are available, they should be used in risk analysis, using indicators derived from model results to evaluate relative risks. If they are not, it can be assumed that the system is not very complex, and risk analysis can be carried out with simpler indicators.

Methods for assessment of water shortage risk: in normal conditions and during a drought event

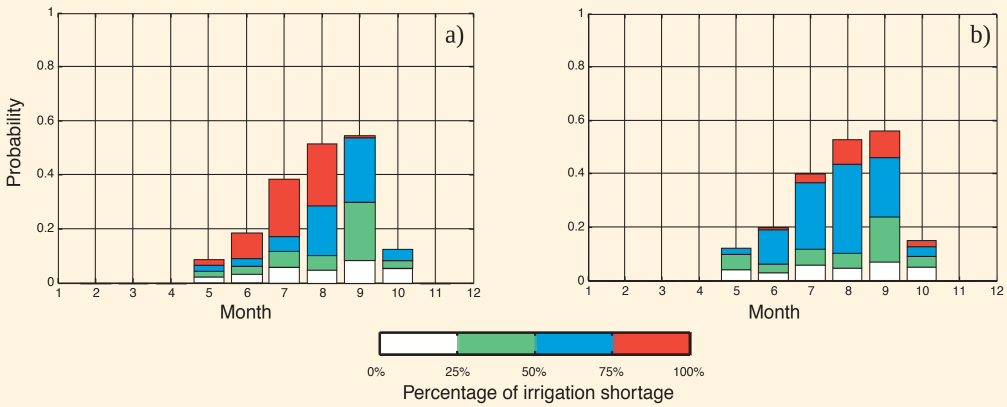
Risk evaluation can find application either at the planning stage or during the operation of a given system. For instance, with reference to water supply system planning, risk assessment enables the risk associated with different planning alternatives to be quantified and compared, generally on a long term basis. On the other hand, during the operation of the system, short-term drought risk assessment can be carried out in order to compare and define alternative

Box 8. Example of the result of risk analysis in a water supply system (Salso-Simeto water supply system, Italy), focusing on the irrigation shortage.

Here the risk is defined as the probability that the monthly shortage lies in one of the four classes of shortage expressed as percentage (< 25%, 25-50%, 50-75%, > 75%) of the whole water demand of crops (irrigation shortage). Irrigation shortage is a good proxy variable of potential economic losses and its probability has to be considered in agricultural management in order to face drought events.

The analysis carried out makes use of the Monte Carlo simulation of the system. In particular, a stochastic model of the streamflows in the system is used together with a simulation model that takes into account the water demands and the current operating rules of the system to obtain the probabilities of different levels of shortage throughout the year.

As an example, the two graphs show the probabilities of the different levels of irrigation shortage (a) if no mitigation measures are taken or (b) if measures are taken. From the plots, a significant reduction of severe shortages can be inferred if mitigation measures are taken, which is indicative of a decrease of drought risk for irrigation.



For more details, consult the Italian example of application of the Guidelines and Chapters 9 and 18 of the Medroplan Technical Annexes.

mitigation measures, on the basis of the consequent risk during a short time horizon (from a few months to 2-3 years in the future). The two approaches differ, not only with regard to the objective of the analysis and to the different lengths of the time horizons, but mostly because of the way the probabilistic assessment is carried out.

In the first case the assessment is generally unconditional, e.g. not referred to a particular state or condition of the system but its general operational rules. This assessment provides information on what could happen at any time during the planning horizon. Different supply and demand scenarios are developed in order to evaluate the response of the system and select the operational rules that ensure a certain level of demand satisfaction in normal conditions.

The short-term risk assessment, on the other hand, is generally conditional, in the sense that in the evaluation, the initial state/conditions of the system are taken into account. Furthermore, the assessment is generally oriented to estimate what could happen at a specific time in the immediate future. For instance, with reference to a water use, one may be interested in the probability of occurrence of a given deficit three months ahead, given the present state of the system (e.g. volumes stored in reservoirs). As such, the conditional assessment is generally adopted for early warning purposes. Since the results of the conditional risk assessment strongly depend on the initial conditions, it follows that the procedure must be repeated as new information becomes available. In this case there is a fixed initial state of the system and the aim is to evaluate the influence that drought mitigation methods can have on the functioning of the system in order to avoid water supply deficits. Chapter 9 of the Technical Annexes of the Guidelines develop the unconditional and the conditional cases of assessment in detail.

4.6. Vulnerability evaluation

> This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
> Chapter 10: Methods for evaluating social vulnerability

Objective

The objective of the vulnerability assessment is to identify characteristics of the systems that modify the level of risk derived from inadequate structures, management, and technology, or by economic, environmental, and social factors.

Methods

The assessment includes two components that define the causes of risk derived from: (1) direct exposure to drought (e.g., location and other natural factors); and (2) social and economic aspects.

For example, given a specific farm, the vulnerability is directly related to the intensity of the drought event. In contrast, given a defined drought event, the most vulnerable farming system is the one that has less social and economic resilience; in general marginal and poor farming systems suffer the greatest consequences of drought.

Expected outcome

The expected outcome is to identify the aspects of each system that make it more sensitive to the potential damage of drought. The vulnerability assessment bridges the gap between impact assessment and policy formulation by directing policy attention to underlying causes of vulnerability rather than to its result, the negative impacts, which follow triggering events such as drought. The vulnerability evaluation helps define the sensitivity of the systems to external shock and identify the most relevant aspects that decrease the level of risk.

An index to evaluate socio-economic vulnerability

An example of the components of socio-economic vulnerability and the representative variables that can be used to characterize it is provided in Table 6. A final indicator for each category of exposure may be computed as the weighted average of all the representative variables within the category.

Table 6. Components of socio-economic vulnerability and representative variables that can be used to characterize the vulnerable groups

Components	Proxy variables
Natural component	Agricultural water use (%) Total water use (% of renewable) Average precipitation (mm/year) Area salinized by irrigation (ha) Irrigated area (% of cropland) Population density
Economic capacity	GDP millions US$ GDP per capita US$ Agricultural value added/GDP % Energy use (kg oil equivalent per capita) Population below poverty line (% population with less that 1 US$/day)
Human and civic resources	Agricultural employment (% of total) Adult literacy rate (% of total) Life expectancy at birth (years) Population without access to improved water (% of total)
Agricultural innovation	Fertilizer consumption (kg/ha of arable land) Agricultural machinery (tractors per 100 km^2 of arable land)

The sequential steps taken for the quantification of the vulnerability index are: (1) Select proxy variables for factors that contribute to the vulnerability. (2) Normalize the proxy variables with respect to a common baseline. (3) Combine the sub-component proxy variables within each vulnerability category by weighted averages. (4) Quantify vulnerability as the weighted sum of the components. These four steps are applied to the normal conditions and to the conditions during a drought event.

Table 6 shows the components of the vulnerability index and proxy variables proposed for evaluating vulnerability of agricultural systems to drought. The variables included were selected because: (1) data is readily available and an example may be computed to assist stakeholders in defining the sensitivity of the system; and (2) the variables are drought-scenario dependent and geographically explicit. The vulnerability index may be used to understand the sensitivity of the system and to assist in the selection of measures to be adopted. For example, improving the efficiency of agricultural water use, decreasing population under the poverty line, increasing adult literacy rates, and increasing agricultural technology, are measures that result in an overall decrease in vulnerability.

5. Operational component

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 12: Implementation of drought management actions
Chapter 13: Description of drought management actions

5.1. Overview

The operational component identifies both the long and short term activities and actions that can be implemented to prevent and mitigate drought impacts. Such activities and actions are essential in the development of specific drought planning and response efforts.

The operational component includes six aspects that need continuous feedback between them (Figure 7):

- Preparedness, early warning, monitoring systems
- Establishing priorities of water use
- Defining the conditions and the thresholds to declare drought levels
- Establishing the management objectives in each drought level
- Defining the actions
- Implementing actions

Monitoring and preparedness planning is the first essential step for moving from crisis to risk management in response to drought, and can be viewed as permanent measures to cope with drought events. The management actions related to agriculture and water supply systems are presented with a common conceptual framework based on the use of drought indices for evaluating the levels of drought risk (pre-alert, alert, and emergency), that allow links to be established between science (risk analysis) and policy (operational component).

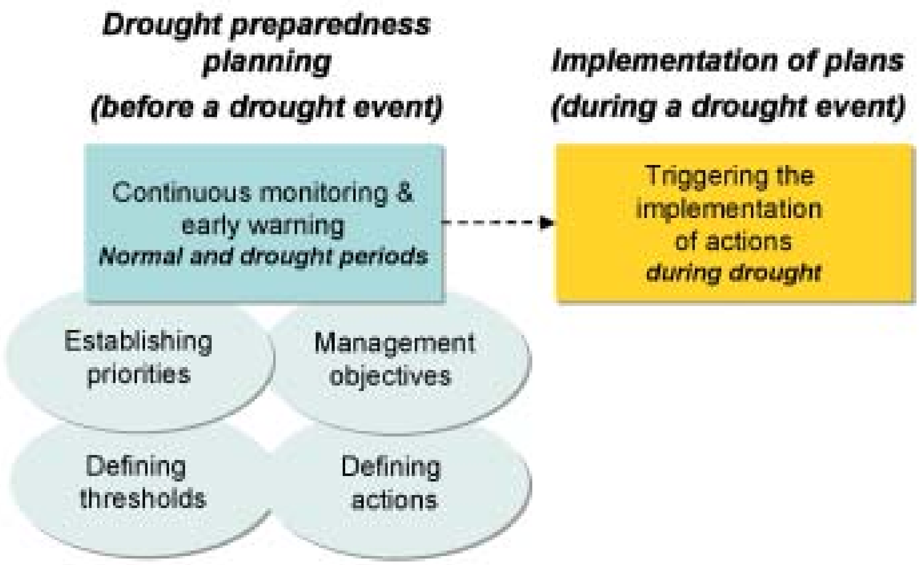


Figure 7. Summary of the aspects of the preparedness and implementation aspects of the operational component

5.2. Preparedness, early warning, monitoring systems

Planning in advance is essential

Preparedness and early warning are the key factors for later operational management and determine the success of the overall drought management plan since they help to:

- Establish the drought plan
- Reduce social vulnerability
- Identify alert mechanisms
- Establish the links between drought and water and development policies

Scientific advances in seasonal to inter-annual climate forecast and monitoring systems offer the possibility for making the early warning systems effective in many regions, especially where the data and information systems are in place.

Why a monitoring system?

The effective response to drought events relies on having a monitoring system able to provide adequate and timely information for an objective drought declaration and for avoiding severe water shortages through effective water resource management under drought conditions.

The main objective of a monitoring system is to help decision-makers identify the drought warning conditions and to provide useful information for identifying the best drought mitigation measures on the basis of a continuous monitoring of the drought evolution in terms of meteorological and hydrological variables and water resource availability.

A common feature of these systems is the particular emphasis generally given to the graphical representation of the results in order to foster an immediate and easy assessment of the drought severity and its evolution. Access to information is ensured through public web sites aiming to reach as many users as possible in addition to the public institutions.

In order to obtain an effective decision support for the measures to be taken to reduce drought vulnerability and mitigate drought impacts, the monitoring system must include information on the meteorological and hydrologic conditions, as well as on the water supply systems conditions.

Box 9. Some examples of drought monitoring systems

Drought monitoring systems in operation are increasing, as their importance becomes essential and recognized at the institutional level. In recent years the information technology that simplifies the collection, elaboration and dissemination of hydrometeorological and agricultural data is widespread. In the United States, the National Drought Mitigation Center has been used by policy makers to develop drought management plans. In Australia, the Bureau of Meteorology also provides a forecasting product. In Europe, the Global Drought Monitoring of the database from the European Centre for Medium-Range Weather Forecasts (United Kingdom) provides a global monitoring product. In Spain, the Ebro River Basin Authority has initiated a monitoring system to characterize meteorological and hydrological drought.

5.3. Establishing priorities for water use

Planning for droughts tends not to receive priority attention of decision and policy makers because drought has diverse impacts. The slow initiation and undefined end of a drought makes it difficult to select the opportunity to take defensive or remedial action. The measures are generally organized to protect water uses with different levels of priority.

- First priority: Ensure that adequate supplies of domestic water are available for public health, safety and welfare.
- Second priority: Minimize adverse drought effects on the economy, environment, and social well-being.

5.4. Defining the conditions to declare drought levels

Key issue: Drought declaration

The formal declaration of drought is both a controversial and an important issue. Most public institutions approach formal declaration with caution, and is only taken when a water shortage situation is of extreme magnitude, therefore in many cases, only emergency actions are possible. The Guidelines address this key issue by linking technical indicators of pre-alert, alert, and emergency to manage actions.

Pre-alert

The pre-alert scenario is declared when monitoring shows the initial stage of drought development, which corresponds to moderate risk (e.g. greater than 10%) of consuming all water stored in the system and not being able to meet water demands. In agricultural systems this level may be determined when a certain indicator, such as a rainfall drought index or a vegetation variable that show high correlation with crop yields reaches a predefined threshold.

Alert

The alert scenario is declared when monitoring shows that drought is occurring and will probably have impacts in the future if measures are not taken immediately. There is a significant probability (e.g. greater than 30%) of water deficits in a certain time horizon.

Emergency

The emergency scenario is declared when drought indices show that impacts have occurred and supply is not guaranteed if drought persists.

5.5. Establishing the management objectives at each drought level

Pre-alert

The management objective in the pre-alert scenario is to prepare for the possibility of a drought. This means to ensure public acceptance of measures to be taken if drought intensity increases by raising awareness of the possibility of societal impacts due to drought. The measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily by stakeholders and are usually low-cost. The goal is to prepare users for future actions. Regarding the water management body, main actions are intensification of monitoring, usually through the creation or activation of drought committees, and evaluation of future scenarios, with special attention to worst case scenarios. Regarding the stakeholders, the focus is on communication and awareness. Generally, non-structural measures are taken, aimed to reduce water demand with the purpose of avoiding alert or emergency situations.

Alert

The management objective in the alert situation is to overcome the drought by avoiding the emergency situation through the application of water conservation policies and mobilization of additional water supplies. These measures should guarantee water supply at least during the time span necessary to activate and implement emergency measures. The kind of measures that are taken in the alert situation are generally of a direct nature, are coercive to stakeholders and are generally of low to medium implementation cost, although they may have significant impacts on stakeholders' economies. Most measures are non-structural, and directed to specific water use groups. Demand management measures include partial restrictions for water uses that do not affect drinking water, or water exchange between uses. This may be a potential source of conflict because water users' rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses.

Emergency

The management objective is to mitigate impacts and minimize damage. The priority is satisfying the minimum requirements for drinking water. Other uses of water are a second priority at this level of drought. Measures adopted in emergency are of high economic and social cost, and they should be direct and restrictive. Usually there has to be some special legal coverage for exceptional measures, which are approved as general interest actions under drought emergency conditions. The nature of the exceptional measures could be non-structural, such as water restrictions for all users (including urban demand), subsidies and low-interest loans, or structural, like new infrastructure, permission for new groundwater abstraction points and water transfers.

Figures 8 and 9 synthesize the threshold levels, the objectives of the actions to be taken and the action groups in each threshold category.

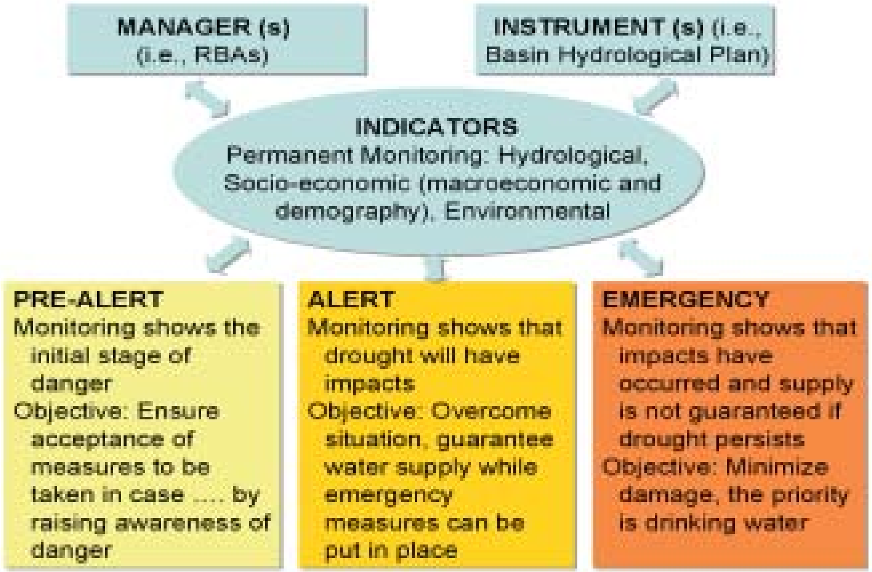


Figure 8. Threshold levels and objectives of the actions to be taken

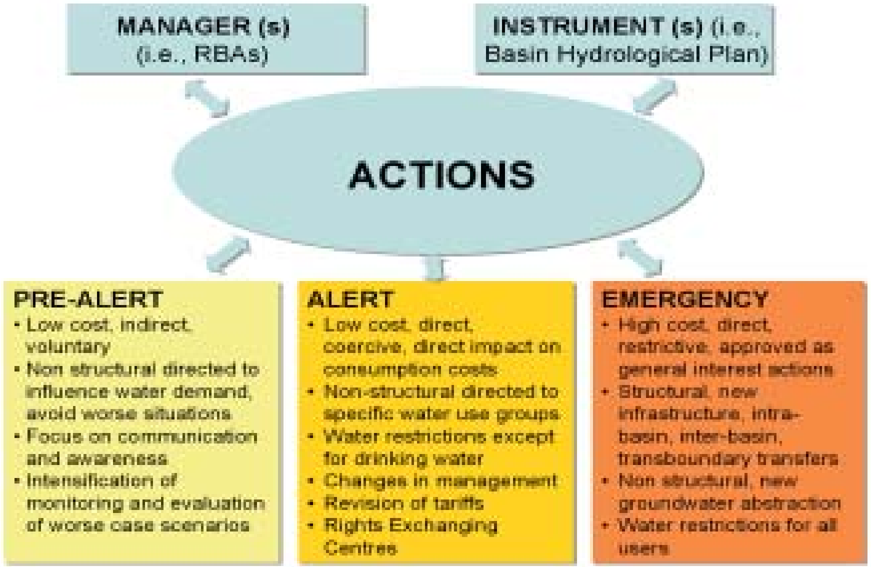


Figure 9. Threshold levels and groups of actions to be taken

5.6. Defining the actions

The actions are defined in two steps: description and ranking.

Description

- A precise and quantified description of the action
- Organizational unit responsible for the action
- Timeframe of implementation
- Comments on the application to other areas

Ranking

The general objective of every operational action is to minimize impacts of drought and water scarcity while maintaining social and ecological services of water. However, not all actions are suitable and applicable in every situation and moment. The ranking of actions allows for a certain level of prioritization depending on the evaluation of selected aspects, such as:

- Consideration of effectiveness to minimize the risk of impacts, cost, feasibility, and assistance required for adoption

- Consideration of adequacy for situation without drought (win-win strategy)
- Each action is ranked and defined from different points and valuation criteria that include the full range of stakeholders defined in the organizational component.

Table 7 gives an example for ranking and valuating the actions.

Table 7. Valuation of attributes of each action

Value	A Effectiveness	B Cost	C Feasibility	D Assistance required for adoption	E Adequacy for non drought situation
0	none	none	non feasible	none	highly inadequate
1	very low	very low	very low	very low	inadequate
2	low	low	low	low	somewhat inadequate
3	medium	medium	medium	medium	indifferent
4	high	high	high	high	adequate
5	very effective	very high	very high	very high	very adequate

Proactive and reactive approaches / short and long term actions

A second classification focuses on the type of response to drought events, distinguishing between a reactive and a proactive approach. Measures that are taken before the initiation of a drought event aim to reduce the vulnerability to drought or improve drought preparedness. They are long-term measures oriented to increase the reliability of water supply systems to meet future demands under drought conditions through a set of appropriate structural and institutional measures. The measures taken after the start of a drought are short-term measures which attempt to mitigate the impacts of the particular drought event within the existing framework of infrastructures and management policies, on the basis of a plan developed in advance and adapted to the ongoing drought, if necessary.

In order to incorporate the actions to drought management plans it may be useful to determine the proactive or reactive, as well as the public or private character of the measures (see Box 10 as an example). Table 8 extends the example and lists a range of long-term and short-term actions, subdivided into the three categories of water supply increase, water demand reduction and drought impact minimization. For each action the affected sectors are also indicated.

Criteria for selecting the actions

Drafting drought management plans requires the selection of the most appropriate combination of long term and short term actions with reference to the vulnerability of the specific water supply system or agricultural system and to the drought severity. Given the high number and the different types of mitigation measures, it is necessary to adopt a proper evaluation procedure for the choice of the best combination. A selection procedure based on purely economic criteria could include equating the marginal costs of long term measures with the marginal costs of implementing short term measures. A more advanced procedure could be based on assessing the expected cost of each combination of long and short term measures using the Monte Carlo simulation. However, due to the variety of drought impacts and in particular to the difficulty of assessing environmental and social impacts in economic terms, a purely economic analysis does not seem adequate to simulate the real decisional process. On the other hand, application of a multicriteria analysis may overcome the above difficulties because of its ability to take into account the points of view of different stakeholders on the different alternatives.

Box 10. Examples of long term and short term private and public measures to reduce drought risk

	Public (1)	Private (2)	Mixed
Long term measures (3)	Insurance plan for agriculture	Education programmes by NGOs	Education programmes under private initiatives with Government funds
Short term measures (4)	Tax abatement to farmers impacted by drought	Water use reduction in households	Issue emergency permits for water use by a private company that manages urban water and/or River Basin Authority

(1) Public. When it is initiated and implemented by governments or administrative bodies at all levels. Measures are the result of a deliberate policy decision, based on awareness of risk. Measures that address collective needs.

(2) Private. When it is initiated and implemented by individuals, households, private companies, or non-governmental organizations. It is in the actor's rational self-interest.

(3) Long term. Measures established before impacts of drought are observed (anticipatory) to lower the risk of damage. Addresses preparedness and risk reduction.

(4) Short term. Measures that take place after impacts of drought have been observed. Addresses crisis management.

Table 8. Long and short term drought mitigation measures

Category	Type of actions	Affected sectors			
	Long-term actions				
Demand reduction	Economic incentives for water saving	U	A	I	R/E
	Agronomic techniques for reducing water consumption		A		
	Dry crops in place of irrigated crops		A		
	Dual distribution network for urban use	U			
	Water recycling in industries			I	
Water supply increase	Conveyance networks for bi-directional exchanges	U	A	I	
	Reuse of treated wastewater		A	I	R
	Inter-basin and within-basin water transfers	U	A	I	R
	Construction of new reservoirs or increase of storage volume of existing reservoirs	U	A	I	
	Construction of farm ponds		A		
	Desalination of brackish or saline waters	U	A		R
	Control of seepage and evaporation losses	U	A	I	
Impacts minimization	Education activities for improving drought preparedness and/or permanent water saving	U	A	I	
	Reallocation of water resources based on water quality requirements	U	A	I	R
	Development of early warning systems	U	A	I	R
	Implementation of a Drought Management Plan	U	A	I	R
	Insurance programmes		A	I	
	Short-term actions				
Demand reduction	Public information campaign for water saving	U	A	I	R
	Restriction in some urban water uses (e.g. car washing, gardening, etc.)	U			
	Restriction of irrigation of annual crops		A		
	Pricing	U	A	I	R
	Mandatory rationing	U	A	I	R
Water supply increase	Improvement of existing water systems efficiency (leak detection programmes, new operating rules, etc.)	U	A	I	
	Use of additional sources of low quality or high exploitation cost	U	A	I	R
	Over-exploitation of aquifers or use of groundwater reserves	U	A	I	
	Increased diversion by relaxing ecological or recreational use constraints	U	A	I	R
Impacts minimization	Temporary reallocation of water resources	U	A	I	R
	Public aids to compensate income losses	U	A	I	
	Tax reduction or delay of payment deadline	U	A	I	
	Public aids for crops insurance		A		

U = urban; A = agricultural; I = industrial; R = recreational

5.7. Evaluating the process to implement the actions

A key point for efficient drought prevention and mitigation is represented by the way of selecting and implementing different interventions on the basis of the priority of water allocation among the various uses, the indications provided by drought monitoring systems and the method adopted to assess drought risk. The choice of drought management interventions has to consider two different priorities: the first is to ensure adequate supplies of domestic water available for public health, safety and welfare; the second is to minimize the negative effects of drought on the economy, the environment and the social well-being.

In Figure 10 there is a general presentation of the sequential steps for implementing drought management actions. In the figure, it is to be noticed that drought planning should be done during normal conditions, before a drought takes place.

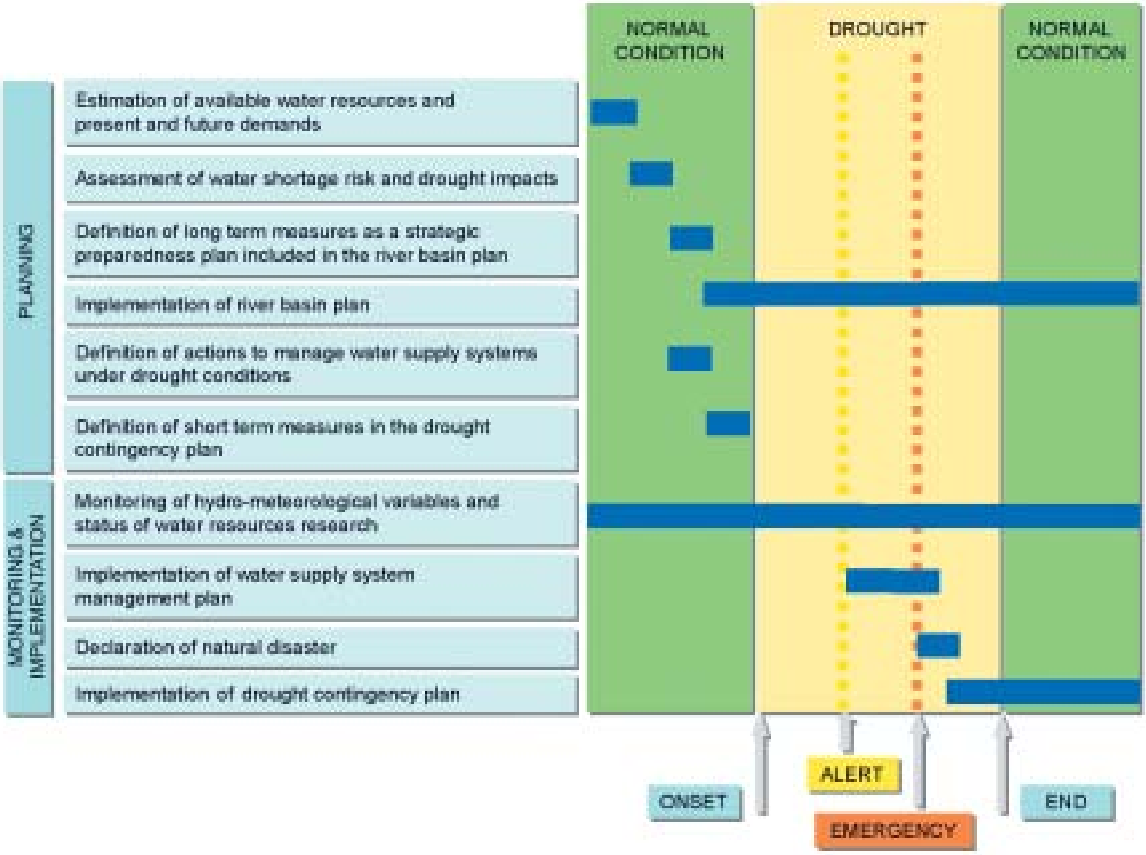


Figure 10. Sequential steps for implementing drought management actions

The possibility to implement the actions in each case is determined by the legislative and institutional framework. An example is given in Figure 11.

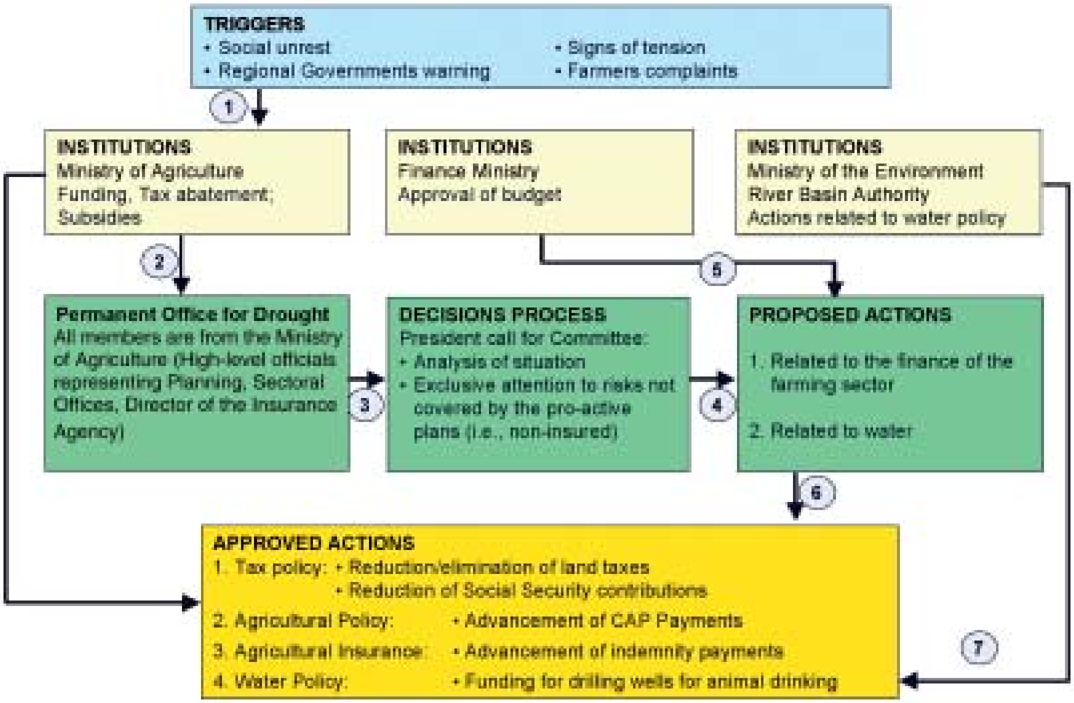


Figure 11. Example of action implementation process

6. Public review component

Public review must play an important role throughout the plan development process since the social and environmental conditions may change and aspects of risk analysis and management improve and evolve. Once the plan is developed, it may be necessary to revise periodically certain aspects or the totality of the plan. In European countries, the information and public participation in the development and the revision of drought management plans shoud be achieved according to article 14 of the European Water Framework Directive (2000/60).

In all cases public revision is complex, but in most cases two aspects are included: dissemination of the information to be revised and multi-stakeholder dialogue to revise the information. The feedback from stakeholders may be collected by means of the responses to questionnaires, group interviews, or other methods to obtain information. The interviews may be public in order to enhance the participation and discussions among all stakeholder groups. The MEDROPLAN Guidelines were reviewed and tested through a multi-stakeholder dialogue process that is described in Chapter 14 of the Technical Annexes.

A periodic revision of the plan by institutions and stakeholders is strongly advisable, as situations change and plans should be adapted accordingly. Moreover, it is obvious that an in-depth revision of a drought management plan should be made after each drought episode, analysing the response of all the aspects of the plan, from the ability of prediction and warning provided by the methodological component to the effectiveness yielded by the operational component. This analysis would provide elements to adapt and improve the plan, in a continuous feedback process that keeps it updated.

Annex 1. Glossary of terms and concepts

Drought and water scarcity

Drought: Concept

Drought is a recurrent feature of climate that is characterized by temporary water shortages relative to normal supply, over an extended period of time – a season, a year, or several years. The term is relative, since droughts differ in extent, duration, and intensity.

Drought: Typologies

Operational definitions define the onset, severity and the end of a drought and refer to the sector, system, or social group impacted by drought. In all cases, drought impacts occur when water supply systems cannot satisfy the needs and demands that are met under normal conditions. The main operational definitions are meteorological, hydrological, and agricultural drought.

Meteorological. Meteorological drought specifies the degree of deficient precipitation from the threshold indicating normal conditions (e.g. average) over a period of time, and the duration of the period with decreased precipitation. Definitions of meteorological drought are region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. In addition to lower than normal precipitation, meteorological drought may also imply higher temperatures, high speed winds, low relative humidity, increased evapotranspiration, less cloud cover and greater sunshine resulting in reduced infiltration, less runoff, reduced deep percolation and reduced groundwater recharge. In many cases the primary indicator of water availability is precipitation.

Agricultural. Agricultural drought for rainfed agriculture: deficit in soil moisture following a meteorological drought that produces negative impacts on crop production and/or natural vegetation growth. Agricultural drought for irrigated agriculture: water shortage in irrigation districts due to drought in surface or groundwater resources supplying agricultural use.

Hydrological. Hydrological drought is concerned with the consequences of rainfall deficiency in the hydrologic system. It refers to the decline in surface and subsurface water supply. Hydrological droughts are usually out of phase with or lag behind the occurrence of meteorological and agricultural droughts (see above) because it takes longer for precipitation deficiencies to show up in components of the hydrological system. It can be measured as a threshold level of stream flow, lake, and groundwater levels.

Water Shortage

Water shortage refers to the relative shortage of water in a water supply system that may lead to restrictions on consumption. Shortage is the extent to which demand exceeds the available resources and can be caused either by drought or by human actions such as population growth, water misuse and inequitable access to water. At the national level water shortage is expressed as m^3 per capita per year. The greater the figure the greater is the shortage. Most of the Mediterranean countries are facing water shortages.

Scarcity

Scarcity refers to a permanent situation of shortage with reference to the water demands in a water supply system or in a large region, characterized by an arid climate and/or a fast growth of water consumptive demands.

Hydrological Drought and Land Use

It is defined as the land use change effect on the hydrological cycle. Land use changes may cause water shortage even when no change in precipitation occurs.

Aridity

Permanent climatic condition with very low annual or seasonal precipitation

Weather and climate

Weather

Weather is the state of the atmosphere for a brief period of time in a particular geographical place.

Climate

Climate represents the normal or average state of the atmosphere for a given time of year and a given location.

Water supply and demand

Natural water resources

The total water resources that flow in fixed rivers and or aquifers for a time interval (generally a year) as average amount or value of a defined probability.

Water Supply

Supply is the aggregate of all water resources that are likely to be used. It includes precipitation, natural resources including groundwater, and non-conventional sources. For a hydrological system, supply takes into account the distribution system, the dimensions and capacity of the infrastructures, the usage rights, and other conditioning factors that should be taken into account.

Water supply system

Facilities for derivation and storage, conveyance, distribution of water and demand centres of use as municipalities, irrigation district, etc.

Available water resources

Available resources are usually the fraction of natural water resources that can be supplied where and when they are required. They are affected by hydrographic, geological, geographical and /or technological constraints (e.g. capacity of abstraction, storage and transport of water), socio-economic considerations, and they have complex institutional implications. They can change in time due to change in natural availability, new ecological constraints and new technological tools.

Renewable water resources

Renewable water resources are the long term average of freshwater volume supplied naturally by the hydrological cycle, derived from the total runoff (surface and underground). Renewable water resources generally refer to the river basin unit. When the geographic unit is different from the basin unit, it is necessary to differentiate between internal resources over the territory, and external or trans-boundary resources outside the territory.

Guarantee of water supply

Guarantee of water supply is the acceptable level of water supply required for a particular supply system. In most countries and systems this value is defined by administrative normatives or recommended by voluntary standards.

Water consumption

Water consumption is the portion of the withdrawals (water supplied) that is not returned to the environment after use, it is either consumed by activities or discharged into the sea or evaporated.

Water demand

Water demand is the actual need for water under current water use practices (i.e. irrigation techniques, efficiency of the system, water pricing policies, present cultural practices, standard of living, etc.). It is determined by the needs of users' activities.

Consumptive demand

Demand of water that is not returned to the environment after use, being either consumed by the activities or discharged to the sea or evaporated. It includes part of urban demand, irrigation, and industrial water demands.

Non-consumptive demand

Demand for water that is returned to the environment without significant alteration to its quality. It includes hydroelectric generation, cooling systems, aquaculture, domestic effluents, irrigation return and environmental flows. Non-consumptive water demand strongly conditions and limits the supply of the consumptive uses, because it needs to be available – in time and space – and with the appropriate quality.

Environmental demand

Environmental demand is the water necessary – in quantity and quality – to support the ecological functioning of ecosystems including their processes and biodiversity. Under some legal frameworks, in-streamflow requirements may impose constraints on other off-stream demands.

Future water demand

Future demand of water based upon future scenarios of water management policies, and influenced by demographic, socio-economic and cultural changes.

Water efficiency

Water efficiency is the percentage of water that is actually used out of the total abstracted volume.

Hydrological systems

Some general terms referring to hydrologic system and water resources extracted from the EC Framework Directive 2000/60.

Hydrographic district

The area of land and sea, made up of one or more neighbouring river basins together with their associated groundwater and coastal water, which is identified under Article 3(1) as the main unit for management of river basins.

Hydrographic basin

The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.

Sub-basin

The area of land from which all surface run-off flows through a series of streams, rivers and, possibly, lakes to a particular point in a water course (normally a lake or a river confluence).

Body of surface water

A discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

Aquifer

A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.

Body of groundwater

A distinct volume of groundwater within an aquifer or aquifers.

Water services

All services which provide, for households, public institutions or any economic activity:

(a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater,

(b) waste-water collection and treatment facilities which subsequently discharge into surface water.

Catchment or basin

Catchment or basin is the area of land drained by a river and its tributaries.

Runoff

Runoff is the portion of rainfall that is not immediately absorbed into the soil and which becomes surface flow.

Flow or discharge

Flow is the amount of water that passes a specified point in a hydraulic system (i.e. river).

Base flow

Base flow is the flow in rivers and streams that occurs in dry weather and usually from groundwater inflows.

Flow regime

Flow regime is the pattern of water flow in a river or stream. In undeveloped rivers and streams flow regimes are related to climatic conditions. In regulated rivers (i.e. dammed rivers), flow regimes are often altered from natural patterns.

Groundwater

Groundwater is the water that occurs beneath the ground held in or moving through saturated layers of soil, sediment or rock.

Recharge

Recharge is the portion of rainfall or river flow that percolates down through the soil and rock formations to reach the groundwater.

Risk, impacts, vulnerability and preparedness

Vulnerability

A set of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards.

Vulnerability Assessment

This provides the framework for identifying or predicting the underlying causes of drought related impacts. In many cases drought may only be one factor along with other adverse social, economic and environmental conditions that create vulnerability.

Hazard

A potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Each hazard is characterized by its location, intensity, frequency and probability.

Risk

The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Risk Analysis

A process to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

Uncertainty

Uncertainty is the situation when the probability of occurrence and potential impacts of a damaging phenomenon are not known.

Disaster

A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Capacity to face with risk

Capacity is a combination of all the strengths and resources available within a community or organization that can reduce the level of risk, or the effects of a disaster.

Preparedness

Preparedness is the reduction of risk and uncertainty. Preparedness therefore refers to the activities and measures taken in advance to ensure effective response to a potential impact of hazards.

Prevention

Prevention is the reduction of risk and the effects of uncertainty. Prevention therefore refers to the activities that provide outright avoidance of the adverse impacts of hazards.

Mitigation

Mitigation is the set of structural and non-structural measures undertaken to limit the adverse impact of hazards.

Strategic reserves

Strategic reserves are those of restricted access, only to be made use of for the resolution of shortage or drought scenarios or for the prevention of similar situations in the near future.

Forecast

Forecast is the statistical estimate or the definite statement of the occurrence of a future event.

Early warning

Early warning is the provision of timely and effective information, through identified institutions, that allows individuals at risk of a disaster, to take action to avoid or reduce their risk and prepare for effective response.

Crisis management

Crisis management is the unplanned reactive approach that implies tactical measures to be implemented in order to meet problems after a disaster has started.

Proactive management

Proactive management are the strategic measures, actions planned in advance, which involve modification of infrastructures, and / or existing laws and institutional agreements.

Drought Impact

A specific effect of drought on the economy, on the social life or on the environment, which is a symptom of vulnerability.

Drought Impact Assessment

This is the process of assessing the magnitude and distribution of the effects due to drought.

Organizations, institutions, networks, and stakeholders

Organizations

A group of persons formally joined together for some common interest.

Institutions

A public organization with a particular purpose or function in relation to law, policy, and administration and that establishes rules for its operation.

Networks

Network is a group that interacts or engages in informal communication for mutual assistance or support.

Stakeholders

Stakeholders are those actors who are directly or indirectly affected by an issue and who could affect the outcome of a decision-making process regarding that issue or are affected by it.

In MEDROPLAN, stakeholders can be individuals, organizations, institutions, decision-makers, or policy-makers, who determine or are affected by water use and exposure to drought and water scarcity.

On the one hand, stakeholders enact institutions - sets of rules, norms, shared strategies - and, on the other hand, they are constrained by them in their responses to drought preparedness and management. Therefore a purposeful description of the map of legitimate actors, as well as an analysis of their interests, values and approaches to risk is a pre-requisite for the understanding of their link with institutional drought policy.

Data, indicators and indices

Data

Individual measurements; facts, figures, pieces of information, statistics, either historical or derived by calculation, experimentation, surveys, etc.; evidence from which conclusions can be inferred.

Proxy data

Data used to study a situation, phenomenon or condition for which no direct information such as instrumental measurements is available.

Indicator

Observed value representative of a phenomenon to be studied (social, economic or environmental). In general, indicators quantify information by aggregating different and multiple data. The resulting information (about complex phenomena) is therefore synthesized and simplified.

Index

A weighted combination of two or more indicators. An index is designed to be a summary of a system. For example, an "environmental index" may include data about air quality, water quality, soil quality, etc. Another example are economic indicators which are used to forecast economic activity, such as GDP growth rate. An index can be used to lead to a particular fact or conclusion.

Correlation

The extent to which two variables vary together (either in a positive or negative relationship). A positive correlation exists when one variable increases as the other increases. A negative correlation exists when one variable decreases as the other increases. A fundamental principle of statistics is that correlation does not necessarily imply causation. This is easy to forget in the quest to understand relationships between different indicators. In the case of drought for example, a positive correlation may exist between deteriorated water quality and a drought index, but the deteriorated water quality does not cause drought.

Accuracy

Refers to how well the measurement of an object or phenomenon reflects its actual state.

Precision

The fineness of the measurement. Values from an instrument that measures parts per million are more precise than values from one which measures in parts per hundred. More precise measurements are not necessarily more accurate.

Units of measurement

Concept	Unit
Rainfall	mm
Natural and available water resources	Mm^3/year (1 Mm^3 = 1,000,000 m^3)
Water demands and abstraction volumes	Mm^3/year
Reservoir capacity	Mm^3/year
Reservoir average regulated volume	Mm^3/year
Total annual flow	Mm^3/year
Instant flow	m^3/sec
Water losses	Mm^3/year or m^3/km (network)/year
Per capita water allowances	l/person/day or m^3/person/year
Irrigation allowances	m^3/hectare/year or m^3/unit of production (1 hectare = 10,000 m^2)

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